IEA 2003 Report: Optical Investigation Of Anomalous Light Phenomena In the Arizona Desert

MASSIMO TEODORANI, Ph.D. ⊗
Astrophysicist

E-mail: **mteodorani@libero.it**

Abstract. A group of scientists composed of geophysicist Marsha Adams, technological scientist Erling Strand, and myself conducted a scientific mission to the Arizona desert in April 2003. The goal of this expedition was to test on-field team-work in difficult areas where anomalous light-phenomena have been observed, and to acquire data using several instruments including magnetometers, VLF receivers, radioactivity detectors, a weather station and optical tools for photography, video and spectroscopy. This report is the description of the results that came from the screening of optical data, which were acquired and subsequently analyzed by this author. The analysis of digital and 35mm film photographs is presented in detail. Three categories of lights were classified: conventional lights, unidentified lights, and highly probable "anomalous cases". The diagnostics of low-resolution spectra is also presented. Almost all of the obtained spectra are due to well-known artificial lights. Finally, tests with a high-resolution spectrograph and optical tests with a reflector telescope are described.

Introduction

A scientific mission to the Arizona desert was carried out in order to test joint fieldwork and acquire data on reoccurring light-phenomena that have been seen in the area. The simultaneous use of optical instrumentation and magnetic and EM sensors (mainly magnetometers and VLF receivers) was aimed at searching for possible correlations between the light-phenomena and the electromagnetic field that they are suspected to produce[1]. This report is specifically devoted to the presentation of the results from the analysis of optical data. Optical data consisted of digital and conventional photographs, some of which were acquired with a small telescope and a powerful catadioptric lens, and of spectra that were recorded on 35mm slide-film.

Accurate preparatory tests were carried out with all the optical instruments some days before the mission started (see Appendix), in particular for the optimization of the telescope, of the digital camera, and of the high-resolution spectrograph.

Digital photographs, which were acquired using a short exposure-time, demonstrated to be very important in the post-processing phase for two reasons:

a) Their very high resolution allowed to obtain very interesting details of some of the light anomalies and permitted to identify successfully many other light-events as conventional phenomena.
b) The very high quantum efficiency of the CCD chip permitted to obtain a sufficient S/N ratio with very short exposures (typically 8 seconds). In such a way the enhanced photographs were able to show field-stars, which were then used as reference points in order to determine with sufficient precision the altazimuthal coordinates (± 2 deg) of the light-targets and the approximate time (±

⊗ During the expedition to Arizona in Spring 2003 this author was working as a researcher on extra solar planet search and on SETI at the Radio Astronomic Station in Medicina (BO), Italy, of the Radio Astronomy Institute of CNR (National Research Council).

[1] *Technical report, in preparation, resulting from Dr. Marsha Adams' & Prof. Erling P. Strand's fieldwork in the Arizona desert.*

10 min) in which they appeared. The reference stars were in several cases identified by using the *Skymap Pro 8* software [2]. This method, by showing the position of the light-phenomena in comparison with star positions (Figs. 3, 4, 6, 7), also permitted to exclude that some of the suspected light-anomalies were astronomical objects, and to ascertain if the light-target was located in the sky or on the ground.

The same method could not be applied to conventional photographs (35mm slide-film), due to the much longer exposure times required. This caused in some cases the apparition of star-trails. In some other cases, also by using a long exposure-time, star trail didn't appear even after drastically enhancing the photos. So digital photography appeared to be much more efficient for a prompt target identification.

On the other hand, both digital and conventional photographs allowed optimum processing of the frames containing light-phenomena of interest. This task was reached using *IrfanView* [3], *Adobe Photoshop 5.5* [4], *Paint Shop Pro 8* [5] and *Iris 3.6* [6] software. The first one was used for quick parallel image visualization. Of the next two ones only the scientific tools for image processing were massively used (the same that are used with software *MATLAB 5.0*). With the fourth one it was possible to study in detail the 3-D profile and the isophotal contours of light-phenomena. A more or less strong image enhancement has permitted us to see features that otherwise would have been unnoticed, including both the "light-anomalies" and light-events that could be promptly identified as "known lights". On the contrary no calculations on luminous power and intrinsic dimensions of the light phenomena of interest could be carried out because the distance was always an unknown parameter, because the planned triangulations could not be carried out due to the transient and short duration of most light phenomena.

Low-resolution spectra were almost completely devoted to the spectral mapping of all the lights that were present in the area, so that they could be used as reference documentation for comparison with possible anomalous spectra. Spectra of all the lights that were continually seen in four different observation spots were taken. Spectra of two very weakly luminous unidentified lights (Figs. 10, 11) that were also seen visually were taken as well, but they resulted to be unsuccessful in terms of S/N ratio so that any analysis of them was not possible. Many of the recorded light-anomalies were unnoticed visually, appearing only in the processed photographs. Therefore only photographs provided data the documention of very brief or very weak light events. Spectra of light-phenomena can be acquired and/or identified only if such phenomena are visible for a sufficiently long time, so that a spectrum can be accurately centered in the camera view field and notes can be promptly taken on these special cases.

High-resolution spectroscopy was carried out only as a "test phase" on known lights, as some custom-built operations have to be carried out before this technique can be used efficiently for the study of anomalous lights.

All the recorded optical data, in particular the photographic data, are described and discussed in detail in the section of Figures, so that there is a more direct correlation between illustrations and comments concerning them.

1. Photo analysis

Several light-phenomena were photographed during the mission in the Arizona desert. Most of them could not be seen with the naked eye, but were recorded by the cameras. A few of them could be seen by naked eye as well, while some of them were only seen by naked eye but could not be photographed in time because they appeared too briefly to point the cameras. This description deals with light-events that were recorded photographically in four observation spots named Location "A", "B", "C" and "D". The optical equipment was composed of the following two main set-ups:

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[2] *Skymap Pro 8*, http://www.5star-shareware.com/Windows/Hobby/Astronomy/skymap.html
[3] *IrfanView*, http://www.irfanview.com/download_sites.htm
[4] *Adobe Photoshop 5.5*, http://acomp.stanford.edu/acpubs/Docs/ps55tutorial/
[5] *Paint Shop Pro 8*, http://www.jasc.com/products/paintshoppro/
[6] *Iris 3.6*, http://www.astrosurf.com/buil/us/iris/iris.htm

1. Questar 3.5” reflector telescope[7], which was permanently connected to a Questar QMax Maximum Resolution Spectrometer and to a Nikon Coolpix 5000 digital camera (with a resolution of 5 Megapixel). The digital camera was alternatively attached to the telescope eyepiece and to the spectrometer eyepiece.
2. Praktica BX 20 reflex camera. The camera was connected 80% of the time to a 270 Pentacon Lens (resulting from the connection of a 135 mm lens to a focal doubler). The 270 mm lens, which was used to acquire low-resolution spectra, was permanently connected to a ROS (Rainbow Optics Spectroscope) holographic diffraction grating. This camera was 20% of the time connected to a 506 mm MTO catadioptric lens, which was mostly used to acquire semi-telescopic images.

The most interesting images were obtained by using the Nikon digital camera standing alone (not connected to the telescope), and the Praktica reflex camera. The high optical quality telescope, was extremely useful too in photographing some distant suspected anomalous phenomena that were faint. In one case (Location D, April 5, 2003, at about 21.30 pm) the telescope permitted us to see one very fast point-like light-phenomenon that crossed the view-field (wide-field eyepiece) in about 3 seconds. Such a light was moving obliquely (45 deg) from the sky to the ground. Unfortunately there was no time to take a photograph of this specific event. During our monitoring operations at Location A from April 6 to April 8, only one light-phenomenon was seen by naked eye (April 6, at about 20.30). It was very clearly observed in the North direction, and it appeared low in the sky as a sequence of two strongly luminous yellow unstructured lights that appeared one after the other and that were traveling towards East direction. The apparition of the two light-phenomena lasted about 20 seconds. These phenomena appeared unexpectedly near sunset, and there was no time to reach optical instruments and aim them at the lights, as the observer was at the moment at another position having dinner with colleagues. In the majority of the cases, suspected anomalous lights appeared only in photos without any direct visual sighting. In few cases some photographed light-events were seen also by the naked eye (Figs. 9, 10, 11).

In one case, one suspected light-phenomenon was discovered in a daytime photo of the landscape, as described in Fig. 1, which shows a strong point-like luminous spot. This light is real as it appears, but, because of the particular temperature conditions in typical desert areas and their effects on objects that are very close to the ground, it cannot be excluded that this light is caused by a refraction effect (mirage)[8]. In such a case the real light-phenomenon might be located some meters below where it is effectively seen. The lighting effect might be due to reflected sunlight by some polished surface such as quartz. Then mirage-like refraction, by bending the light path might make the light-source appear higher. Other more ordinary light sources are considered as well. Therefore this case is doubtful in terms of a real anomalous light-phenomenon.

The most interesting photos of unidentified light-phenomena were obtained in Location A by taking digital photographs. In the night of April 6, 2003, about 20 digital photos were taken (in about 2 hours) in all directions from South-West to North-West in order to try to catch any possible short-lasting flashing lights, which were occasionally seen by eye several times in all directions. A similar but shorter sequence of panoramic photos was taken the following two days as well. By chance, on April 6 the camera-flash was accidentally turned on (*see footnote* ♣) in spite of the relatively long exposure-time that was used (8 seconds). The CCD chip of the digital camera recorded three suspected lights. In two cases (Figs. 2 and 3) the light-events appeared as light-spots whose luminosity and angular dimensions are respectively much higher and larger than those due to stars and planets appearing in the camera view-field. In one of the two cases cited above (Fig. 2) it was possible to ascertain that the light-spot was an extraneous event in the well-known astronomical sky. In one case in particular, the recorded light-event was considered highly anomalous (Fig. 4), both

[7] *See Appendix.*

[8] An Introduction to Mirages, http://mintaka.sdsu.edu/GF/mirages/mirintro.html

♣ *There was no reason why the flash was suddenly self-activated. In the camera menu it appeared to be de-activated, but so it wasn’t. There is no explanation for this, except for, maybe, the possibility that sometimes an external magnetic field was interfering with several electronic equipments. Two events in particular induced this suspect: a) the camera batteries were very often dead even if they were at their maximum charge, b) the locking of our SUV car, which was parked about 300 feet away from us (air-line), was suddenly self-activated (we heard the typical noise and we verified that the car was suddenly unlocked) without none of us using the unlocking device.*

because of its features and because it was not identified as a known astronomical, atmospheric or terrestrial light-source.

More details are given on these three interesting light-events documented from Location A, including the identification of two known objects. Fig. 2 shows one interesting light-phenomenon that was photographed at nighttime. Its light-distribution resembles the one of a plasma-like object. It also presents a weakly luminous tail. The direction and the altitude where it appeared are very far from the position of planet Jupiter (the most luminous celestial object, more than 40 deg higher) at that specific time and location. This has been ascertained by using astronomical software. Fig. 3 shows a similar light-phenomenon with a nebulosity around it. In such a specific case the position of the light in the sky was precisely determined. In both cases (Figs. 2, 3), it is possible that these events were caused by some of the very short-lasting "light-flashes" or flares that were often reported visually as well. In the case of Fig. 2, the orange color is similar to a military flare. Unless fog was present in the sky that was smoothing the luminosity profile, or a flying insect was passing in front of the camera lens - wings that are moving with a rate higher than a standard camera-flash exposure-time of 1/90 sec [9], can smooth the luminosity contour by simulating a plasma-like distribution - it is unlikely that the plasma-like luminosity distribution of these lights is caused by reflection of the camera-flash on something that was occasionally in the sky. Anyway, the possibility that the camera-flash is able to produce a photo-excitation of pre-existing low-energy invisible plasmas cannot be ruled out, and should be investigated theoretically, but it cannot be demonstrated yet. In one case (Fig. 5), the detected lighted-feature was identified as a reflection of the camera-flash on a night bird that passed in front of the camera lens. In another case (Fig. 6), the light-reflection is possibly caused by a piece of aluminum foil that was lying on the ground.

Fig. 4 shows probably the most interesting light-anomaly that was photographed during this expedition. This light appears as a central luminous core from which several low-luminosity "tube-like rays" depart. The light-distribution, which might resemble an illuminated solid body, shows that the central core is not typical of plasma due to its very steep trend towards the top, while the rays show features typical of plasma due to the very gradual trend of a Gaussian-like Point Spread Function [10]. The central core doesn't appear to be uniformly illuminated and presents some short protrusions. Any possible reflection on metal-like devices (such as tripods, chairs, aluminum foils) can be excluded. This light-phenomenon, which was unnoticed at sight, is just a fortunate case in which flash-like light-phenomena could be impressed by a camera during the exposure. By considering that this phenomenon might have lasted probably less than 8 seconds (the used standard exposure-time), it is possible to infer that it must have been very luminous. The lack of knowledge on the phenomenon's distance makes any evaluation of intrinsic luminosity impossible. Fig. 7 shows another possible green flash-like event that left a green glow around itself.

Strange tracks in the sky were also recorded (Fig. 8). Some of them can be easily diagnosed as tracks produced by airplanes. Some others are not easily identified due to the undulating trend that cannot be produced by any known airplane, unless air turbulence effects are considered.

One apparently anomalous group of blinking lights (from Location A) and two unidentified blinking lights (from Location B) were photographed using the Questar telescope and the Nikon digital camera. All these light-events were on the ground. Fig. 9 shows a group of lights, located in a riverbed area, which were identified as house lights. Fig. 10 shows a sequence of two telescopic photographs of another light-event: these lights were suddenly noticed as very tiny lights from very far away, and were compared with permanent known road lights and streetlights. These two photographs, which were taken during a time interval of few minutes, show first a twin light, then a single light that was probably subject to a refraction effect. No identification and reliable image-analysis is possible in this case due to the proximity of these lights to the ground and the consequent effects of atmospheric turbulence, scintillation, and refraction, which typically occur very close to the ground in desert areas and that can be amplified by telescopic observation. Fig. 11 shows the photo of a group of three more lights (red and green colored): in this case the weakness of luminosity and all the well known atmospheric-optical effects occurring in desert areas prevent one from doing a reliable analysis.

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9 Fastest Wing Beat, http://ufbir.ifas.ufl.edu/chap09.htm
10 Point Spread Function, http://www.astro.ubc.ca/courses/astr405/psf

Some photos of interesting light-events were also taken with the conventional reflex camera: in this case two such events were not noticed by sight. One red light spot was recorded at the time in which a ROS spectrum was taken (Fig. 12). This light can probably be explained as atmospheric excitation produced by a Laser beam that was intermittently aimed from far away at the direction of the camera lens, and which caused an expanded visible spot.

Fig. 13 shows two lights that appear to be taking off in opposite directions. The light-distribution shows that the two light-sources are probably caused by some kind of blinking illumination system that occasionally releases some plasma-like or nebular-like glows in its path. In one of the two lights it is possible to notice a sort of "helical motion" quite well. The only way to explain this case as a ordinary one is that a crop duster (airplane) is intermittently aiming its lights towards the observer causing light diffusion of the fertilizer that is spread over the field.

The only anomalous case that was recorded with conventional photography is presented in Fig. 14, which shows simultaneously a triangular group of lights close to the top of distant mountains and an isolated fixed light in the sky. In the first case image processing shows that the strongest light of the group has an annular light distribution that might be caused by a light-ball that is revolving around a barycenter.

The case in Fig. 15 shows the sudden disappearance of a group of three lights, which might be explained as the turning off of the lights of a house.

In general, by looking at all of the recorded light-events (see Table 1), most of them can be probably explained as more or less conventional phenomena such as: refraction effects, military flares, laser beams, tractor headlights, house and street lights, reflected light from flying objects, and light diffusion from known light sources. Only 2 out of the 15 investigated photographic cases, unless an ordinary explanation will be furnished in the future, look to be anomalous: these are the light-phenomena presented in Figs. 4 and 14. Some others cannot be defined anomalous yet, but are still unidentified. Unfortunately the lack of knowledge on parameters such as distance and duration prevents one from carrying out a quantitative analysis that could permit determination of the intrinsic luminous power and the intrinsic dimensions. The lack of spectra of these phenomena that have been considered "anomalous" is also unfortunate, but nevertheless there is no wonder that spectra of these anomalies are lacking, because spectra can be taken only of objects that are in sight, while all the anomalous phenomena that were recorded by the cameras were noticed only after the photographs were processed.

The optical experience that was acquired on the field in the Arizona desert has shown that:

A. A reflector portable telescope with excellent optical qualities is extremely important in order to permit the identification of details of any kind of suspect light source, but really anomalous light-phenomena are normally very short-lasting and very rarely in sight so that, in normal conditions and out of fortunate circumstances, the telescope cannot be aimed at them in a useful time. On the other hand, the telescope has demonstrated to be an absolutely necessary tool to identify weak and/or very far light-features that were in sight for a sufficiently long time: in such a way it was very useful to help promptly identify conventional lights that otherwise would have remained suspect cases.
B. Photographs taken by using a digital camera (with a resolution of 5 Megapixel) have demonstrated to be extremely efficient in showing very faint light-signals by using a very short exposure-time. A powerful zoom digital camera is with no doubts the most suitable optical equipment in order to carry out all-sky surveys in such desert areas. High resolution is a fundamental prerequisite to permit to resize and enhance the light-phenomena without appreciable loss of resolution, while high-quantum efficiency of the CCD sensor can permit to detect short lasting phenomena with a good S/N ratio. Therefore in the future even higher resolution digital cameras (up to 12 Megapixel of resolution) are highly invoked[11].

[11] Fuij Finepix S-3 Pro digital camera, http://www.fotoconnection.com/vi-6269_________Fuji-43020509-FinePix-S3.html

C. Digital cameras, depending on the type, in general often show distortions, border aberrations, pixel malfunctions, but these effects can be identified with some careful attention in the post-processing phase[♦]. Most importantly, this mission has proven that relatively high-resolution digital images obtained using a Nikon 5000 camera, if correctly exposed and formatted, don't show relevant distortions and/or pixilation effects when quasi point-like light phenomena are resized for a better zoomed examination. Comparing the TIFF resized images (5 Megapixel) that are obtained with the Nikon 5000, to the low-resolution (1-2 Megapixel) JPG still frames / images that are obtained with a non-professional digital video camera and/or a low-cost low-resolution digital camera, it can be verified that distortions and/or strong pixilation are often standard in low-resolution devices. These effects become evident when an image resize using interpolation is carried out in order to enlarge the particular of interest (real "zooming" is totally another operation, of no analytic interest). Low-resolution images coupled with the low performance CCD chips of commercial digital cameras and/or non-professional video cameras produce an effect that could be highly misleading when one attempts to study the light distribution of point-like light-sources. The same effect does not appear in the Nikon 5000, if the light phenomenon that is photographed is not on the extreme border of the photo and if the exposure mode is "matrix" (all over the frame). A matrix exposure mode, instead of a spot mode, is the best when one doesn't know exactly where a light phenomenon will appear in the photographic frame. On the contrary, the spot mode is the ideal exposure mode if the light phenomenon is identified visually so that it can be centered in the photographic frame. Moreover, the auto focus mechanism of the Nikon 5000 camera didn't seem to distort and/or enlarge the image itself when a point-like light phenomenon was photographed in darkness. This effect may be produced in other types of (high-resolution) digital cameras but it was not recorded in the Nikon 5000. Finally, previous tests demonstrated that, if the resolution is maintained reasonably high, the change from TIFF to JPG format didn't affect the shape of the image of the light phenomenon, but it produced only a very slight change in the colors, which didn't appreciably affect the study of light distribution. The Point Spread Function that can be obtained using a good digital camera is very reliable because it mirrors the high dynamic range of luminosity that can be obtained with a good CCD sensor.

D. Normal reflex cameras are useful as well, as a parallel tool able to detect light-phenomena with high spatial resolution during relatively long panoramic exposures. The resolution of 100-200 ASA films is greater than the one obtained by a digital camera, but its dynamic range is less and a much more emphasized image enlargement can occur when the photograph is overexposed.

[♦] A "hot pixel", which was often present in the photos that were taken using the Nikon Coolpix 5000 camera during the mission in the Arizona desert, was promptly identified. The camera anomaly was always present at the same position. This suggested a defect of the CCD chip at that specific location of the pixel matrix. The photo below shows the position of the anomalous camera pixel. A zoom image is also presented above on the left. The hot pixel didn't affect at all the other camera performances.

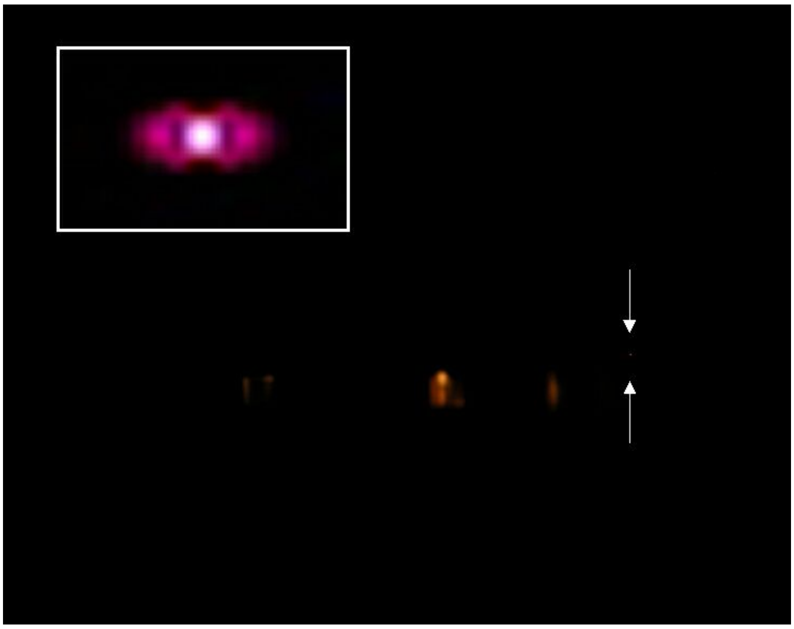
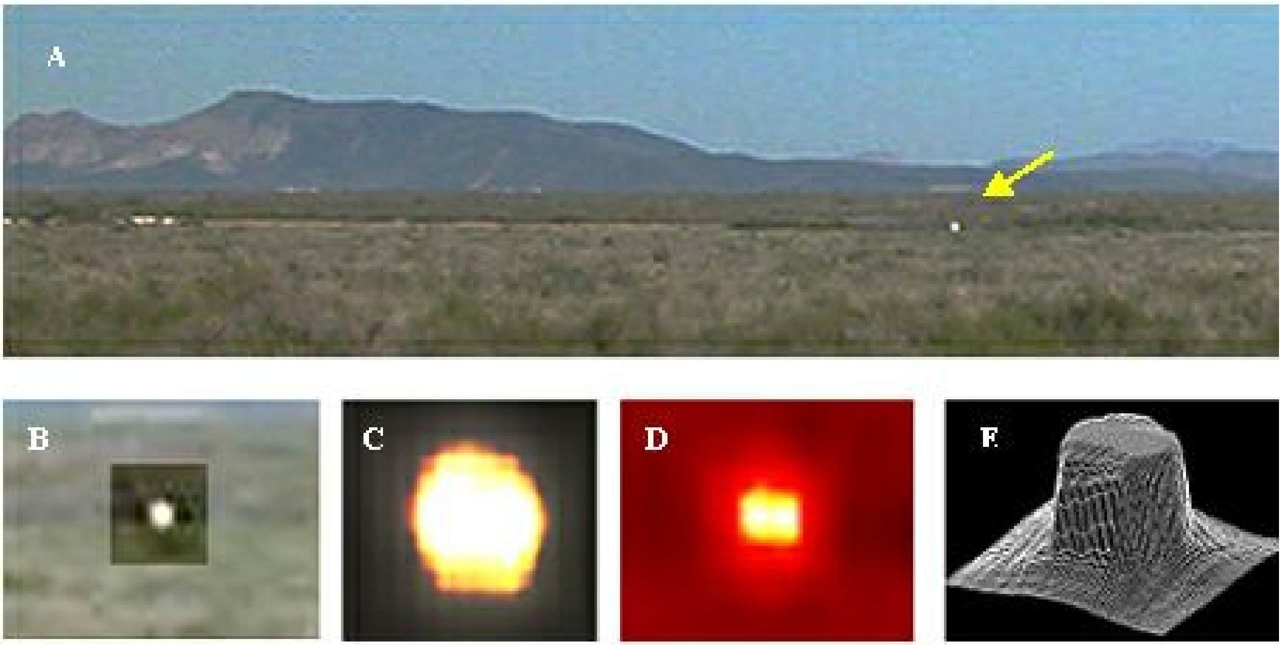


Table 1. Observed light phenomena

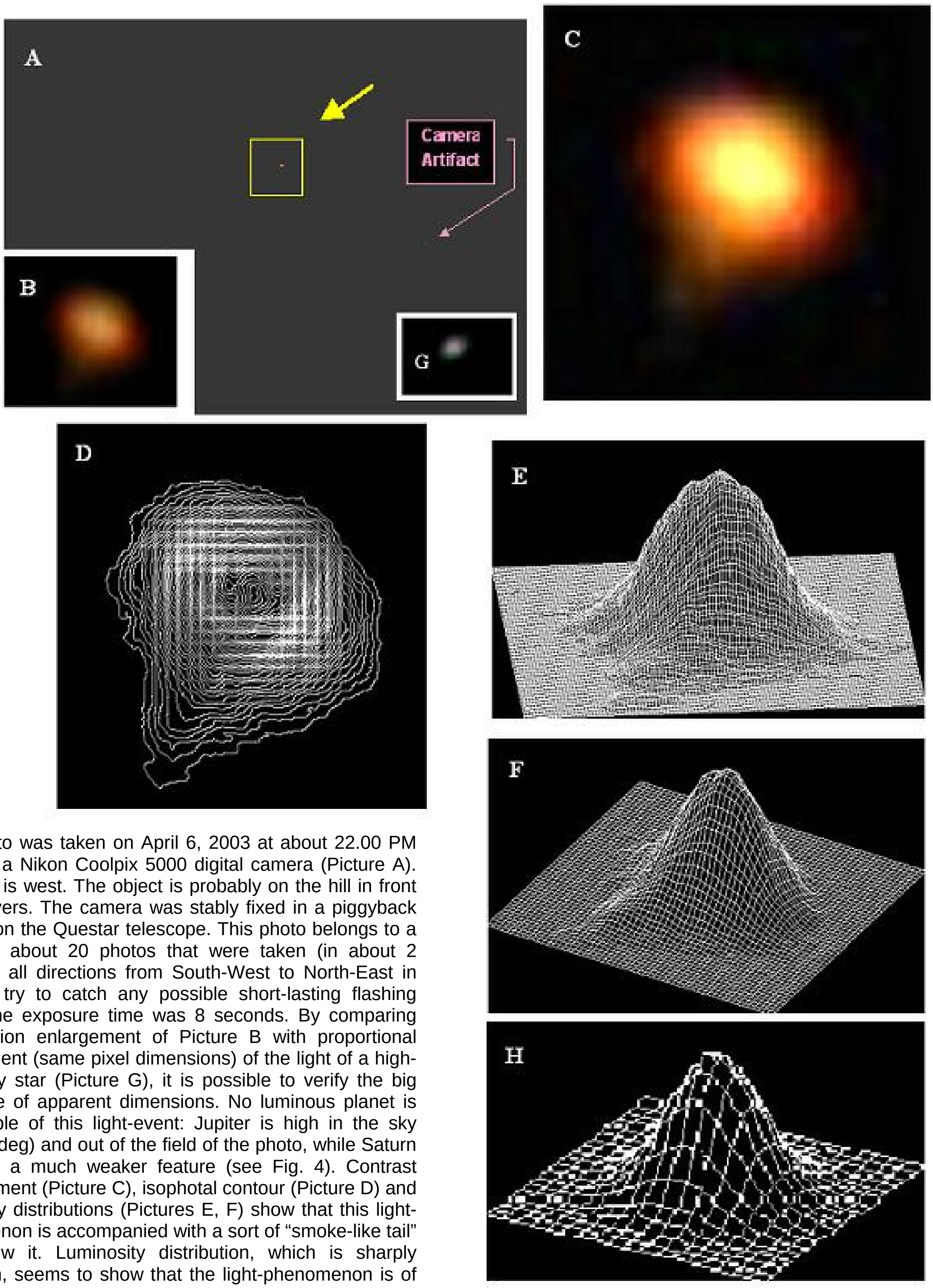
LOCATION	TYPE	INSTRUMENTATION	DIRECTION / ALTITUDE - AZIMUTH	*FIGURE*
A	Unidentified	seen visually	north	-
A	Possibly Identified	Nikon 5000 digital camera	west	*1*
A	Unidentified	Nikon 5000 digital camera	west	*2*
A	Unidentified	Nikon 5000 digital camera	7 deg - 192 deg	*3*
A	**Anomalous**	**Nikon 5000 digital camera**	**few deg – 310 deg**	***4***
A	Identified	Nikon 5000 digital camera	-	*5*
A	Possibly Identified	Nikon 5000 digital camera	few deg – 272 deg	*6*
A	Unidentified	Nikon 5000 digital camera	18 deg – 325 deg	*7*
A	Unidentified	Nikon 5000 digital camera Erling Strand's reflex camera Praktica BX-20 reflex camera + 270 mm lens	-	*8*
A	Identified	Questar telescope + Nikon 5000 digital camera	west	*9*
B	Unidentified	Questar telescope + Nikon 5000 digital camera	west	*10*
B	Unidentified	Questar telescope + Nikon 5000 digital camera	east	*11*
B	Possibly Identified	Praktica BX-20 reflex camera + 270 mm lens	-	*12*
B	Possibly Identified	Praktica BX-20 reflex camera + 270 mm lens	-	*13*
C	**Anomalous**	**Praktica BX-20 reflex camera + 506 mm lens**	**-**	***14***
D	Possibly Identified	Praktica BX-20 reflex camera + 270 mm lens	-	*15*
D	Unidentified	Questar telescope	-	-
A, B, C, D	Identified (17 spectra)	Praktica BX-20 reflex camera + 270 mm lens + ROS grating	*all directions*	*16*

<u>FIGURE 1</u>. Location “A”
Possibly Explained as a Conventional Phenomenon



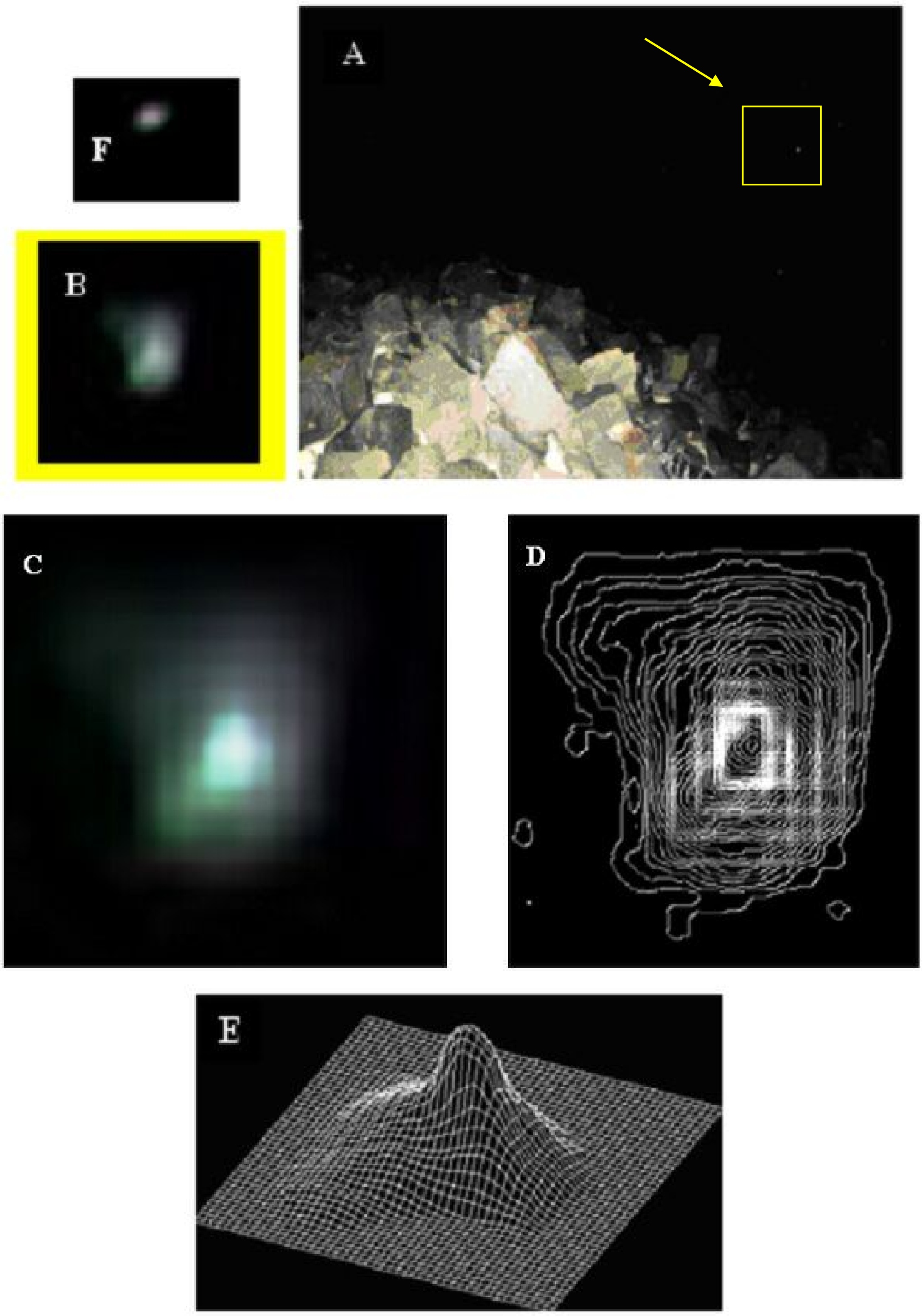
This photo was taken on April 7, 2003 at 14:43 Local Time, using a Nikon Coolpix 5000 digital camera. Direction is west. Picture A is an enhanced enlargement of Picture *Dscn0086* by M. Teodorani. The light is located along the riverbed. The fact that it is fully in sight means that the light was several meters over the ground, just over the bush. By enhancing the light (starting from Picture A) using frame interpolation (Picture B) and changing contrast (Picture C) it is possible to see more clearly the shape of the light (Picture C), which shows some kind of rectilinear contour on the bottom and on the top. By eliminating blue and green filters, the light appears as an oblique rectangle (Picture D). The 3-D light distribution (PSF: Point Spread Function) of Picture E shows that the top is saturated due to very high luminosity that saturated the pixels of the CCD chip even using a very short exposure (1/125 sec), while the trend to the peak is highly rectilinear. This behavior excludes that the light is produced by any kind of plasma phenomenon. The PSF shows the feature of a strongly illuminated solid body. Luminosity might be produced sporadically by sunlight striking a highly reflective surface. This reflection is seen and/or recorded by the observer only when the sunrays make a specific favorable angle. This presumably occurred at a specific time of day depending on the angular height of the sun, and it was photographed by chance. Photo enhancement shows that there are no buildings or houses around the light, so any window reflection is excluded. Nevertheless, the presence in the area of remnants that were possibly left by trekkers, such as pieces of glass, aluminum foil or any other kind of reflecting surfaces, cannot be excluded. Alternatively, a quartz stone (or other reflecting mineral) present in the riverbed, with its polished surface at the right inclination, might have been the cause of the illumination. A small polished stone, as well as a small piece of glass, is sufficient to produce a high brightening effect, which disappears as the sun’s angular height changes. Finally, if one assumes that the light is produced by a reflecting surface of any kind, then one would expect that such a surface must be several feet above, so that it emerges from the bush. This can happen, for instance, if an aluminum foil, for instance, is captured by some high rows in the bush. On the contrary, if the reflecting surface is situated on the ground and below the top of the bush’ rows, the problem might be solved if one assumes a mirage-like refraction effect of a lighted surface that is located several meters lower. In fact, the still high temperature in the desert favored refraction indeed at the time the photograph was taken. In spite of these interpretations, the possibility of another kind of luminous phenomena cannot be excluded a priori. Therefore this case can be considered “possibly identified” but not fully ascertained. This light-phenomenon was not noticed by eye, but appeared as a very small light spot in the original photo. Any effect caused by possible camera “hot pixels” (constantly controlled) is excluded.

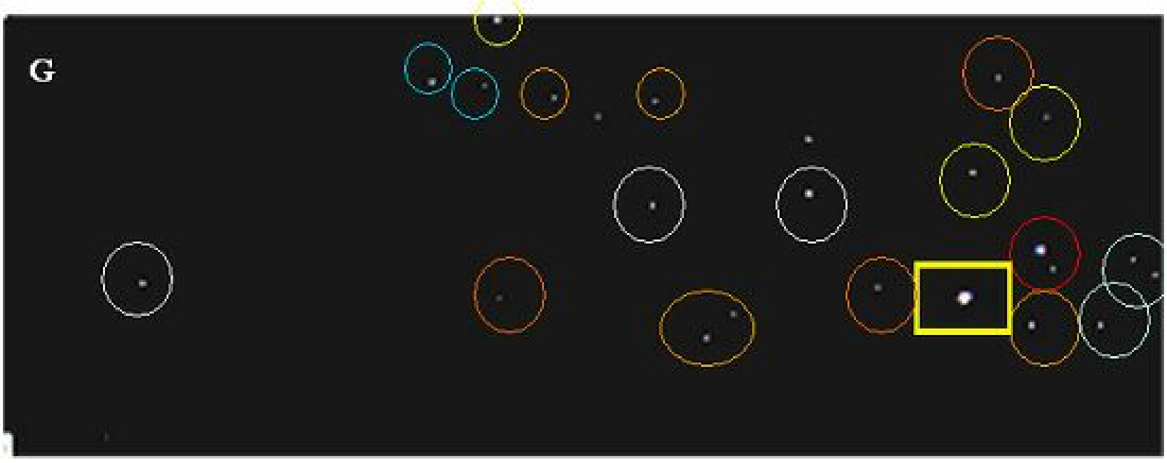
FIGURE 2. Location "A"
Unidentified Case

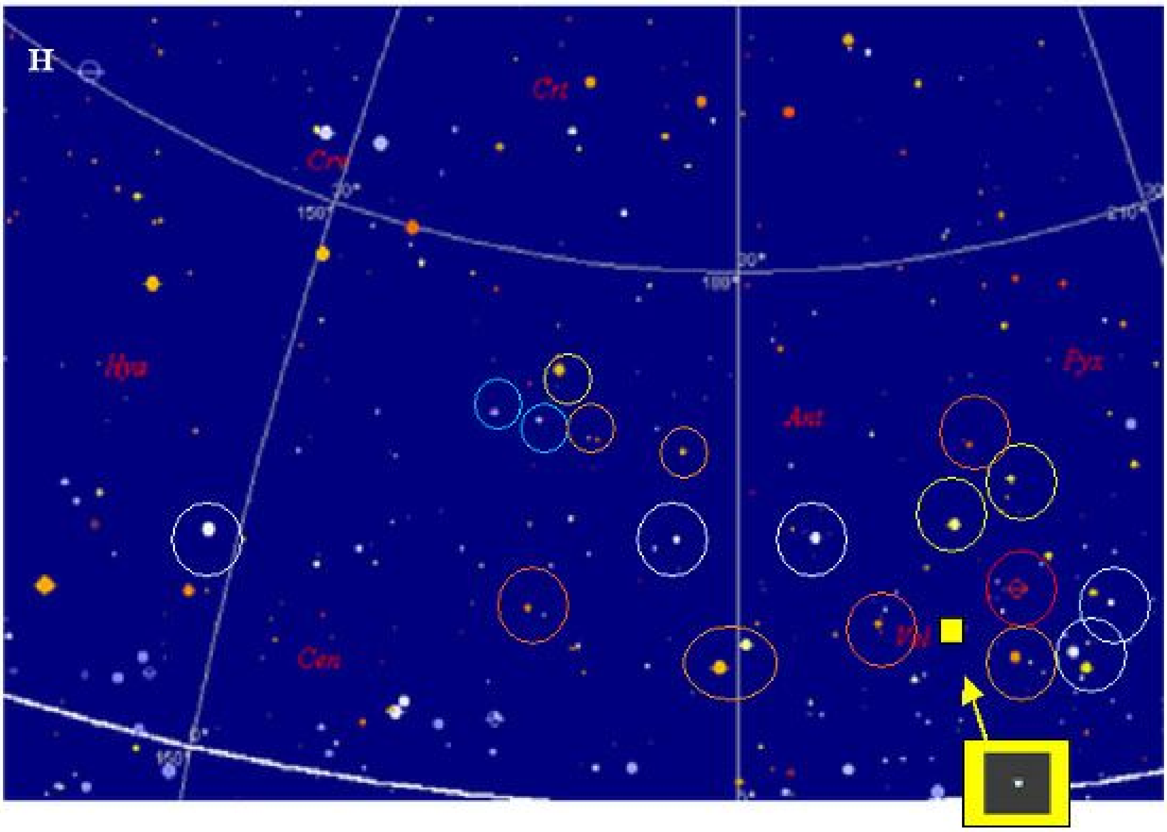


This photo was taken on April 6, 2003 at about 22.00 PM by using a Nikon Coolpix 5000 digital camera (Picture A). Direction is west. The object is probably on the hill in front of observers. The camera was stably fixed in a piggyback position on the Questar telescope. This photo belongs to a series of about 20 photos that were taken (in about 2 hours) in all directions from South-West to North-East in order to try to catch any possible short-lasting flashing lights. The exposure time was 8 seconds. By comparing interpolation enlargement of Picture B with proportional enlargement (same pixel dimensions) of the light of a high-luminosity star (Picture G), it is possible to verify the big difference of apparent dimensions. No luminous planet is responsible of this light-event: Jupiter is high in the sky (over 60 deg) and out of the field of the photo, while Saturn produces a much weaker feature (see Fig. 4). Contrast enhancement (Picture C), isophotal contour (Picture D) and luminosity distributions (Pictures E, F) show that this light-phenomenon is accompanied with a sort of "smoke-like tail" just below it. Luminosity distribution, which is sharply Gaussian, seems to show that the light-phenomenon is of plasma-like kind. A confrontation can be made with the theoretically modeled light-distribution of a typical plasma light-source (Picture H). This object is unidentified and maybe it appeared as a short-lasting light during the exposure. Comparison with eye-sightings makes one suspect (but not confirm) it is a military flare. The camera-flash was intermittently turned on.

FIGURE 3. Location "A"
Unidentified Case

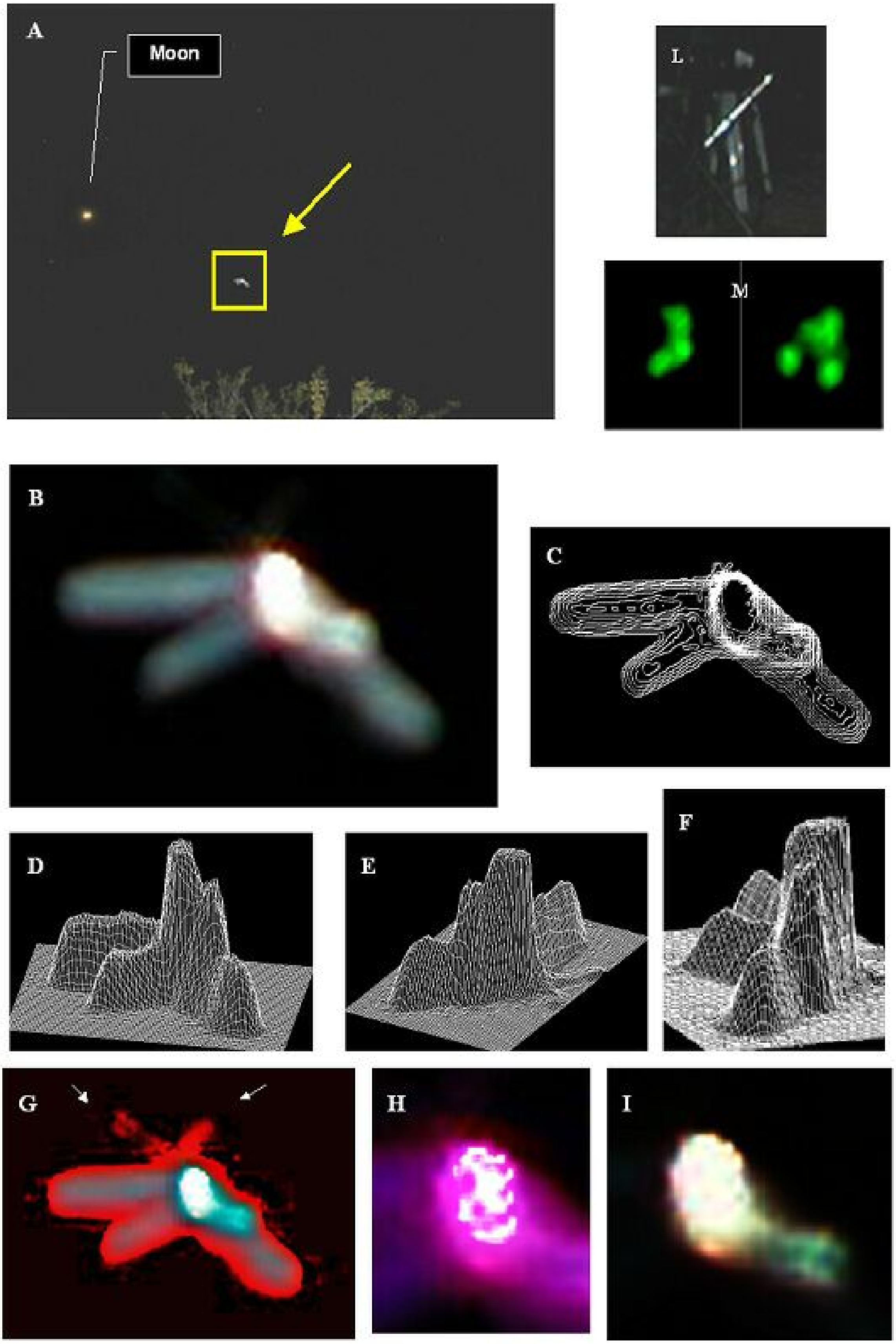


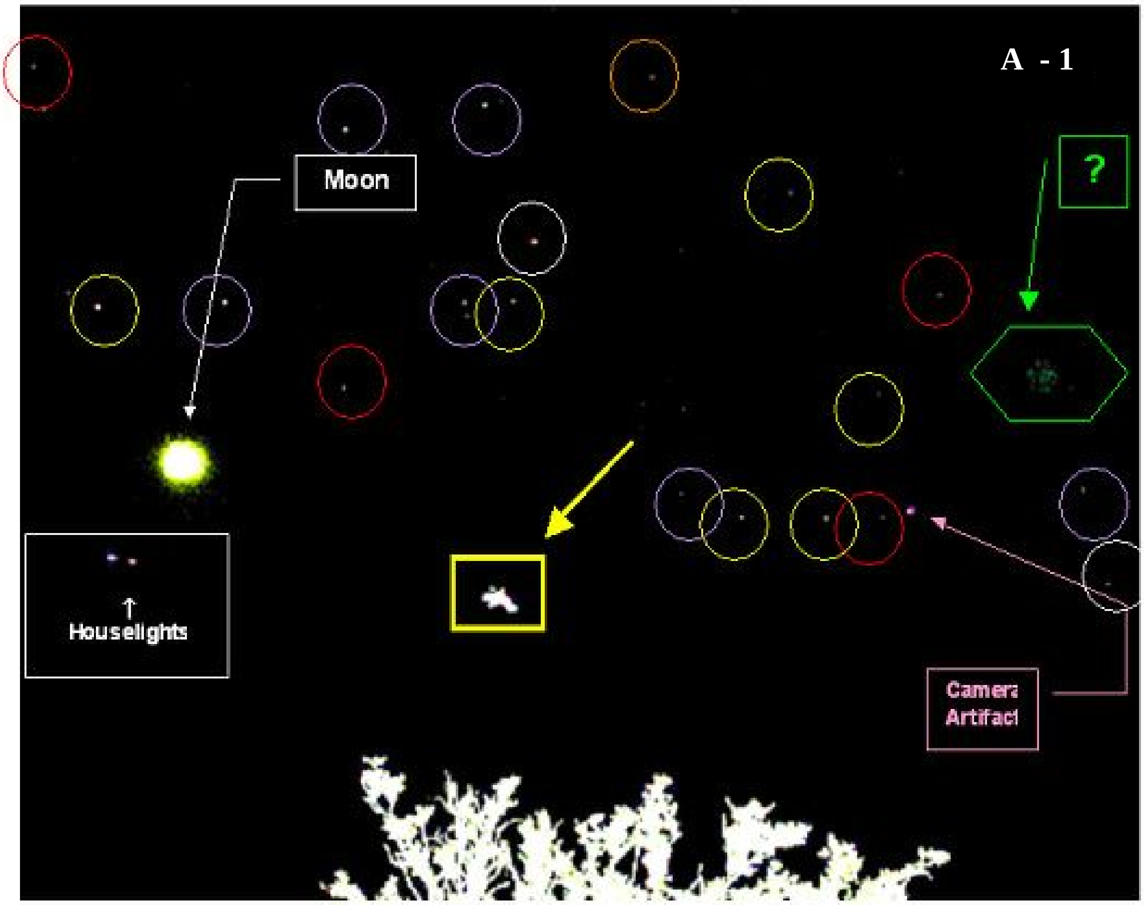


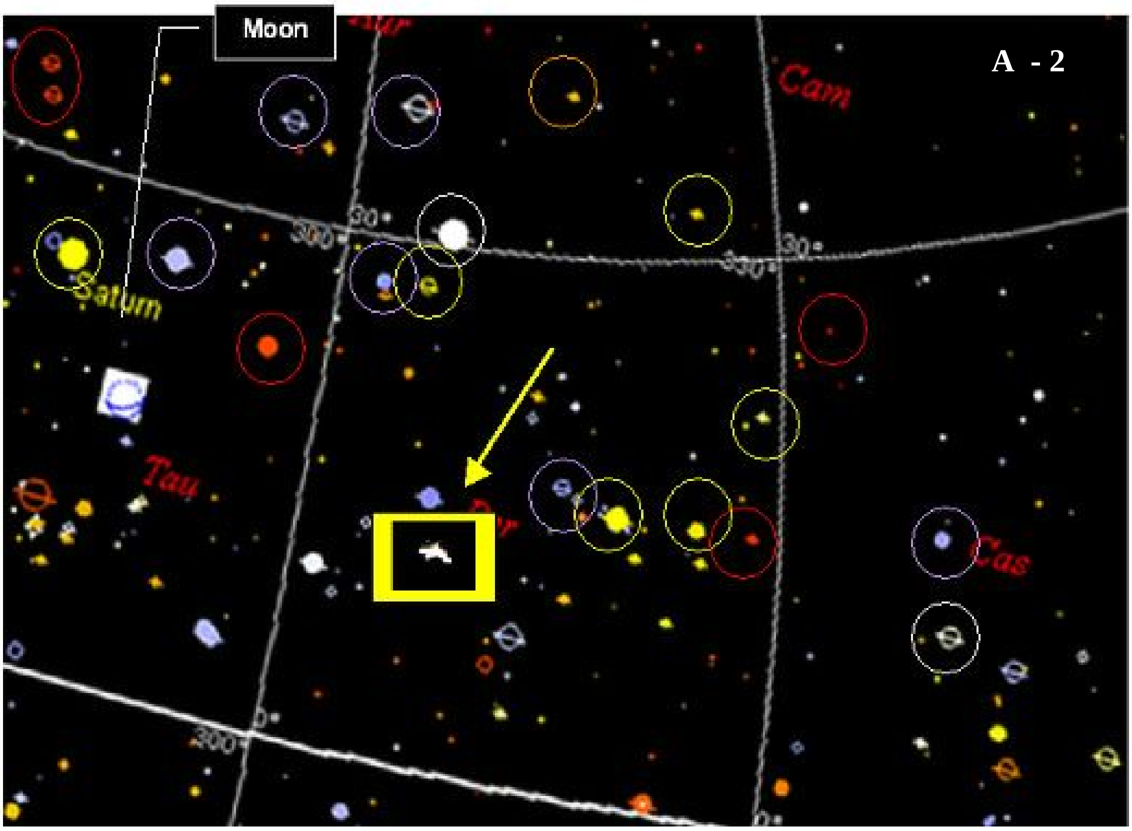


This photo was taken on April 6, 2003 around 22.00 Local Time, using a Nikon Coolpix 5000 digital camera (Picture A). Direction is south. Altitude is about 7 deg. Azimuth is about 192 deg. The camera was stably fixed on a piggyback position on the Questar telescope, using, in this case, a slight horizontal camera inclination with respect to the horizon line. This photo belongs to a series of photos that were taken towards all directions from South-West to North-West in order to try to catch any possible short-lasting flashing lights. The used exposure time was 8 seconds. The position of 18 identified reference stars (*the two remained unidentified celestial objects are possibly asteroids that are not included in the Skymap Pro 8 database*) furnished the precise position of the target (Pictures G, H). The original photo has been strongly contrast-enhanced in order to make so that the field stars appear. Subsequently these field stars could be used as reference points. By comparing interpolation enlargement of Picture B with proportional enlargement (same pixel dimensions) of the light of a high-luminosity star (Picture F), it is possible to see a significant difference of apparent dimensions and shape. By looking at the position of the light-phenomenon in comparison with the one of reference stars (Pictures G, H), it is possible to exclude definitively that it is a star or a planet. The position of the light-phenomenon with respect to reference stars demonstrates that it appeared just in the sky, probably as a short lasting (less than 8 seconds) flash-like light-event. Contrast enhancement (Picture C), isophotal contour (Picture D) and luminosity distribution (Pictures E), show that this light-phenomenon has a sort of smoke-like nebulosity around it and a very sharp and point-like nuclear luminosity. Luminosity distribution, which is sharply Gaussian, shows that the light-phenomenon is of plasma-kind, with a strong point-like concentration in the nucleus. This light-phenomenon, even if the quality of the image is low, can be considered definitively unidentified. The camera-flash was occasionally turned on. Reflection of camera flash from flying birds is excluded (see Fig. 5). Instead, a possible reflection on flying insects that were occasionally passing in front of the camera cannot be ruled out but cannot be demonstrated as well.

FIGURE 4. Location “A”
Anomalous Phenomenon




A - 1
Moon
?
Houselights

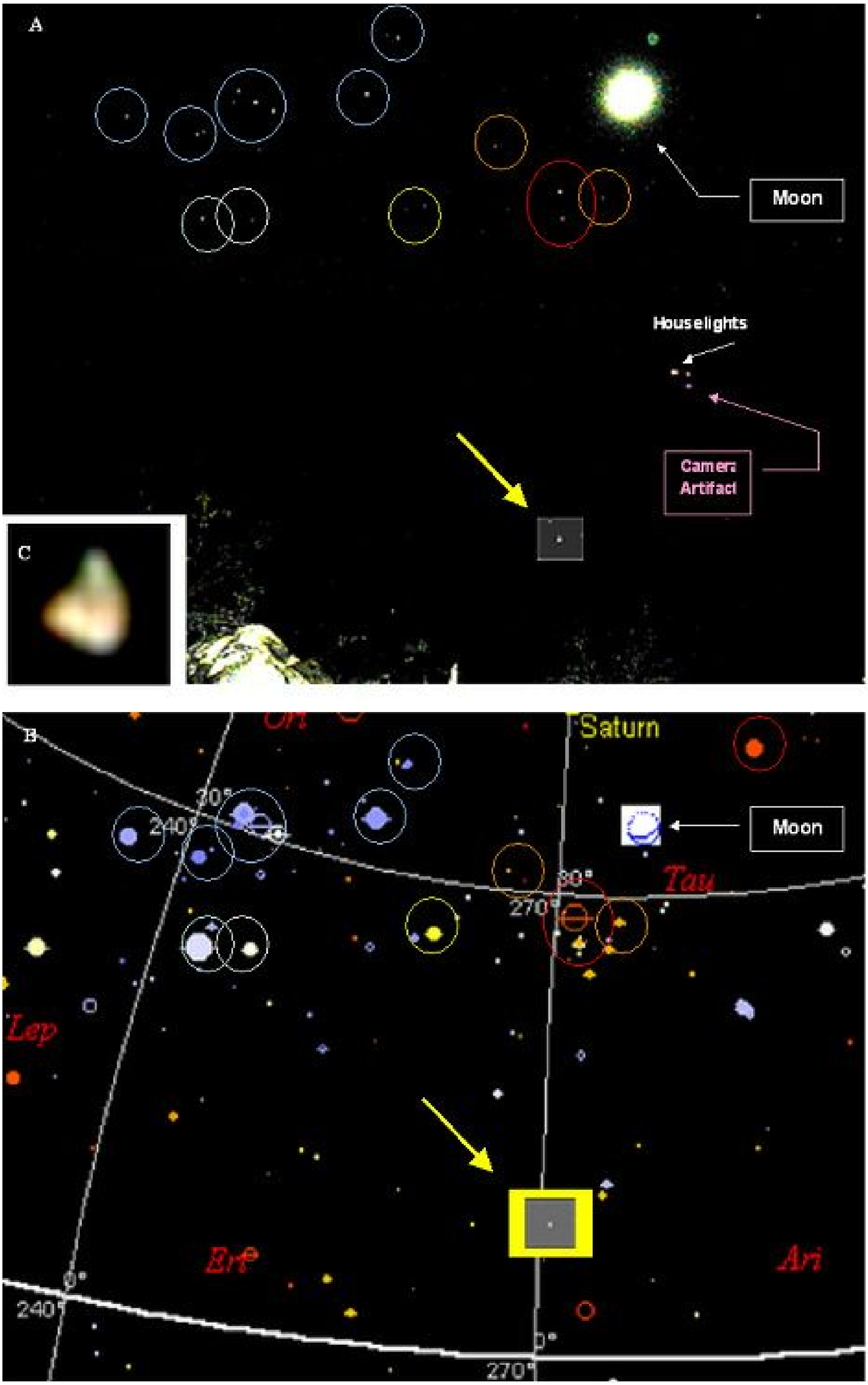

A - 2
Moon
Cam
Saturn
Tau
Cas

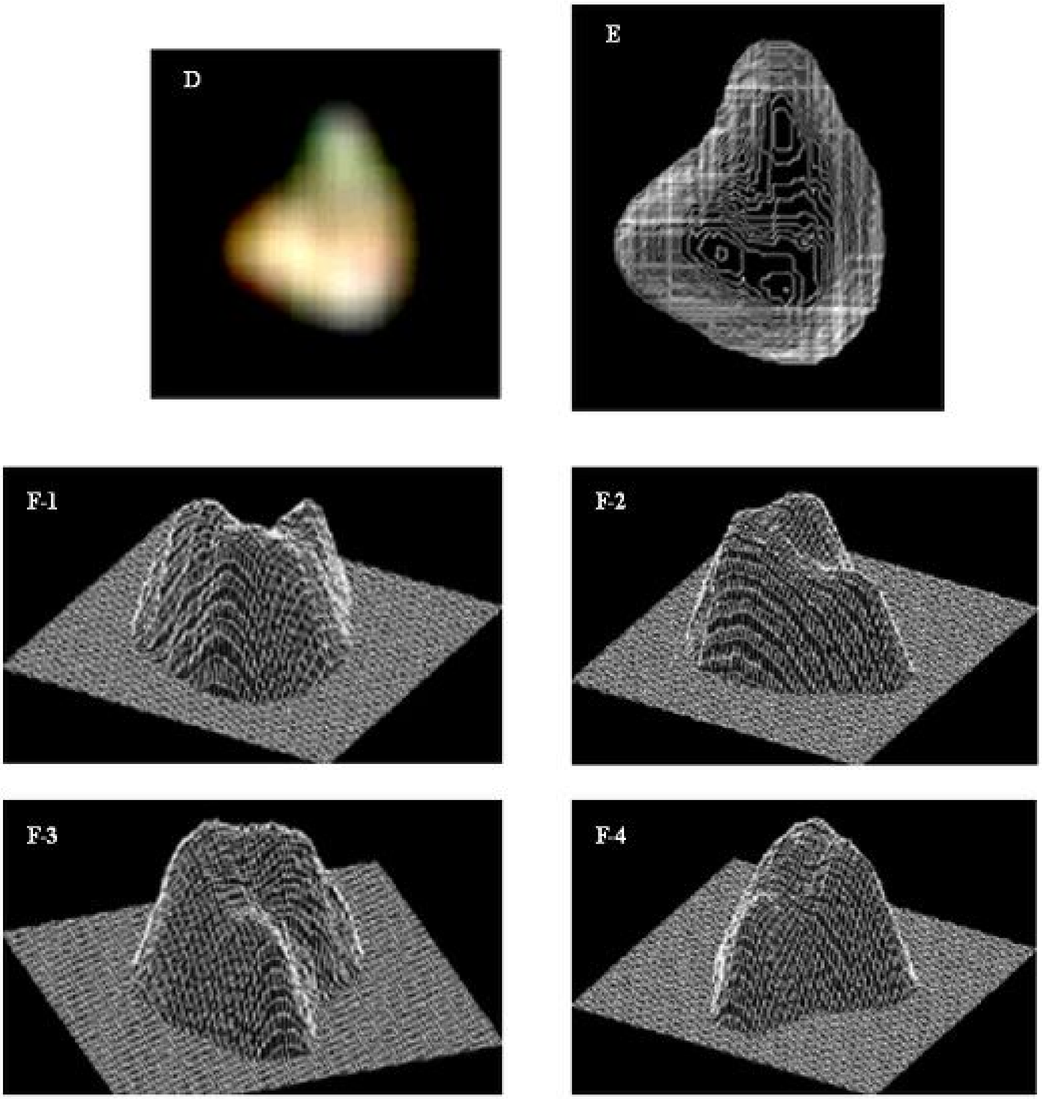
This photo was taken on April 6, 2003 around 22.00 Local Time, using a Nikon Coolpix 5000 digital camera (Picture A). Direction is west. Azimuth is about 310 deg. The object is probably located on a low-altitude hill, or anyway very few degrees over the horizon (Moon altitude: about 17 deg). The camera was stably fixed in a piggyback position on the Questar telescope, with an occasional horizontal slope of about 10 deg with respect to the horizon line. This photo belongs to a series of about 20 photos that were taken in about 2 hours towards all directions from South-West to North-West in order to try to catch any possible short-lasting flashing lights. The used exposure time was 8 seconds. The position of the Moon at that exact time could be determined, and photo enhancement permitted to find 18 reference stars and planet Saturn. The position of the Moon together with 19 identified celestial objects of reference furnished the precise position of the target (Pictures A-1, A-2). The original photo has been strongly contrast-enhanced in order to make so that the field stars appear. Subsequently these field stars could be used as reference points. By interpolating-resizing the object of interest (Picture B), it is possible to notice a very complex shape, showing a strong nuclear luminosity and at least four "tube-like rays" that are aimed at several directions. Contrast enhancement and color filtering show that the nuclear region is featured by some kind of short protrusions (Picture I) and marked non-uniformity (Picture H: "the profile mask"). Color and contrast enhancement and 3-D light-distribution show that two more rays are visible in the upper part (Pictures E, G). Isophotal contour (Picture C) shows a very homogeneous light-distribution of the ray-like features with no glow around. 3-D light-distribution shows a complex profile with mixed characteristics of plasma in the rays and of non-uniformly illuminated solid in the nucleus (Pictures D, E, F). This light-phenomenon was supposed to last less than 8 seconds, and appeared by chance in the view-field of the lens, being unnoticed visually. It appeared as a whitish-bluish feature in the original photo. The level of anomaly of this light-phenomenon can be considered high. Any comparison with reflected light (at the moment of the photo, the flash was occasionally turned on) from iron tube-like objects such as tripods and portable folding chairs (Picture L), and with green laser tracks on the near hill (Picture M), shows that the recorded anomalous light-phenomenon has nothing to do with these artifacts, which were very easily distinguishable with little enhancement. Photo enhancement (Picture A-1, on right) shows also another unidentified object, nebular-shaped and green-colored in this specific case, which is located in the sky.

FIGURE 5. Location "A"
Explained as a Conventional Phenomenon

This photo was taken on April 6, 2003 at about 22.00 Local Time, using a Nikon Coolpix 5000 digital camera. It is a part of a sequence of about 20 photographs that were taken towards all directions from South-West to North-East in order to try to catch any possible short-lasting flashing lights. The used exposure time was 8 seconds. The photo is highly contrast-enhanced. The camera-flash was occasionally turned on. The target is evidently a night bird (probably an owl) that was instantly lighted by the flash, during its passage in front of the lens.

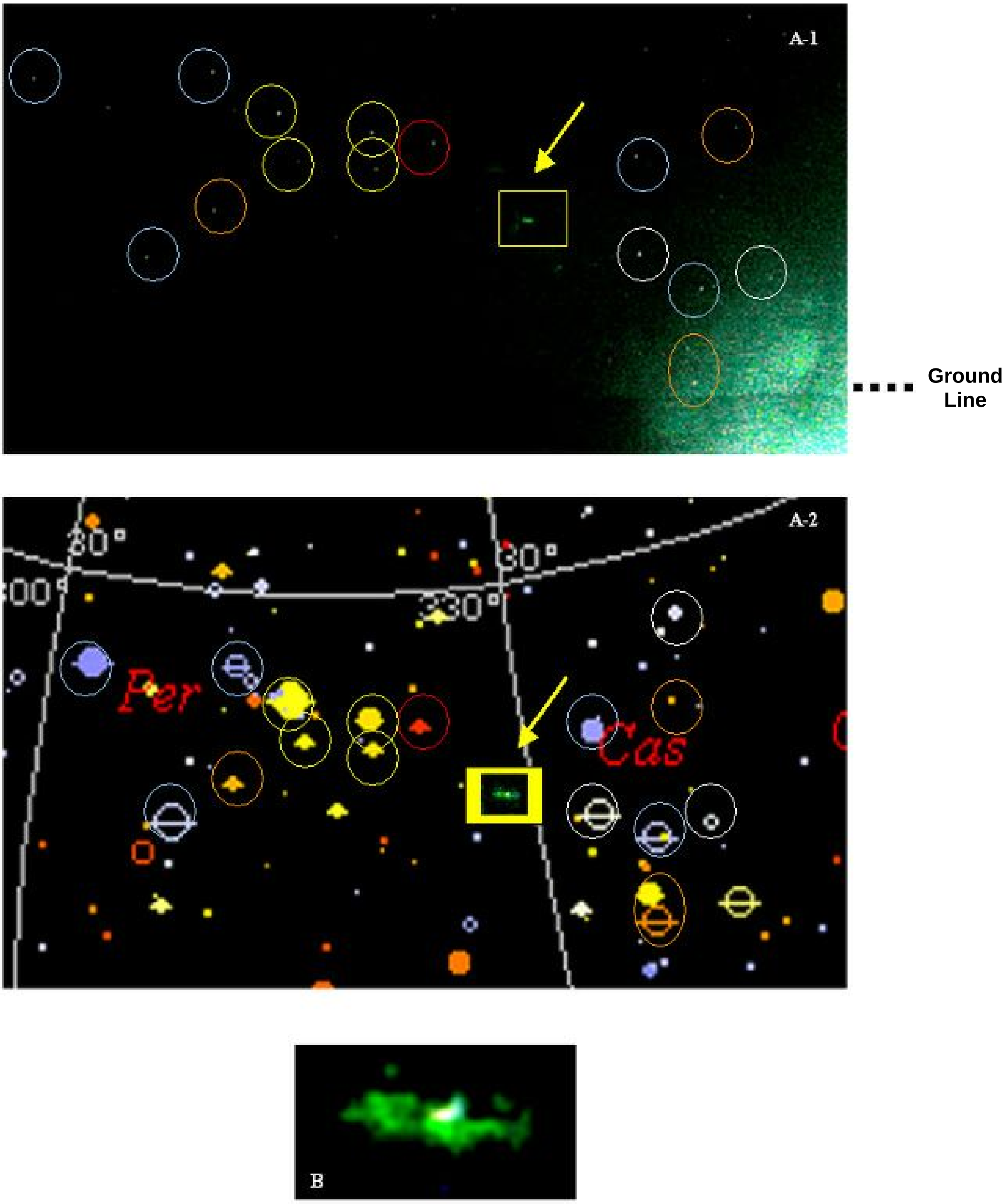
FIGURE 6. Location "A"
Possibly Identified Case

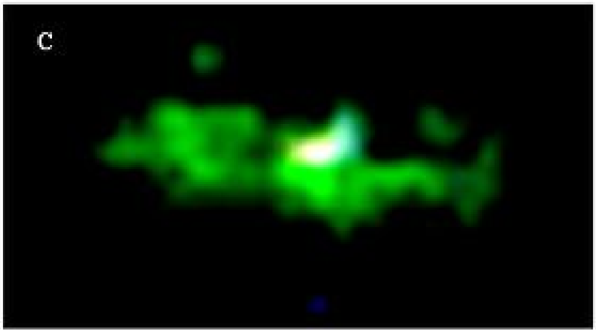


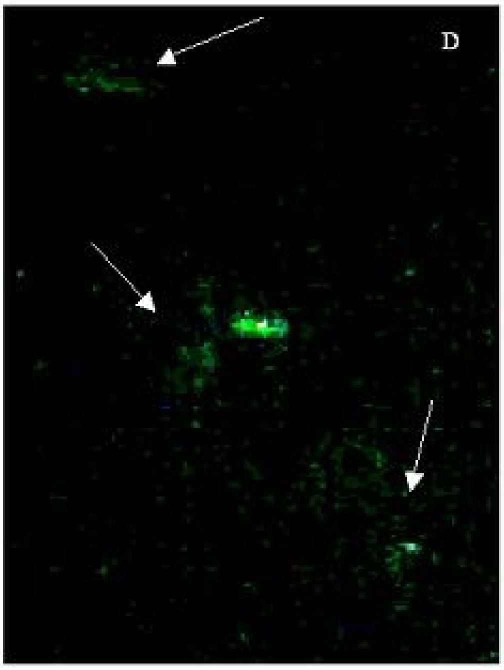


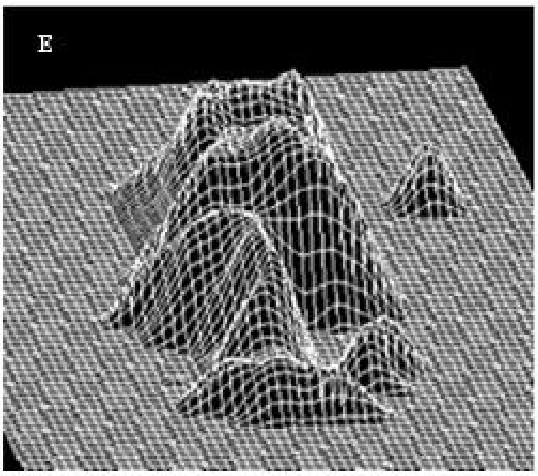
This photo was taken on April 6, 2003 around 20.30 Local Time using a Nikon Coolpix 5000 digital camera (Picture A). Direction is west. Azimuth is about 272 deg. The object is probably on the hilly ground. The Moon altitude is about 35 deg. The camera was stably fixed in a piggyback position on the Questar telescope. The used exposure time was 8 seconds. The position of the Moon at that exact time together with 14 identified reference stars furnished the precise position (Pictures A, B) of the target (indicated by yellow arrow). The original photo has been strongly contrast-enhanced in order to make so that the field stars appear, which then could be used as reference points. The light-target was greatly resized and contrast enhanced (Picture C, D). Isophotal contour (Picture E) shows a homogeneous light distribution on a curved surface. 3-D light-distribution (Pictures F-1, F-2, F-3, F-4) shows that an illuminated solid curved body produces luminosity, while no plasma or glow-like signature is evident. This object cannot be directly identified, but it is strongly suspected that the produced light is caused by light-reflection of the camera-flash from a big foil of aluminum paper that was frequently used by the group to cover instruments, some large pieces of which were found about 300 feet away from the observation spot due to the wind which sometimes gusted. The camera-flash was occasionally turned on.

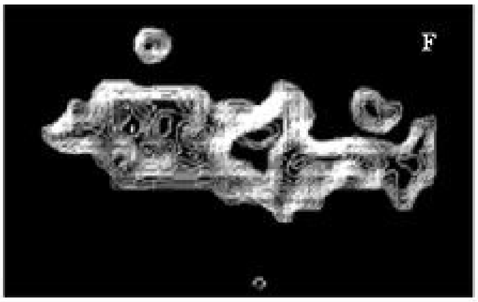
FIGURE 7. Location “A”
Unidentified Case







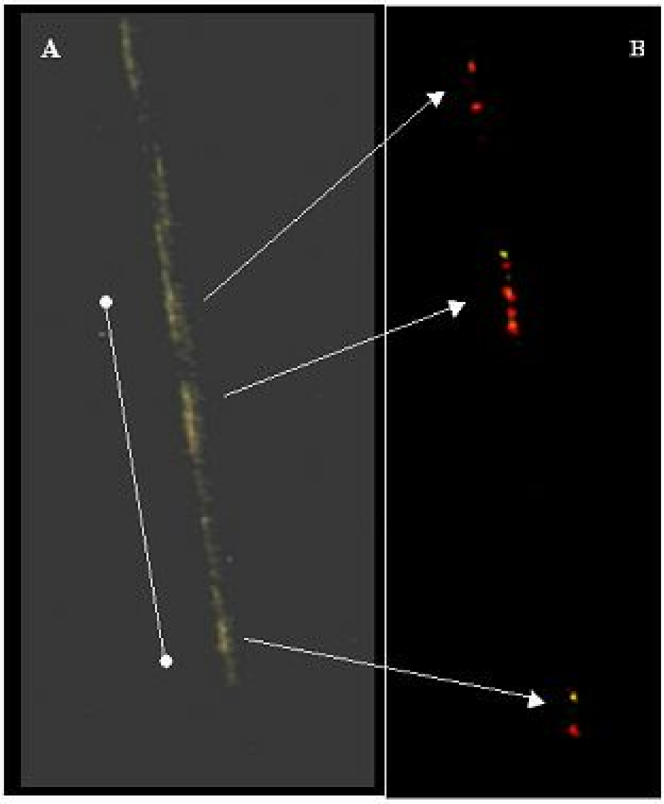




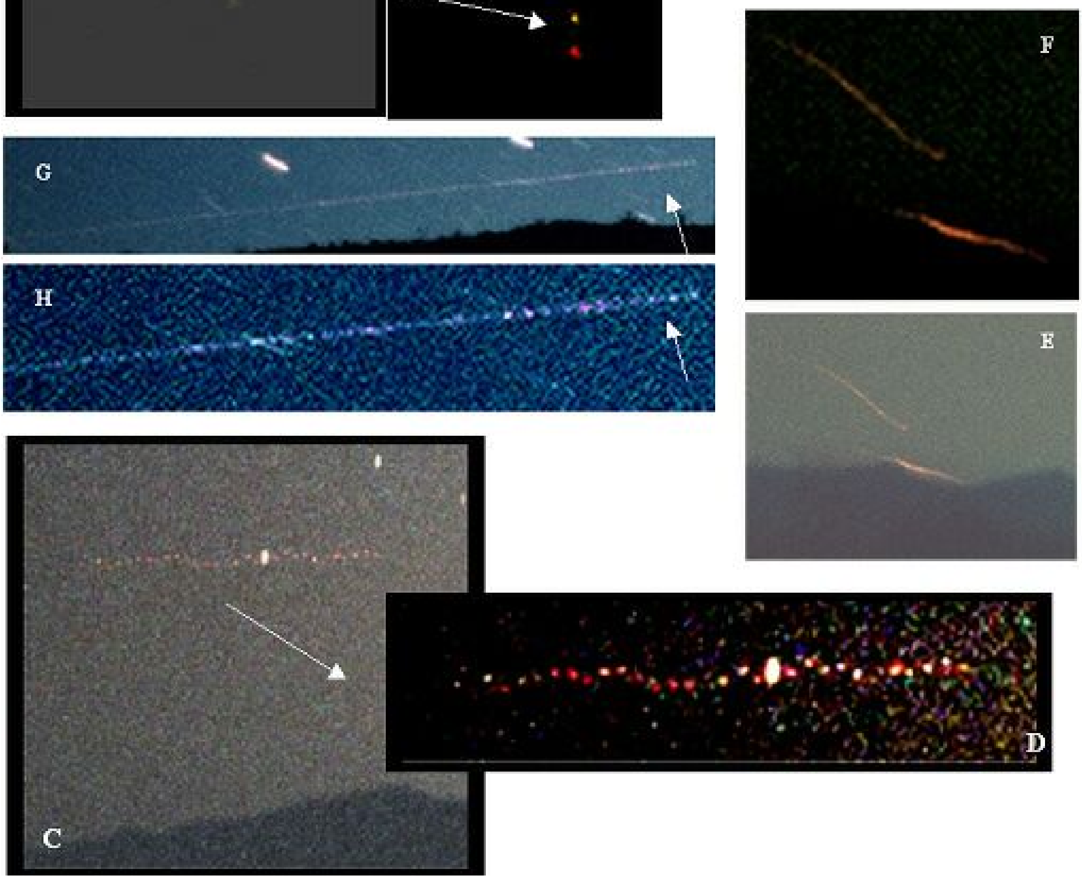
This photo was taken on April 6, 2003 around 21.00 Local Time by using a Nikon Coolpix 5000 digital camera (Picture A-1). Direction is north. Azimuth is about 325 deg. Altitude is about 18 deg. The camera was stably fixed in a piggyback position on the Questar telescope, with a slight horizontal camera inclination with respect to the horizon line. The profile of some hills is visible below on the right (Picture A-1). The exposure time was 8 seconds. The position of 16 identified reference stars (Picture A-2) furnished the precise position of the target (indicated by yellow arrow, Pictures A-1, B). The original photo has been strongly contrast-enhanced in order to make so that the field stars appear, which then could be used as reference stars. The light-target was highly resized and contrast enhanced (Picture C). A further enhancement of the region surrounding the green elongated light shows very diffuse green glows too in a box of 4 x 7 deg (Picture D). The study of the green object (Picture C), which was clearly located low in the sky, shows that its luminosity is characterized by a more or less concentrated glow and with slight peak luminosity in the center (Pictures C, F). The 3-D light-distribution shows that the low-intensity regions resemble a plasma-like (Gaussian) distribution, while the high-intensity regions show a profile that is steeper than the one shown by typical plasma. This object is not easily identifiable. A green Laser was occasionally used during the mission. It needs to have encountered a screen in form of a low cloud or distant fog condensation in order to produce a (moving) spot in the sky that could be photographed. On the contrary, the sky at the moment of the photo was completely clear as all the stars, up to the horizon, are clearly distinguishable and identifiable.

NOTE. Dust is another possible absorbing screen that the Laser might have encountered in its path, especially in desert areas. If one wants to produce a green spot in the sky an optically thick absorbing screen is needed. In order that this is possible it is necessary to accumulate a substantial amount of dust in form of “column density” that is aligned along the observer’s line of sight. Anyway this can become effective only at great distance. But this is expected to be too large in comparison with the effective range of the employed green Laser (at least 1500 feet). Moreover, in the photo there is no track of the Laser beam, which should have been recorded photographically. The Laser spot and the Laser beam are two distinct manifestations. The first one requires a large distance to form, the second, whose visibility is made easier indeed by a large amount of dust, can be seen – and consequently photographed - as soon as the Laser is turned on.

FIGURE 8. Location "A"
Unidentified Cases

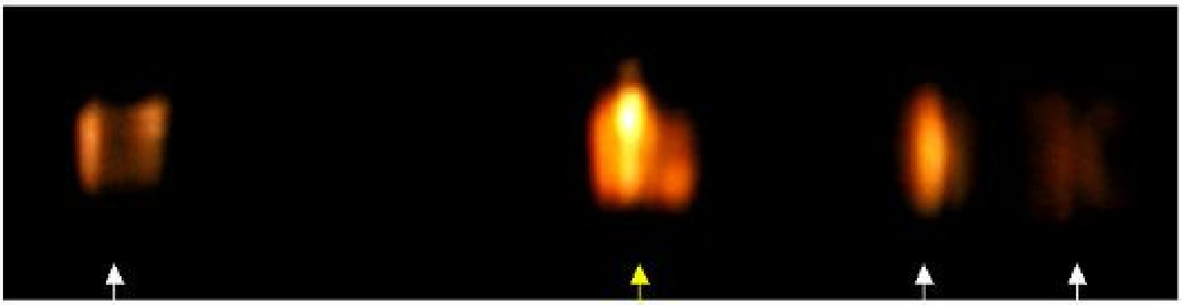


Tracks in the sky. Track I. This is an irregular trail in the sky that was impressed on the Nikon 5000 Coolpix digital camera, an 8 second exposure-time was used. The track has been slightly resized and enhanced (Picture A). A further strong resizing and contrast enhancement shows the points in which the light is concentrated (Picture B). Track II. This is a strange undulating track that was recorded on film (400 ASA) by engineer E. P. Strand on April 5, 2003 from Location D. The track has been slightly resized and enhanced (Picture C). A further strong resize and contrast enhancement shows the sharply undulating behavior of a light that is pulsating (Picture D). The vertical elliptical white spot is a star. Track III. A couple of unusual trails at very low altitude recorded with a 100 ASA film by M. Teodorani (Pictures E, F). One of them is very close to the top of the hill. Track IV. Normal airplane trails, which are intermittent but rectilinear, are shown, for comparison, in a photo taken by M. Teodorani using a 100 ASA film (Pictures G, H).



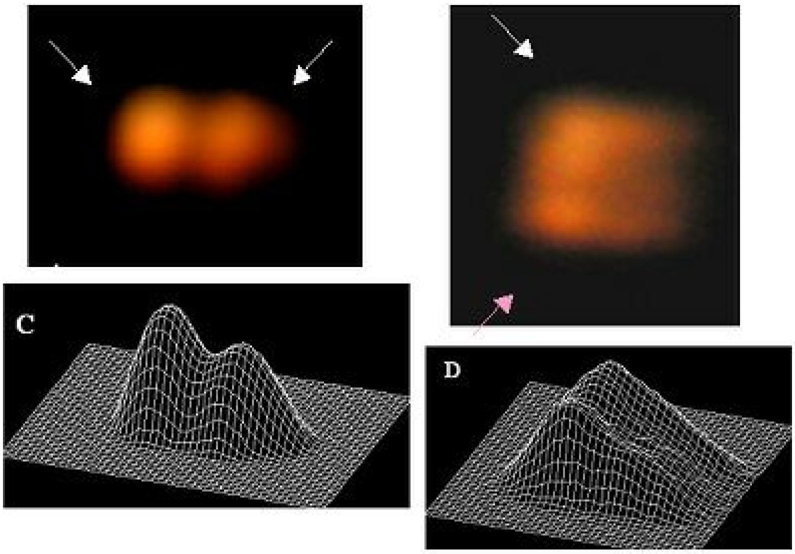
NOTE. The undulating effect in Track II might be likely caused by strong clear air turbulence, which often exists over desert areas, affecting an airplane passage. Nevertheless, the same effect is not recorded in Track IV produced by an ascertained airplane that is flying approximately at the same angular height, involving the same air mass, unless the level of turbulence was much lower at the time of this airplane passage. In fact clear air turbulence is often very localized in only a small section of the sky, and it is different at different times. Therefore this apparently anomalous case might be explained as an airplane track.

FIGURE 9. Location "A"
Definitively Explained as a Conventional Phenomenon



This photo was taken on April 7, 2003 at about 21.00 Local Time using a Questar 3.5" telescope connected to a Nikon Coolpix 5000 digital camera. The exposure time was 8 seconds. Direction is west. These lights were seen from far away, occasionally blinking, on the ground. With most probability these lights are caused by the lighted windows of one or more isolated houses that are close together and partially hidden in the bush. White arrows indicate windows that are probably illuminated from the inside. Probably a curtain is also present beyond the windows. The yellow arrow indicates a light that is outside and which is probably illuminating a porch (outside). The elongated shape of the lights is surely due to refraction caused by air turbulence that is typical of the desert areas, which causes a mirage-like effect when the lights are just on the ground, as in this specific case. The blinking effect that was seen and alerted the observers (these lights, looking to be very faint as seen from far away, were observed with the naked eye too), is surely caused by transient atmospheric light scintillation [12] due to air turbulence, which has been amplified by the enlargement effect due to telescopic observation. The image has been resized and contrast enhanced.

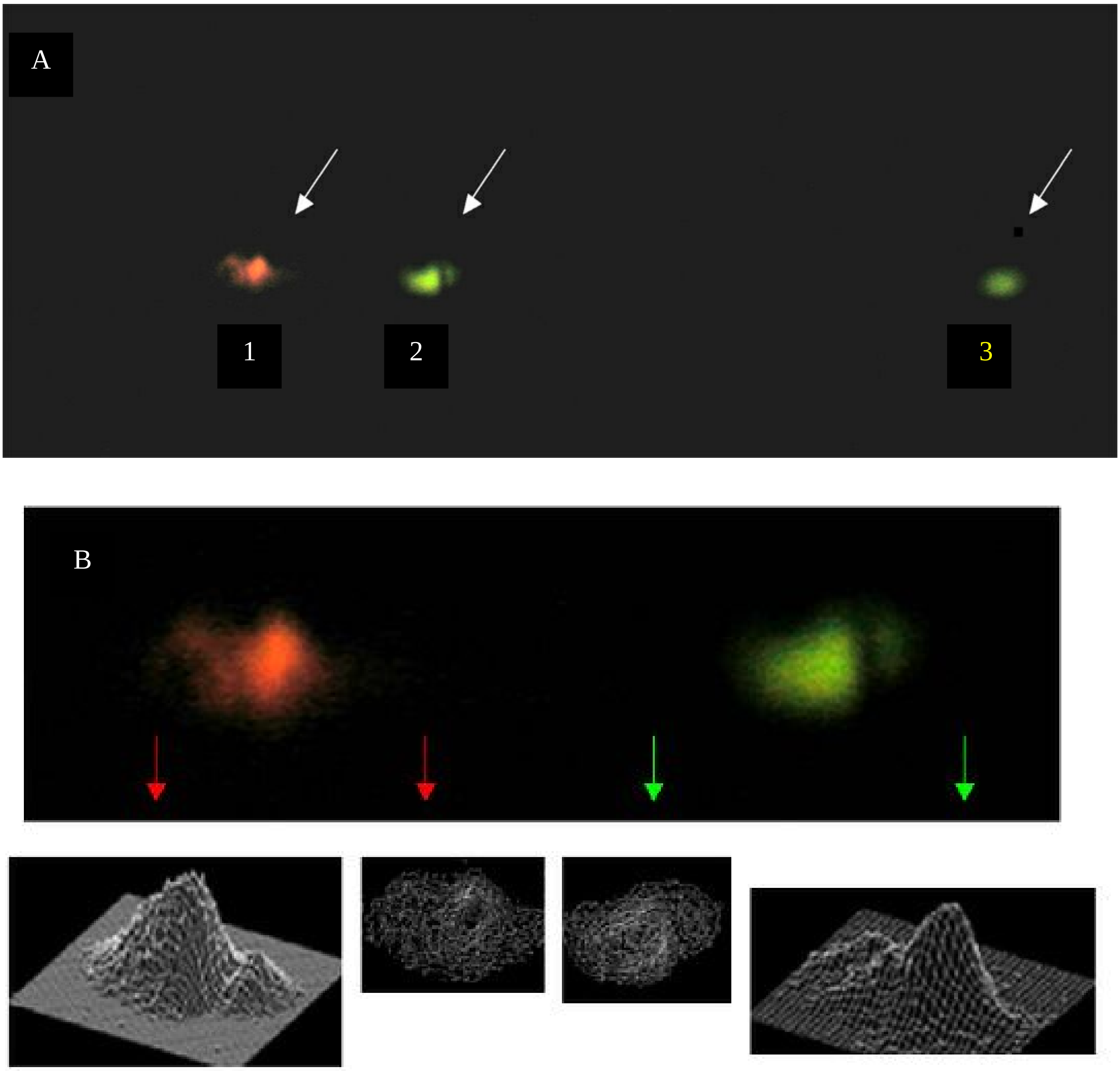
FIGURE 10. Location "B"
Unidentified Case



These two photos were taken on April 9, 2003 at about 22.30 Local Time using a Questar 3.5" telescope connected to a Nikon Coolpix 5000 digital camera. The used exposure time was 8 seconds. Direction is west. These lights were seen as very faint and distant blinking lights that were located on the ground. The two photographs were taken at a time interval of about 2 minutes (Pictures A and B). The sequence shows that the lights have apparently moved one under the other. The 3-D light distribution (Pictures C, D) seems to show a plasma-like signature with typical smooth profile. In such a specific case the smoothing of the profile is surely due to atmospheric turbulence affecting lights that are just on the ground in desert areas. Therefore their alleged plasma nature is doubtful. The apparent doubling of light of picture B is possibly not due to a movement of the second light under the first one, but just to a (transiently increased) refraction effect of the first one that was occasionally much stronger when Picture B was taken. Therefore the real variability effect that can be recorded is just the disappearance of one of the two lights. The observed blinking effect might be surely due to atmospheric light scintillation. The image has been drastically resized and contrast enhanced.

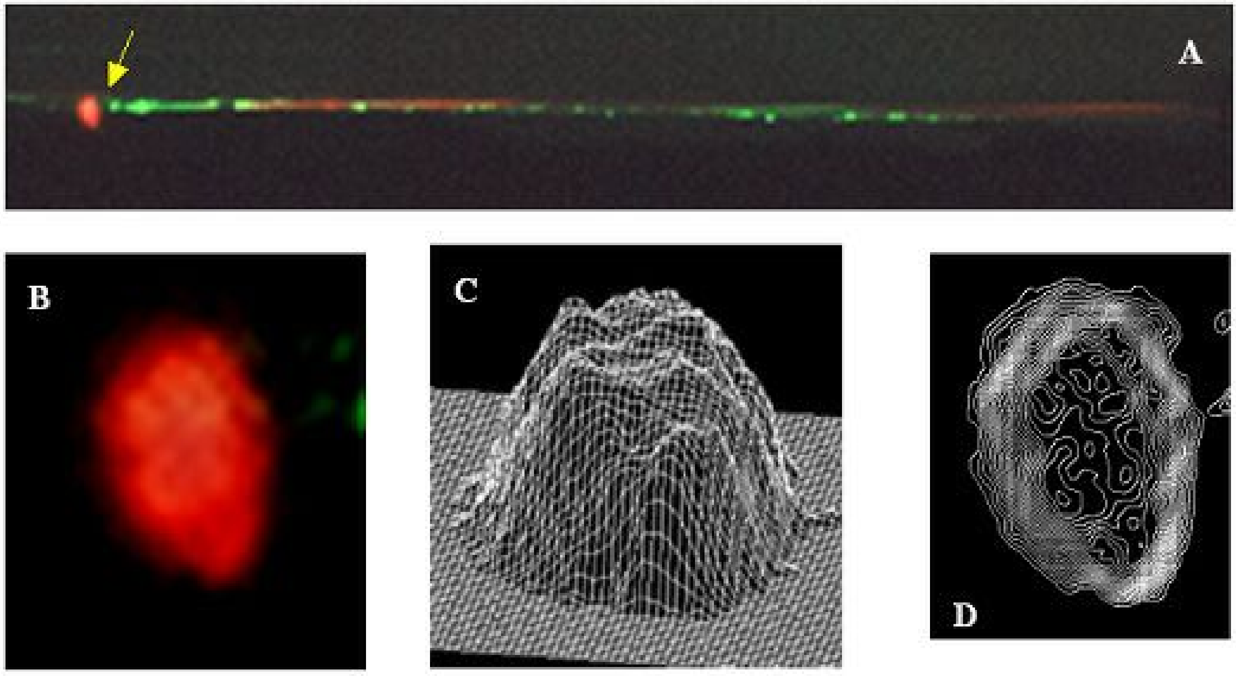
[12] Regarding Scintillation and Seeing, http://www.astro.livjm.ac.uk/courses/phys134/scopes.html

FIGURE 11. Location "B"
Unidentified Case



This photo (Picture A) was taken on April 9, 2003 at about 23.15 Local Time by using a Questar 3.5" telescope connected to a Nikon_Coolpix 5000 digital camera. The used exposure time was 8 seconds. Direction is east. Two lights (1 and 2) were seen as very faint and distant blinking lights, which were just on the ground. A third much weaker light (3) appeared only after processing the image. Analysis of 3-D light distribution (Picture B) of the most luminous lights apparently indicates that these lights show plasma-like features, but a strong air-turbulence effect originated very close to the ground might simulate this feature, by drastically smoothing the profile. Scintillation effects due to atmospheric conditions can be the cause of the observed blinking effect. The image has been reasonably resized and very strongly contrast-enhanced.

FIGURE 12. Location “B”
Possibly Explained as a Conventional Phenomenon

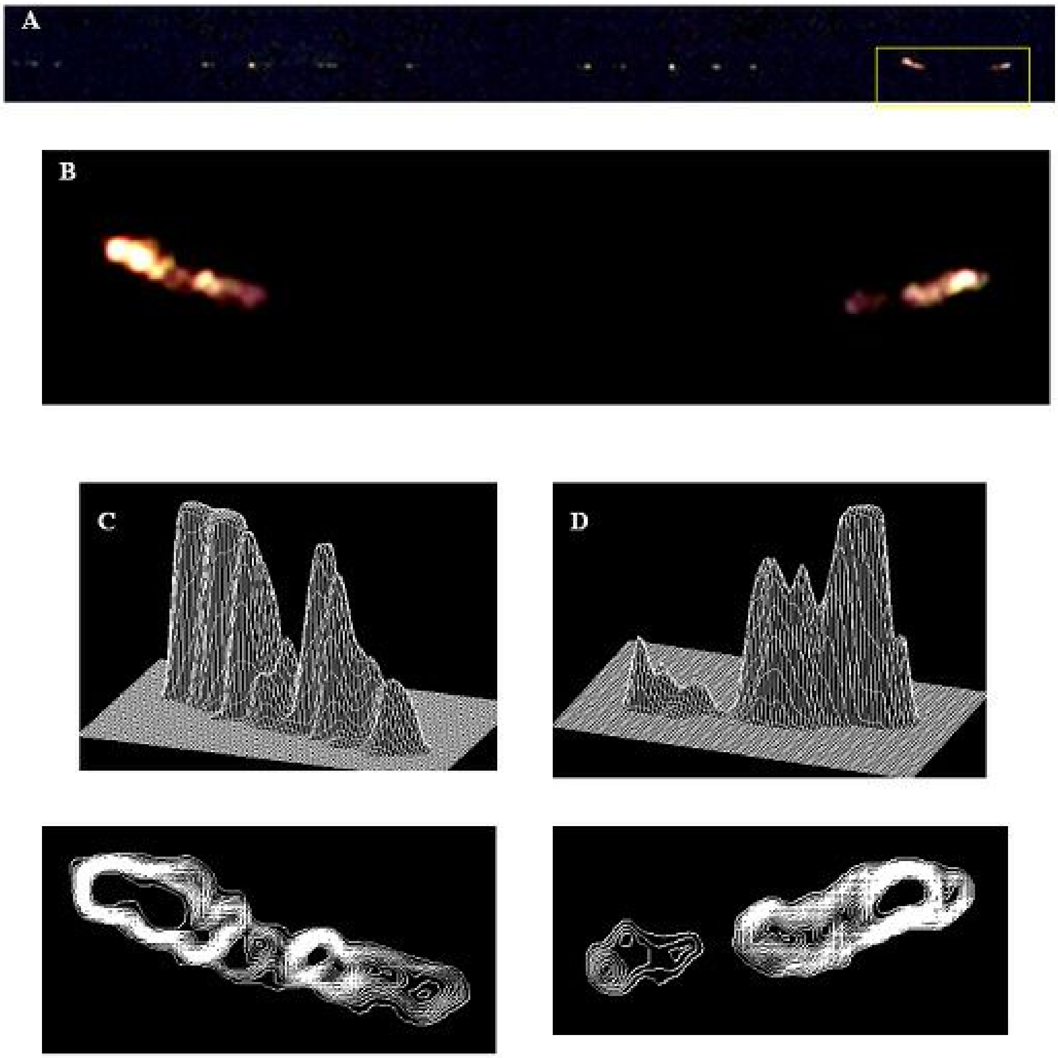


This photo was taken on April 9, 2003 at about 21.30 Local Time using a 270 mm lens connected to a Praktica BX-20 reflex camera and to a ROS spectrographic grating. Agfa 100 ASA was the used film (slide). The used exposure time was about 1 minute. The spectrum is shown in the photo (Picture A[13]). The “red spot” is the feature of interest in this photo. The red spot is not an emission line and does not belong to any spectrum, but it is a light that appeared while the spectrum was taken. A red Laser beam that was intermittently aimed towards the lens from a distance that cannot be determined probably produces this light, which is of monochromatic type. The Laser beam, which at large distance tends to expand and to become fainter at the same time, is absorbed by the air mass in the line of sight, producing an enlarged spot. The contrast-enhanced resized image (Picture B), the 3-D light distribution (Picture C) and the isophotal contour (Picture D) show a marked “granularity” of the red spot, indicating a Laser-excited turbulent air very close to the ground, which is also responsible for the elongated shape of the spot because of possibly ongoing refraction effects. A previous experiment (carried out in Hessdalen, Norway, in summer 2000) showed that when a laser pointer is aimed at an observer who is 1 Mile away, it produces exactly the same effect if the beam is pointed towards the same direction.

NOTE. Where did the Laser spot come from? It is well known that police border patrol and/or military monitor some areas of the desert in search for illegal immigrants, possibly escaped criminals or someone else. The IEA investigators by pure chance were within a few miles of military areas. They were operating in the darkness in order to carry out their own research on earthlights. It is not unreasonable to suspect that the military or border patrol were occasionally monitoring the area using infrared and/or night-vision systems, and noticed the movements of the IEA investigators whose identity or intentions were unknown to them. For nighttime operations, M-16 rifles (standard for US Army and other corps) and/or larger caliber sniper rifles, are effectively equipped both with an IR viewer and a red Laser targeting system (http://www.outdoorguides.com/outdoor/lazer.htm). If the Laser beam was the result of a standard device that was attached to their rifles to which an IR viewer is also attached (standard), it is possible that they were looking towards the IEA investigators using the IR viewer while the laser aimer was occasionally turned on, as always happens in military monitoring checks. Therefore, at that time the military may have been attempting to use the rifle as a scope and with the laser turned on. This is obviously a hypothesis, but it is a reasonable explanation. Hunters and camera focusing mechanisms are another possibility. Concerning the shape of the laser spot (namely, its opening angle), it effectively increases with distance. The observed effect is almost exactly the one that is observed when the Laser is pointed from a distance of about 1 mile in clear air (as from the tests carried out in Norway). This is just a little less than the full range of a powerful sniper rifle and a little more than the range of an M16 rifle. Considering that the dusty air of desert areas increases the optical thickness, it is highly reasonable to guess that the intensity of the red Laser spot was greater than in the case of the previous tests carried out in Norway.

[13] *The spectrum is an overlap of three spectra due to: sodium lamp, metal halide lamp and incandescent lamp.*

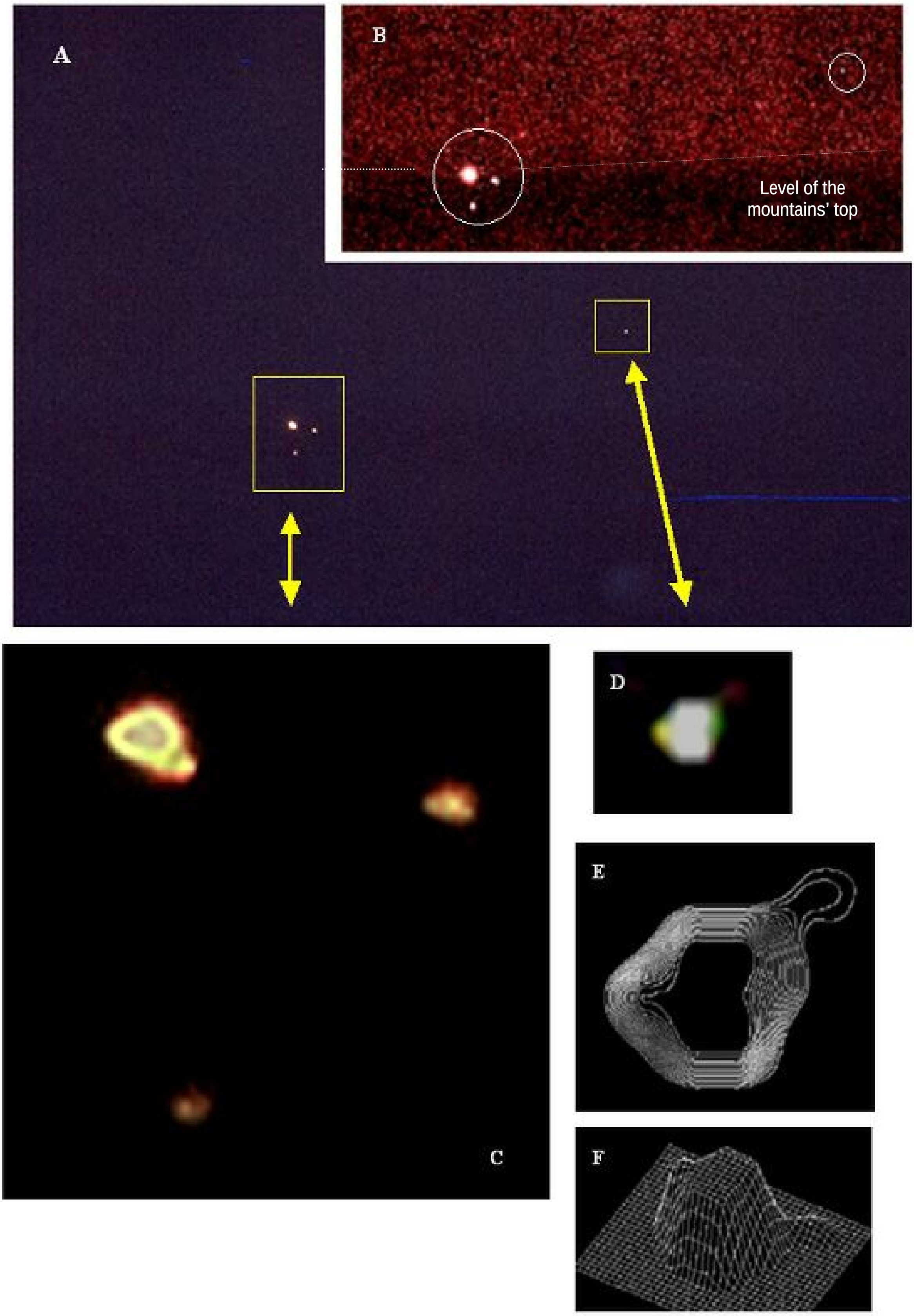
<u>FIGURE 13</u>. Location “B”
Possibly Identified Case

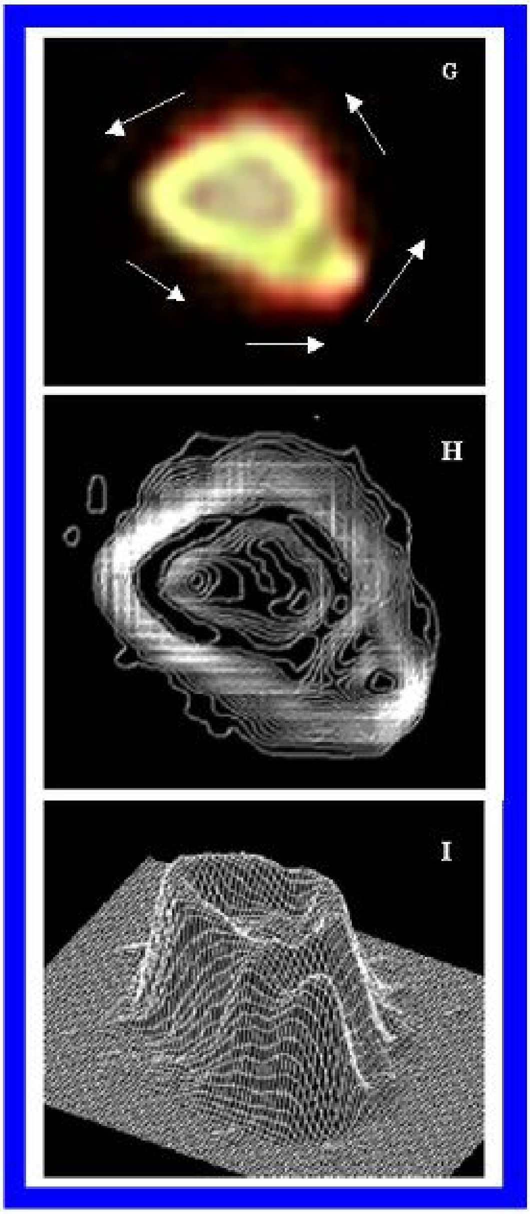


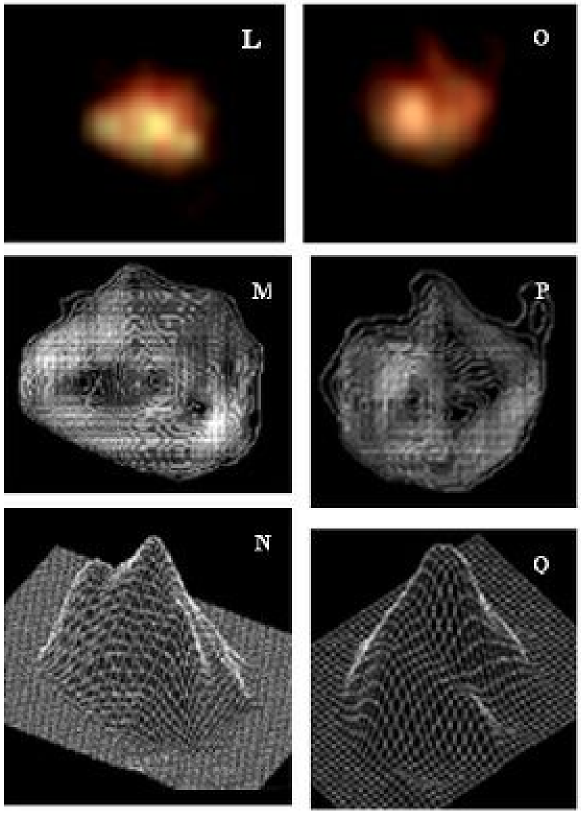
This photo was taken on April 9, 2003 at about 22.30 Local Time using a 270 mm lens connected to a Praktica BX-20 reflex camera. Agfa 100 ASA was the used film (slide). The used exposure time was about 30 seconds. The “twin ascending lights” start their path just from the horizon, whose line is well defined by distant streetlights (Picture A). These lights are clearly subject to an oppositely inclined upward motion (Picture B) and their luminosity increases when they are more above the ground. The fact that the trajectory is not continuously illuminated seems to show that these lights are like irregularly blinking. The 3-D light-distribution (Pictures C, D) shows that the most strongly illuminated parts resemble a uniformly illuminated solid. Some plasma-like and/or nebular-like (Gaussian) light-distribution can be seen in the low-intensity parts, which correspond to the glowing tail that they produce (Picture B). This tail might be due to a glowing effect caused by air excitation and/or light diffusion after the passage of the main light that is moving upwards with an angle of 30 deg. Isophotal contours (Pictures E, F) permit to visualize some of the aspects of the trajectory. In particular Picture E seems to show a sharp helical regime of motion. This light-phenomenon was not noticed at sight, but appeared as a very tiny light spot in an underexposed photograph. The image of the object of interest has been greatly resized and contrast-enhanced.

<u>NOTE</u>. Crop dusters are known to fly over the area. They are equipped with very strong lights because when they spread fertilizers and/or pesticides over the ground they are obliged to fly at very low altitude (around 10-30 feet). The picture above might be due to the flight pattern of such an airplane that is occasionally aiming its light towards the observer and then turning back and down very close to the ground with its lights opposite or perpendicular to the observer (no illumination seen). The main problem in this interpretation is that the behavior of the light that is recorded on the film is not that which is expected by an airplane aiming its strong lights towards the observer. The light track during the exposure should be continuous, more intense and not discontinuous and the helical motion should not be present. The only way to explain helical motion, if we are really dealing with crop dusters, is that the light produced by the airplane’s illumination system is diffused by the fertilizer, whose path is typically whirling or turbulent (http://www.pshowell.com/at-work/cropduster_72.jpg).

<u>FIGURE 14</u>. Location "C"
Anomalous Phenomenon







This photo (Picture A) was taken on April 3, 2003 at about 23.00 Local Time, using a MTO 506 mm catadioptric lens connected to a Praktica BX-20 reflex camera. Agfa 100 ASA was the used film (slide). The used exposure time was about 2 minutes. This photo belongs to a sequence of about 5 long-exposure photos that were taken towards very dark areas where some very short-lasting flashing lights were seen. It is possible to see: a) A group of three lights disposed in a triangular shape (Picture C), b) A small light on the right (Pictures D, E, F). The small light shows to be highly symmetric and luminosity is sharply homogeneous. Possible pixilation (maybe caused by interpolation of photo-grains) can be the cause of the apparent geometric shape, but symmetry remains surprising.

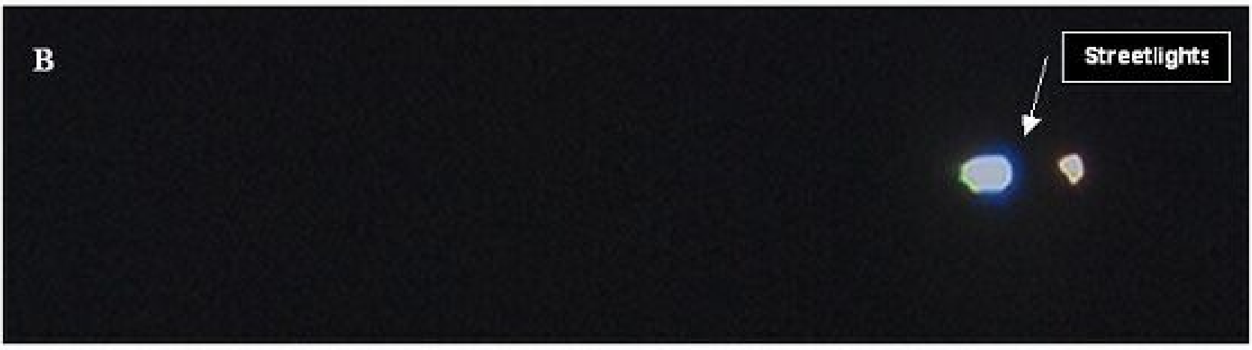
After greatly processing the entire photo in order to fix the line of the horizon (distant mountains in this case) (Picture B), it was verified that: I) the small light is located in the sky, II) the largest light of the triangular group is just a little over the mountains' top, III) the two smallest lights of the triangular group are located close to the top of distant mountains. The group of three lights is largely the most interesting. In particular the most luminous one shows very peculiar features (Pictures G, H, I). The luminosity seems to be produced by a yellow light-ball that is like “orbiting” around during one cycle, by following an angled and not circular path. The two extremes make a sort of “link”. The annular light-distribution is probably due to movement. Inside and outside the ring some glow is clearly present (whitish-yellowish inside and red outside). The 3-D light-distribution shows plasma-like features only in the parts in which the red glow is present, all the rest looks to be a kind of illumination system. The other two components of the triangular formation (Pictures L, M, N, O, P, Q) show a general reddish glow and some luminous nuclei. The probable presence of air turbulence can be responsible of some smoothing of the 3-D light-distribution. Unfortunately it is not possible to determine the distance of this phenomenon. Clearly it is not caused by any kind of streetlights. Moving tractor headlights are very doubtful in this case.

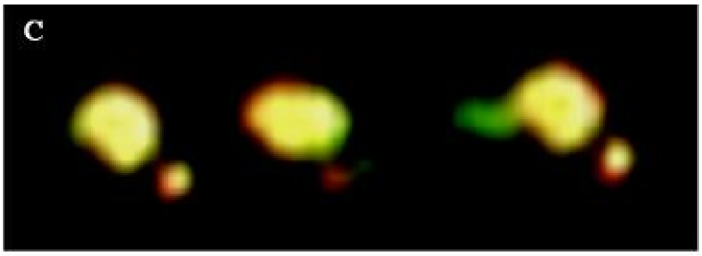
The small geometric light (Picture D), independently from the possible pixilation effect on photo grains, is evidently fixed in the sky. It shows no trail, as it would be expected by a star (during a relatively long exposure) or by an airplane. It is not possible to establish any apparent link between the triangular light formation (the largest of the three lights is rotating) and the small fixed light in the sky.

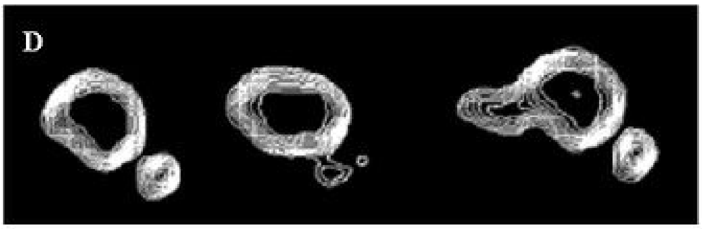
This multiple phenomenon can be considered anomalous. All the lights have been greatly resized and contrast-enhanced.

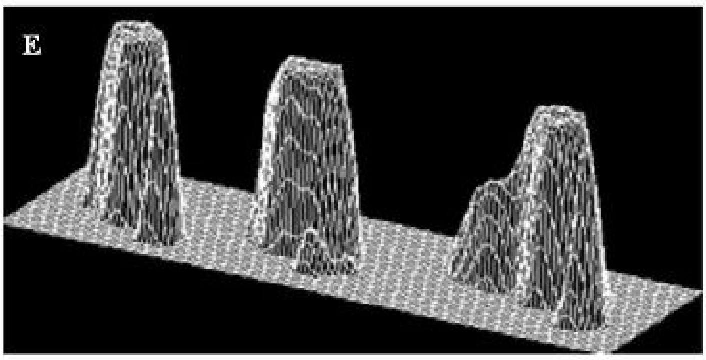
<u>FIGURE 15</u>. Location “D”

Possibly Explained as a Conventional Phenomenon









These two photos (Pictures A, B) were taken on April 5, 2003 at about 22.00 Local Time, using a 270 mm lens connected to a Praktica BX-20 reflex camera and to a ROS spectrographic grating. Agfa 100 ASA was the used film (slide). The used exposure time was of about 30 seconds for each photo. These photos were taken in order to obtain spectra of two close streetlights that are located on the right (spectra not visible here). The spectrum present in these photos has been cut because it is of no importance in this section. In about one minute a group of three lights disappeared in the second photo (Pictures A, B, C with resize and contrast enhancement). The lights are subject to aberration (the photo shows smaller lights caused by internal camera reflection) due to connection with ROS grating. Isophotal contour (Picture D) and 3-D light distribution (Picture E), show that the illumination is homogeneous and due to a uniformly illuminated solid body (no plasma-like features are detected). They are possibly the occasionally illuminated windows of one house that were turned off just in the moment in which the second photo was taken, but this cannot be demonstrated. The spectrum of these lights is absent, as it (unfortunately) formed only out of the field. This case is not definitively identified.

2. Low-resolution spectroscopy of light sources

All the spectra, which normally cover a wavelength window that is 3000 Å wide (from 4000 Å to 7000 Å), were taken using a ROS (Rainbow Optics Spectroscope [14]) holographic diffraction grating (resolution: 200 lines/mm) connected to the Skylight filter of the 270 mm lens of a Praktica BX-20 reflex camera, and an Agfa 100 ASA slide film. Typical exposure times ranging from 30 seconds up to 3 minutes was used, according to the luminosity of the light source. The use of a long focal length greatly increases the spectral resolution due to an increased spatial resolution of the spectrum itself. In such a way the spectrum occupies a large part of the photo-frame: this means that the spectrum contains a high number of pixels, while the choice of a 100 ASA film determines a small dimension of any pixel. The only disadvantage of this way of taking spectra is that the photo-frame contains only the spectrum, while the light producing it is out of the frame (on the left). This means that in order to take a spectrum using this method, it is necessary first to aim at the light source and then move horizontally the camera (to the right) where the spectrum is formed. In practice this means that the spectrum is not formed in the same view-field where the light-source is seen. Conversely, if a short focal length (such as a 50 mm lens) would be used, the photo-frame would contain both the light and the spectrum, but in this case the resolution of the spectrum would be so low that any detailed scientific analysis would be almost impossible. Such a 50 mm set-up can be useful to determine if a spectrum is a line or continuum spectrum, but not more. Line identification is almost impossible in most cases. That was the reason why the 270 mm lens option was used.

Some of the slides turned out dark due to unknown causes. The spectra that were analyzed were not the only spectra which were taken: possibly some other spectra were present in “dark slides”, which couldn’t be enhanced in a satisfactorily way. Almost all the spectra that were analyzed appeared to be produced by conventional light-sources, mostly caused by street illumination[15]. Such spectra were obtained from generally bright and fixed lights that were permanently in sight. In order to ascertain once the nature of all those illumination systems, spectra of these lights (Fig. 16) were taken from the three different observation points (Location D, Location B, Location A) that were used for observations during the IEA 2003 mission.

Spectral diagnostics showed that most of the spectra were caused by:

1. <u>High Pressure Sodium Vapor Lamps</u>

The corresponding light produces a typical orange color. These lamps are commonly used as streetlights, and produce a line spectrum.

2. <u>Metal Halide Lamps</u>

The corresponding light produces a typical white-bluish color. These types of lamp are commonly used for street and road illumination, for the illumination of some interiors (like inside hydroponic cultivation), and for the headlights of some new types of cars. These lamps, which produce a line spectrum, are parent of the High Pressure Mercury Vapor Lamps. The only difference is that Metal Halide Lamps in addition to mercury spectral lines produce several other spectral lines due to metallic ions.

3. <u>Incandescent Lights</u>

Nowadays, this illumination system (typically produced by an incandescent wire of tungsten) is rarely used for street illumination, but is mostly used for the interior of the houses, and for the most diffused car and tractor headlights (halogen light). These lamps produce a continuum spectrum.

4. <u>Strobe Lights</u>

They appear to be a continuum spectrum with overlapped very few lines in the green part of the spectrum. This is the typical light that was flashing on the sprinklers that were seen from Location D.

In many cases the spectra result to be an overlap (vertically and/or horizontally) of spectra of more than one light-source (often 2 or 3 light-sources). The vertical and the horizontal displacements are due to the different mutual positions of the lights producing the spectrum.

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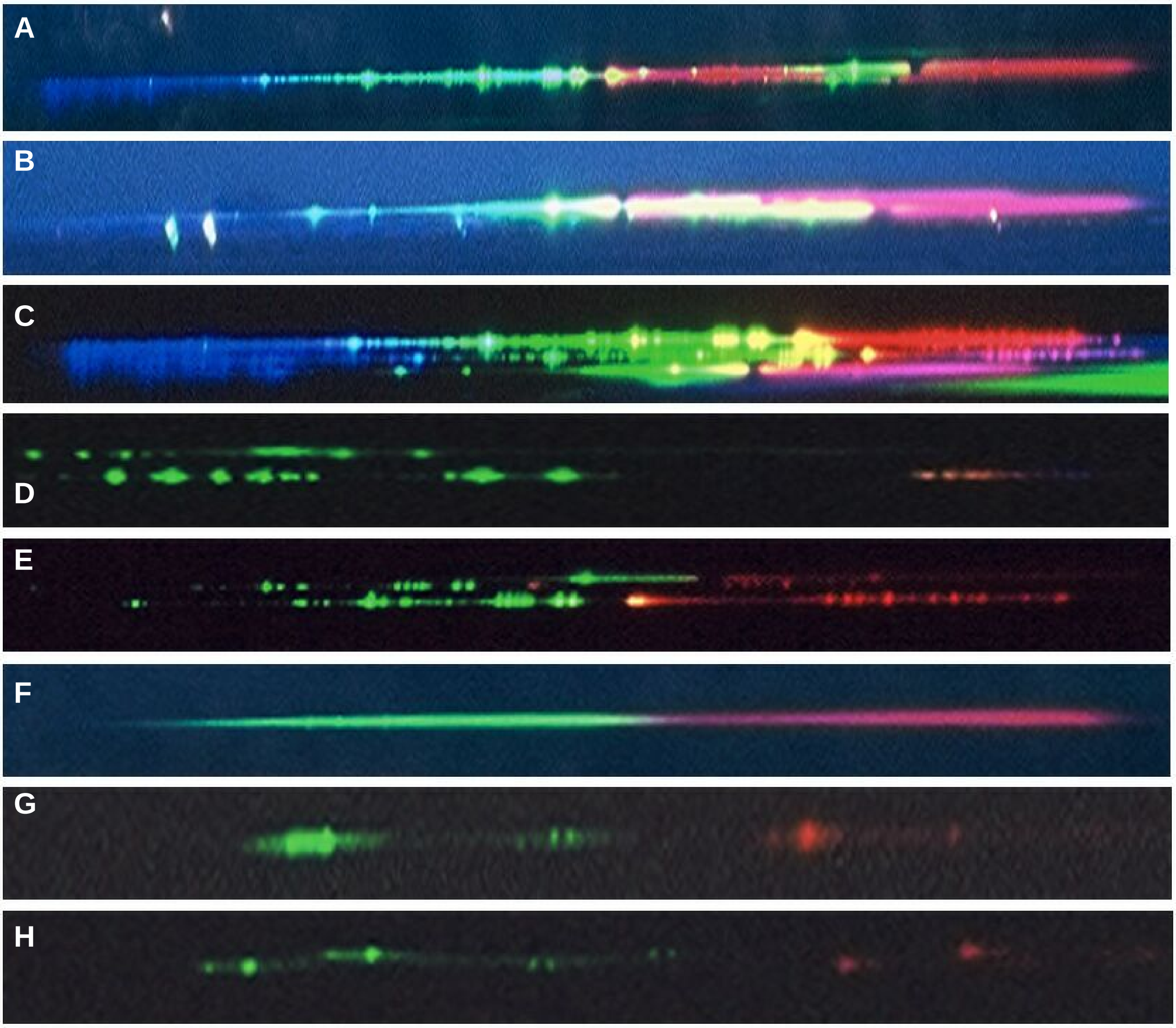
[14] Rainbow Optics Spectroscope, http://www.astrovid.com/Rainbow%20Optics%20Star%20Spectroscope.htm
[15] Lamp Emission Spectra, http://cc.joensuu.fi/photobio/lamps.html

In some cases the spectra appear to be distorted, especially if the lights producing them are very strong and very low on the horizon. This is due to refraction caused by (supposedly transiently varying) high turbulence very close to the ground typical in desert areas. This experiment shows that taking spectra in the desert of lights that are close to the ground cannot be very suitable in certain cases. Of course the refraction effect occurs also to the lights themselves, in addition to their spectrum.

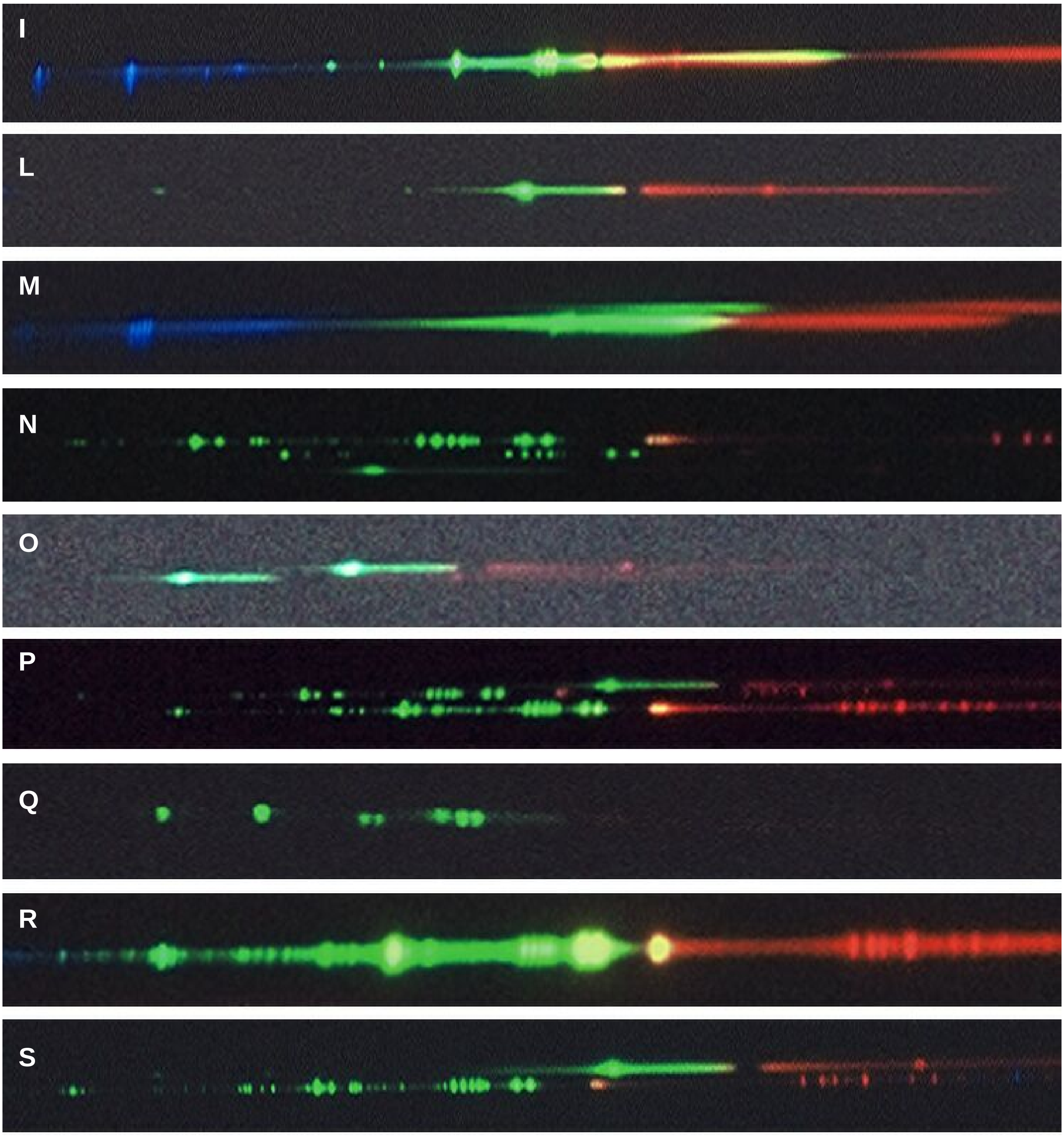
Very few spectra appear to be unidentified (3 out of 36): on one hand their faintness makes them useless for any kind of scientific analysis, on the other hand it is possible that they are different kinds of fluorescent or metal halide lamps that are added with different metallic components.

The list of identified spectra of conventional lights can be a useful reference source, in order to distinguish conventional light-sources from anomalous light-sources.

<u>FIGURE 16</u>. Low-resolution spectra



Spectra of various light sources, obtained with the ROS low-resolution grating, and their identification. Description in the next page.



Spectra of various light sources, obtained with the ROS low-resolution grating, and their identification. **A)** Strong high-pressure Sodium Lamp (above right) + (overlapped) Metal Halide Lamp (below left). **B)** High-pressure Sodium Lamp (left) + (overlapped) High-pressure Sodium Lamp (center)+ (overlapped) High-pressure Sodium Lamp (right). **C)** Strong high-pressure Sodium Lamp (below) + Metal Halide Lamp (center) + Strong Metal Halide Lamp (above) + Atmospheric Refraction. **D)** Unidentified Lamp + Unidentified Lamp (possibly: types of Metal Halide or Fluorescent Lamps). **E)** Weak high-pressure Sodium Lamp (above)+ Weak Metal Halide Lamp (center) + Strong Metal Halide Lamp (below). **F)** Strobe Light ("walking" sprinklers). **G)** Weak high-pressure Sodium Lamp. **H)** Weak high-pressure Sodium Lamp (two lamps). **I)** Strong Metal Halide Lamp (left) + Strobe Light (right, and partly overlapped). **L)** Strong High-Pressure Sodium Lamp. **M)** Strong Incandescent Light (below) + Strobe Light (above). **N)** Strong Metal Halide Lamp (above) + Weak Metal Halide Lamp (center) + Unidentified Lamp (below). **O)** Two high-pressure Sodium Lamps (displaced, below and above). **P)** Weak high-pressure Sodium Lamp (above) + Weak Metal Halide Lamp (center) + Strong Metal Halide Lamp (Below). **Q)** Possibly Fluorescent Lamp. **R)** Strong Metal Halide Lamp. **S)** High-pressure Sodium Lamp (above) + Metal Halide Lamp (below).

3. High-resolution spectroscopy tests

In order to try to take high-resolution spectra, a Questar QMax Maximum Resolution Spectrometer [16] was used in conjunction with a Questar 3.5" reflector telescope (broadband type) and a Nikon Coolpix 5000 digital camera. This high-resolution optical spectrometer was the least expensive one on the market in 2003, and was also the lightest one, so that it could be easily transported for on-field missions. Other available high-resolution spectrometers are very heavy and extremely expensive, moreover they can be used only with high-aperture telescopes.

The Questar QMax spectrometer is normally used for solar spectroscopy, and its resolution (11.6 Å/mm) is so high that it is possible to resolve the Zeeman splitting effect of some spectral lines due to magnetic fields near the sunspots. Test spectra taken of the solar photosphere demonstrated that the QMax spectrometer is working very well. An example of Test spectra that were taken of the Sun during the mission is shown in Figure 17. The spectrum, which is about 100 Å long, is one of the 30 spectral windows that can be obtained by simply changing the inclination of a prism, which gradually changes the wavelength window from an overall interval going from 4000 Å to 7000 Å. The spectral window that can be obtained using the QMax spectrometer is just 1/30 of the entire spectrum which is normally obtained by using a ROS low-resolution grating. It is possible to notice that the solar (Fraunhofer) absorption (dark) lines can be resolved extremely well. Figure 17 shows how the obtained QMax spectra appear. Figure 18 shows the corresponding wavelength interval of one of the QMax spectral windows, compared to the entire length of a ROS spectrum usually used to capture spectra.

The QMax spectrometer in its actual basic configuration was intended to be used in order to try to acquire high-resolution spectra of anomalous light-phenomena that might be observed in the following highly favorable conditions: a) very high luminosity, b) extended angular dimensions (of the order of 30', like the Moon), c) no motion, d) long duration. Phenomena with such characteristics were not observed during the sky watching sessions that were carried out in the Arizona desert. During this mission, the QMax spectrometer was effectively used as a Test-Platform to see what supplementary instrumentation is necessary in order to make this instrument more suitable for the optimum observation of anomalous light phenomena. High-resolution spectroscopy has never been carried out on such anomalous light-phenomena. The experience on the field has shown that the following custom-built operations [17] are now necessary:

1. High-resolution spectra of light-sources that are much less luminous than the Sun can be visible only if their light is opportunely amplified. Therefore, the light reaching the focal plane of the telescope must be intensified before passing through the QMax spectrometer. For this reason an image intensifier must be mounted between the telescope and the spectrometer, or directly to the spectrometer's eyepiece. Image intensifiers are normally used in astronomy to take spectra of stars whose luminosity is very weak. Special video cameras [18], which are very suitable for very weak light-sources, can be used for this specific task.

2. It is necessary to use a longer focal length for the QMax eyepiece, in order to focus the spectrum of a source that is expected to have (apart from existing exceptions) a much smaller angular diameter (typically 1') than the one of the sun (30'). Therefore it is necessary to use a new eyepiece or a focal tele-extender.

3. The dispersion of light that is obtained with the QMax spectrometer, similar to all the other high-resolution spectrometers, requires that the light beam passes through a very narrow slit. Therefore the luminous target must be kept aligned with the slit. In order to perform this task efficiently the eyepiece of the Questar telescope (to which the QMax is attached) must contain an illuminated cross inside in order to keep the target well centered in the field of view. Only when the luminous target is in the center of the field of view, is it aligned with the dispersions slit of the QMax spectrometer. Such an operation could be facilitated by connecting the Questar telescope to a CCD tracking camera and a monitor showing an illuminated cross. In such a way the

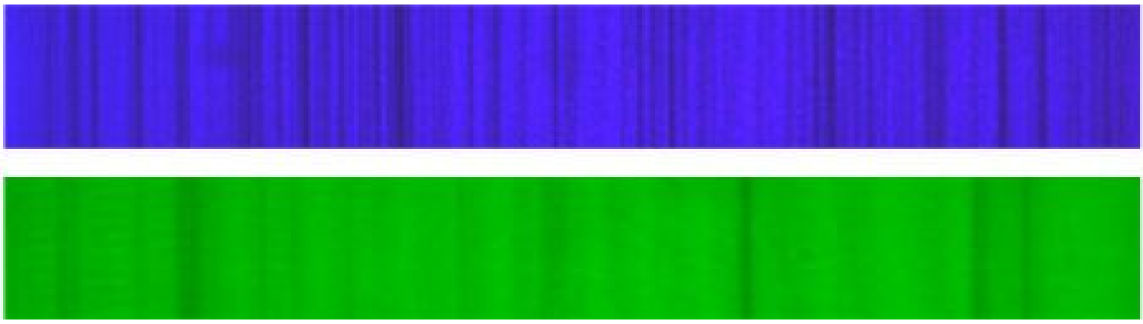
[16] Questar QMax Maximum Resolution Spectrometer, http://www.questarcorporation.com/questar.htm
[17] *A master thesis in optical engineering devoted to this specific subject would be highly invoked.*
[18] Andor EMCCD Camera, http://www.andor-tech.com/pulse/OTP%20Jan-Mar%2003%20HR.pdf

telescope can be guided to the target. Implementing additional the necessary commercially available instrumentation could enable such operations [19].

These custom-built operations are feasible with some effort but can be done successfully [20]. After all these new implementations are carried out, effort should be concentrated in the observation of weakly luminous targets having small angular diameters (1', like Venus) and with behaviour such as c) and d). If the target is moving too quickly any operation is probably impossible using this setup, unless the target is kept fixed in the slit using appropriate tracking using a video camera.

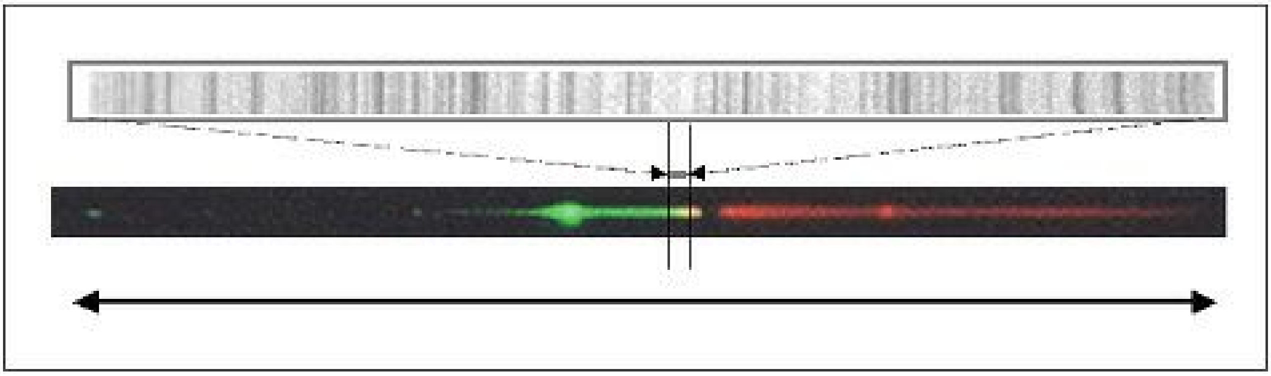
Alternatively to a QMax spectrometer, the use of the *Ansbro Wide-Field Fast Scanning High-Resolution Spectrograph* [21] is highly recommended in order to obtain high-resolution spectra of moving extended light-sources of any luminosity. Irish astronomer Eamonn Ansbro has projected this instrument, whose cost is over 20 times more expensive than the QMax. This instrument, which is based on a high-speed lens system and a moving slit assembly, is best suited for measuring moving sources such as meteors and comets, and other applications where a wide field of view and/or a moving target is involved.

FIGURE 17. High-resolution spectra



Two spectra of the sun obtained at different wavelengths windows (width = 100 Å) by using the QMax high-resolution spectrometer connected to a Nikon Coolpix 5000 digital camera during the April 2003 preparatory tests. Absorption Fraunhofer lines are clearly shown.

FIGURE 18. High-resolution spectrum vs. low-resolution spectrum



This photo shows a comparison between a QMax high-resolution spectrum (above, in grayscale) and a ROS low-resolution spectrum (below, in color). The indicated narrow interval shows the corresponding 100 Å wavelength window of the QMax spectrum, compared with the 3000 Å wavelength interval of the ROS spectrum.

[19] SBIG STV Digital CCD Star Tracker System, http://www.sbig.com/sbwhtmls/stv_announcement.htm
[20] *I am going to establish contacts in this sense with Jim Perkins of Questar, and with other optical and informatics technicians.*
[21] Ansbro Wide-Field Fast Scanning High-Resolution Spectrograph, http://star.arm.ac.uk/asgi/2002_autumn_nuig_abstracts.html

Concluding remarks

In general the optical part of this scientific mission permitted recording of a few unexpected possibly anomalous light-events with the following main characteristics:

- Presumably short-duration light-events (less than 8 seconds) that were occasionally recorded by the digital camera, with globular, elliptical, elongated and complex shapes, having several colors and some nebulosity and/or surrounding glow in some cases.
- Possibly longer-duration light-events that were occasionally recorded by the reflex camera, with marked characteristics of curved motion.
- Both of the two designated light-anomalies showed characteristics of an illuminated solid body surrounded by a plasma-like glow.
- Undulating and irregularly intermittent tracks occurred in the sky.

Some other light-events that so far remain unidentified could be explained as known phenomena, even if this cannot be ascertained yet.

This part of the mission, even if physical parameters could not be derived due to the lack of knowledge about distance and to the lack of crucial spectra, permitted demonstration that a light-phenomenon indeed exists in the Arizona desert, although it occurs infrequently. Nevertheless this phenomenon in most cases occurs as a very short-duration event, in other cases it is generally unnoticed by the sight. But this doesn't mean necessarily that it cannot be effectively seen. This behavior demonstrated that taking a large number of high-resolution panoramic digital photographs is probably the most efficacious way to record these kinds of light-phenomena. Moreover, sophisticated techniques of image processing have demonstrated the ability to strongly enhance very weak light-sources such as field-stars, or other light-phenomena whose nature can be eventually identified.

With few doubts some of the optical data concerning phenomena that have been definitively considered "anomalous", and maybe some of the "unidentified" cases too, might acquire a much greater physical importance if their times of occurrence coincide (precisely or approximately) with the times of possibly anomalous data acquired using EM instrumentation by geophysicist M. H. Adams and engineer E. P. Strand. Nevertheless, EM emission from anomalous lights seen and/or photographed may or may not be recorded if they are too distant from the observer. On the other hand, the possibility exists that anomalous EM emissions may be produced by radiating phenomena (possibly in the infrared) that are relatively close to the observer but invisible (no infrared observations were made during the 2003 mission). Therefore the analysis of EM emissions might also (or only) show EM anomalous events with different timing than the recorded optical events. This report is the first of a three part effort. The answer to these speculations will come when the other mission participants publish the analysis of their electromagnetic, magnetic and ionizing radiation data acquired during the mission.

21 April 2005

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I also want to thank all of the so kind and very friendly persons who often assisted us in that area of the Arizona desert, persons of whom I have a very pleasant remembering especially for their kindness and warm sense of hospitality.

Many thanks to Marsha Adams of *IEA* and Prof. Erling Strand of *IEA* and *Project Hessdalen* for their prompt and sound comments on this report.

General References

Here is a list of selected papers, books, websites, and research communications that do not specifically deal with light phenomena in the Arizona desert. These are examples of good interdisciplinary scientific experimental and theoretical research on so-called "earthlights". This subject is considered from several points of view. Some of these works do not deal only with "earthlights" but also with other subjects that might be related to this phenomenon.

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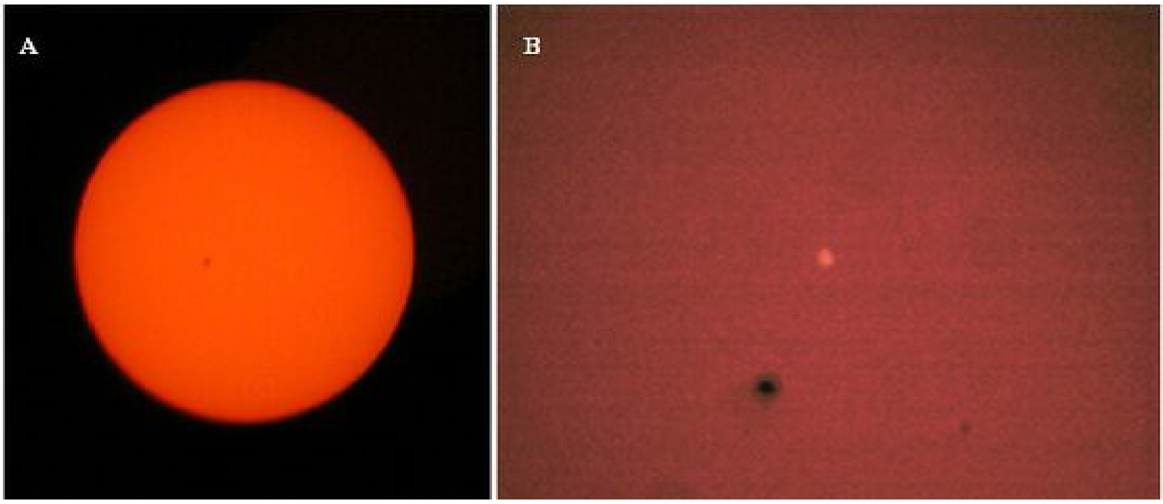
Appendix: Test of the accuracy of the Questar 3.5" telescope

The preparatory tests with the optical equipment were mostly dedicated to the observation of the Sun and of the planets (Figure 19). The results demonstrated that the coupling of the Questar 3.5" telescope[22] with the Nikon Coolpix 5000 digital camera [23], worked very well in terms of spatial resolution, color definition and dynamic range. Other tests with photographs of distant lights (such as sprinklers: Figure 20) has shown that turbulence effects, which affect luminous sources especially when they are observed very close to the ground in desert areas, become evident when high magnifications are used. Using very sophisticated software in the post-processing phase can efficaciously solve this problem [24].

FIGURE 19. Images of the Sun



This picture shows two photos of the sun obtained with a Questar 3.5" telescope connected to a Nikon Coolpix 5000 digital camera, during the April 2003 preparatory tests. An appropriate Questar solar filter was used. Picture A shows a frame obtained using the wide field eyepiece. Picture B shows a frame obtained using a zoom eyepiece. Two sunspots and a small flare are shown with very good resolution. Solar granulation is also shown.

FIGURE 20. Strobe lights

This picture (A) shows the photo of a walking sprinkler strobe light as seen from Location C, in the Arizona desert, which was taken using a Questar 3.5" telescope connected to a Nikon Coolpix 5000 digital camera, during the April 2003 preparatory tests. The highest magnification (B) has been used. The effect of turbulence in this case starts to merge, causing a blurring effect in the images.

[22] Questar 3.5" telescope, http://www.questarcorporation.com/3-5.html
[23] Nikon Coolpix 5000 digital camera, http://www.nikon-coolpix.com/products/coolpix5000/index.htm
[24] VISAR Video Processing Software, http://www.rti.org/page.cfm?objectid=BC9D9BEF-F9E5-46AA-AE1788EFF8F6B8AC

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