A rebuttal of the EMBLA 2002 report on the optical survey in Hessdalen: Part Three

MATTEO LEONE

Italian Committee for Project Hessdalen (CIPH)
scientific advisor

e-mail: matteo.leone@usa.net

Abstract – A paper by the leader of the EMBLA physics team, concerning the nature of the allegedly anomalous luminous phenomenon sighted in August 2002 in the Hessdalen valley, is here briefly reviewed. It is shown that such a paper lists several previously undisclosed photometric and spectroscopic data on this luminous phenomenon. It is shown as well that these new data strongly corroborate the headlamps hypothesis formerly suggested by this author.

Introduction

In August 2002, a team of Italian physicists, astronomers, engineers and technicians, jointly with two Østfold College researchers (Sarpsborg, Norway), carried out a survey – codenamed EMBLA 2002 – in the Hessdalen valley (Norway). During this survey it was collected photographical and spectroscopic evidence on an unrecognised luminous phenomenon in the low atmosphere.

As it was shown by Leone (2003a,b) this optical survey "was lacking both in the methodology of data collection and in the evaluation of the evidence" (Leone, 2003a, p. 26). A thorough analysis of the topographical, photometrical and spectroscopic data led this author to draw the conclusion that the whole optical evidence reported in the EMBLA physics report (Teodorani and Nobili, 2002) is consistent with, and points at, an explanation involving an unrecognised vehicle headlights source of light. The leader of the EMBLA physics team reacted to this conclusion by writing a paper allegedly refuting it (Teodorani, 2003) but, as formerly reported (Leone, 2003b), he failed to provide convincing reasons against this explanation.

In a recent paper, Teodorani (2004) has come back to this subject with the goal of refuting one more time this author's interpretation of the luminous phenomenon reported in the EMBLA 2002 physics report. Although most of Teodorani's paper is devoted to irrelevant *ad hominem* remarks, it is not devoid of interest and it reports so far undisclosed data on the photographic evidence collected in August 2002. Since Teodorani (2004), as in the former paper, avoids looking at the visual and topographic evidence pointing at the vehicle headlamps explanation, these topics will not be discussed here (see Leone, 2003b, pp. 2-4, 11-15).

Photometric evidence

Teodorani (2004, p. 18) obtains a new value of the absolute power of the light phenomenon. This value – 18.8 kW, as opposed to the former 100 kW figure (see Teodorani & Nobili, 2002) – is derived out of a photometric equation (1) suggested by Maccabee (1979, 1999).

$$P = 4\pi d^2 \frac{E}{\tau \frac{\pi}{4}\left(\frac{F}{f}\right)^2 T} e^{\frac{3.9d}{V}} \tag{1}$$

In order to arrive at this absolute radiant power estimate Teodorani analysed a "correctly exposed photo" (Teodorani, 2004, p. 17) that he took in Hessdalen. This is one of the photos published in the EMBLA 2002 physics report (Teodorani & Nobili, 2002, p. 5). Such a photo

> was scanned and the image of interest was resized (image interpolation) and then transformed into a black and white frame (by using software Adobe Photoshop version 5.5). By using software Iris the counts and the 2-D light distribution (Point Spread Function) of any single component of the light cluster was measured. After determining the saturation level and ascertaining that no substantial overexposure was present, the counts were scaled with the exposure parameter which was deduced from the Density – Log (Exposure) characteristic curve for the specific Kodak film (Teodorani, 2004, p. 18).

Quantities, symbols and estimates reported by Teodorani are listed in Tab. 1.

Absolute radiant power[1]	**P**	18.8 kW
Distance[2]	**d**	$9 \cdot 10^3$ m
Total energy received by the film[3]	**E**	$3.4 \cdot 10^{-5}$ lm s
Exposure time[4]	**τ**	5 s
Focal length	**F**	0.27 m
f-number	**f**	2.8
Lens transmission factor	**T**	0.9
Visibility[5]	**V**	$1.5 \cdot 10^4$ m

Tab. 1 – Parameters of the photometrical equation (1).

According to Teodorani, "no more comments" on this matter are required since this alleged 18.8 kW absolute power estimate would led to a figure 60 times higher than the luminous power emitted by a "known streetlight" of known distance which was present in the same photo analysed by the leader of the EMBLA 2002 physics team. Since this author's estimate of the luminous power emitted by car headlamps (Leone, 2003b, pp. 15-20) "brings to an even smaller value" than that concerning the streetlight, this would led *a fortiori*, according to Teodorani, to a refutation of the headlamps hypothesis.

Although the photometric equation (1) used by Teodorani is correct in itself, his methodology is flawed and his assumptions are groundless. Teodorani assumes in fact that the stationary light is an isotropic radiator (4π). No evidence allows such a conjecture. The video and photographs allegedly documenting "clustering and ejection effects […] coming from lighted plasma-like balls" (Teodorani, 2004, p. 18) do not support the isotropic radiator assumption since they are shot from one single point

[1] Teodorani's estimate is affected by a minor calculation mistake, since the value quoted in Tab. 1 led to P = 16.3 kW.
[2] This distance value was obtained through an alleged triangulation carried out in August 2002. Since no details on this topic have ever been published, neither in the EMBLA 2002 physics report (Teodorani & Nobili, 2002) nor in the following paper by Teodorani (2003, 2004), it is not possible to cross-check the accomplished methodology and the reliability of the figure. Although a more correct estimate is 11.5 km, corresponding to a country road on the Løbergsvollen-Heggsetvollen hill (Leone, 2003b, p. 14), since such values are of the same order of magnitude, the figure reported by Teodorani is here considered.
[3] The total energy received by the film was obtained by multiplying the average film exposure level (8.8 lm·s/m²) and the image area ($3.9 \cdot 10^{-6}$ m²).
[4] It is fair to remember that Teodorani did not time the duration of the phenomenon. On the unreliability of this estimate see Leone (2003b, p. 18).
[5] No source for this parameter is given by Teodorani (2004).

of view and their resolution is too much low to resolve the non-isotropic beam emitted by a couple of car headlamps. Moreover, this author's visual observation jointly with the topographic and spectroscopic evidence, suggests a non-isotropic source of light explanation.

In spite of the above quoted flaws, Teodorani's treatment deserves to be praised since he lists carefully the values of each parameter included into the photometrical equation. This healthy procedure allows us to check the employed methodology as well as to suggests – should it be necessary – alternative interpretations out of the physical data.

By writing equation (1) as P = 4πI, where I is the luminous intensity (lm/sr = cd), and by letting:

- $A = (\pi/4) \cdot (F/f)^2$, where A is the area of the lens aperture (m^2), F is the focal length (m) and f is the f-number,
- $E = H \cdot A_i$, where E is the photometric energy deposited within the boundary of the image (lm ·s), H is the average film exposure level ($lm \cdot s/m^2$) and A_i is the image area (m^2),
- b = 3.9/V, where b is the atmospheric extinction (m^{-1}) and V is the visibility (m),

one gets the following formula

$$I = \frac{H \cdot A_i \cdot d^2 \cdot e^{bd}}{\tau \cdot A \cdot T} \qquad (2)$$

i.e. the very same equation used by Leone (2003b, p. 19, equation 5). As it was written by Maccabee, this formula "can be found by inverting standard photometric equations which give the image exposure in terms of source intensity" (Maccabee, 1987, p. 265). By introducing in (2) the parameters values reported by Teodorani himself, it is possible to get an estimate of luminous intensity.

The visibility V – or visual range – quantity in (1) and (2) follows from equation (3), when the standard value of 0.02 for the threshold of brightness contrast ε is used,

$$V = \frac{1}{b}\ln\left(\frac{1}{\varepsilon}\right) = \frac{3.912}{b} \qquad (3)$$

However, in the derivation of the visual range, it was assumed that a black object was viewed against a uniformly illuminated horizon sky (Johnson, 1954, p. 80). This condition is hardly applicable in the case of the photograph shot by the leader of the EMBLA physics team, where a bright point-like source of light was photographed at night.

According to the general theory of the visual range (Johnson, 1954, p. 86), the optical slant range $\bar{r}$ is given by equation (4), where σ_0 is a constant extinction coefficient in the horizontal plane presently existing at ground level, B_B^* and B_o^* are the intrinsic brightness of background and object respectively (lm/m^2), B_B, B_0 and B_H are the apparent brightness of background, object and horizon, and C* and C are, respectively, the intrinsic and apparent brightness contrast.

$$\bar{r} = \frac{1}{\sigma_0}\ln\left[\frac{B_B^*}{B_H}\left(\frac{C^*}{C} - 1\right) + 1\right] \qquad (4)$$

$$C = \frac{B_0 - B_B}{B_B} \qquad (4^*)$$

$$C^* = \frac{B_0^* - B_B^*}{B_B^*} \qquad (4^{**})$$

Equation (4) can be adapted for nighttime use. Let $\bar{r}$ = D be the visual range at night, σ_0 may be related to the daytime visual range V (equation 3). At night, $B_B^* / B_H \approx 1$ (background and horizon brightness ratio). $C^* = \frac{B_0^*}{B_H} - 1 \cong \frac{B_0^*}{B_H}$ (for all practical purposes $B_o^* / B_H >>1$). Therefore, if we denote the threshold value of C by C_0,

$$D = \frac{1}{b} \ln \frac{C^*}{C_0} = \frac{V}{3.912} \ln \frac{C^*}{C_0} \tag{5}$$

This equation can be used as an aid in determining what intensity lights make suitable markers for determining the visual range at night.

It is unclear the source of the visibility value reported by Teodorani (15 km), however, granted that this value is reliable, the visual range at night for light is not independent of the luminous intensity and therefore has to be extrapolated from the available experimental data. In 1935, M.G. Bennett carried out a set of empirical studies to establish the relationship between the visual range at night as estimated from lights of varying candlepower and the visual range during the day (see Tab. 2).

Daytime Visibility	**Visual Range at Night for Lights of**			
	1 cd	**10^2 cd**	**10^4 cd**	**10^6 cd**
10 km	2.1 km	7.6 km	16.1 km	25.8 km
20 km	2.4 km	12.1 km	29 km	48.3 km

Tab. 2 – Visual range at night for lights of different luminous intensity compared with the visual range by day in the same atmosphere (data excerpted from: Bennett, 1935, as cited in Johnson, 1954, p. 98).

In order to test the headlamps hypothesis, a luminous intensity of 10^5 cd (order of magnitude) should be considered (ECE Regulation, 2002, p. 18). From Tab. 2 it turns out that the visual range at night for lights having a luminous intensity headlamps-like is 1.5 to 2.5 times higher than the corresponding daytime visibility. Letting V = 15 km, the visual range at night D to be inserted in (2) will be taken as a factor 2 greater, i.e. the average 30 km figure. By inserting the parameters values into (2) the equation yields:

$$I = \frac{3.4 \cdot 10^{-5}\, lm \cdot s \cdot \left(9 \cdot 10^3 m\right)^2 e^{\frac{3.9 \cdot 9 \cdot 10^3 m}{3 \cdot 10^4 m}}}{5s \cdot 7.3 \cdot 10^{-3} m^2 \cdot 0.9} = 2.7 \cdot 10^5 \text{ cd} \tag{6}$$

The motor vehicle headlamps illumination is regulated by rigid international regulations issued by the *United Nations Economic Commission for Europe*. These regulations fix the maximum luminous intensity ($2.25 \cdot 10^5$ cd) for vehicle headlamps (ECE Regulation, 2002, p. 18). By comparing the maximum luminous intensity with the estimated value obtained out of the formula used by Teodorani, using the very same parameter figures (with the cautions as above concerning the visual range), it results a strong corroboration of the headlamps hypothesis. The discrepancy between the expected maximum luminous intensity and the experimental figure is within the 30% of error associated with this measurement, as reported by Teodorani (2004, p. 18) himself.[6]

[6] It is unclear how Teodorani estimated this 30% value and how the scans and image interpolations carried out by the leader of the EMBLA 2002 physics team affected the final result. Anyhow, this figure is very likely a conservative estimate, given the large uncertainties associated with the time parameter (see Leone, 2003b, p. 18), and the as well unclear estimates of d and V. Independently of this, the calculation reported in this section shows that – as mere order of magnitude – the measurements carried out by Teodorani are entirely consistent with the vehicle headlamps explanation.

Spectroscopic evidence

Teodorani (2004, p. 12) agrees with this author that the film sensitivity curve is an important factor in establishing the nature of the light. In fact, he goes on to see "what happens when one multiplies a function which reproduces the Kodak sensitivity curve by another function reproducing several kinds of illumination systems". He "discovers" six spectra (one of them being emitted by an incandescent source of light) that resemble the EMBLA experimental spectrum, and that are "morphologically similar" each other. He arrives at admitting that the incandescent source of light is worth of consideration, although "so far it is not possible to confirm which one is the correct light source" (Ibid., p. 13). This is an interesting shift with respect to the former Teodorani's paper where the issue of the role of the film sensitivity curve was largely avoided and this author's simulation was rejected because "the resulting spectrum, apart from some rough wavelength coincidences, is different from the sensitivity curve mostly because of different ratios between the three peak amplitudes and because of a much higher amplitude of the single peaks" (Teodorani, 2003, p. 4).[7]

Unfortunately, Teodorani's methodology is far from convincing.

He states that several sources of light (Xenon flash, metal-halide, fluorescent, Xenon lamp and two-LED), upon considering the film sensitivity curve, "give a similar or better trend" (Teodorani, 2004, p. 13) with respect to the incandescent source typical of vehicle headlamps, when compared with the EMBLA experimental spectrum. In order to show that "several illumination systems which are different from the ones produced by car headlights" (Ibid., p. 14) could account for the EMBLA spectrum he provides a figure where the spectra are compared (Ibid., p. 14, Fig. 2).

This procedure is not legitimate for two reasons:

1) the alleged better fit between Teodorani's hypothetical sources and the experimental spectrum is provided *by declaration* as opposed to a quantitative statistical test; while the spectroscopic argument for a vehicle headlamps explanation is supported by a correlation coefficient test (Leone, 2003b, pp. 6-8), the Teodorani's position against this hypothesis is only supported by an *argument from authority*.

2) His comparison of spectra is carried out by conveniently neglecting the 400 nm – 500 nm range of wavelengths (where the film sensitivity curve is higher). If the whole visual range of wavelengths is considered the agreement between Teodorani's five (of six) theoretical spectra with the EMBLA's one becomes less than satisfying (Fig. 1).

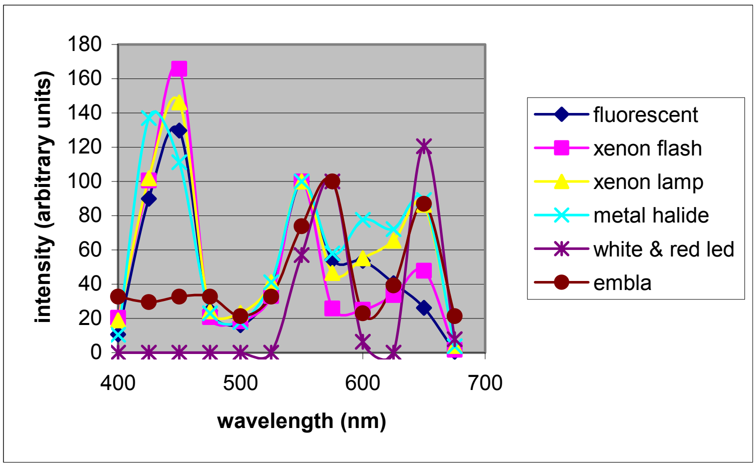


Fig. 1 – Comparison between theoretical spectra reported by Teodorani (2004) and EMBLA experimental spectrum. Data drawn from: http://www.photo.net/photo/edscott/cf000030.htm (fluorescent daylight); http://optoelectronics.perkinelmer.com/library/papers/tp9.asp (xenon flash); http://msp.rmit.edu.au/Article_01/04.html (xenon lamp); http://cc.joensuu.fi/photobio/pdf/spectra/HQI400D.pdf (metal halide); Teodorani, 2004, p. 29 (white/red led).

[7] For an exposition of Teodorani's misrepresentation on this issue see Leone (2003b, p. 6).

The roughly flat spectra characteristic of fluorescent, Xenon flash, Xenon lamp, and metal halide lights jointly with the Kodak Ektachrome 100 sensitivity led to resulting theoretical spectra quite similar to the film sensitivity curve, i.e. three peaks, the highest one being at the violet end of the spectrum. This outcome flatly contradicts the experimental results, where the violet peak is by far the lowest one. On the contrary, the white and red led source of light chosen by Teodorani does not show any relevant peak at short wavelengths, differently from both the EMBLA experimental spectrum and headlamps one formerly suggested by this author.[8]

The only theoretical spectrum still showing a (very close) resemblance with the experimental one is the spectrum emitted by an incandescent source of light, i.e. the typical vehicle headlamps spectrum (Fig. 2). The small morphological differences between the experimental spectrum and expected headlamps and film sensitivity one, like the peaks relative heights and the slight shift toward the low frequencies (Leone, 2003b, p. 9; Moroni, 2003) are at present object of inquiries.

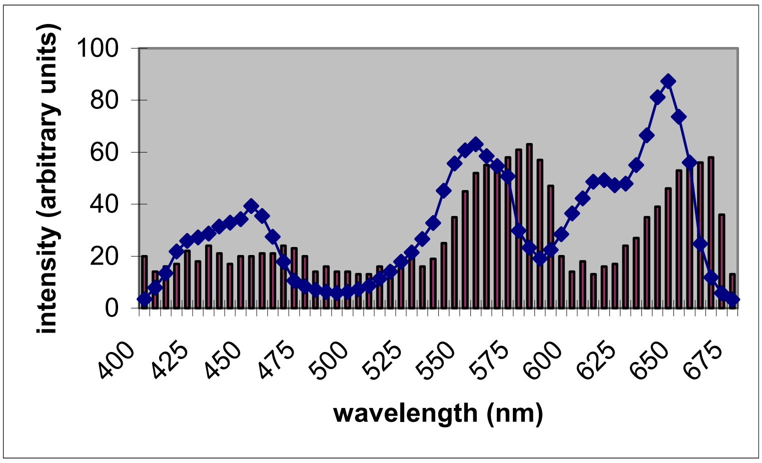


Fig. 2 – EMBLA experimental spectrum (histogram) vs. headlamps & film sensitivity theoretical spectrum (line) (source: Leone, 2003b, p. 9).

The heuristic power of the vehicle headlamp hypothesis, i.e. its power to explain new facts (not only "new" in a chronological sense but also in a retrospective way), is also shown by a cursory examination of the spectroscopic evidence collected during the 2001 EMBLA mission.

By means of a Canon XM1 CCD videocamera, the EMBLA 2001 team collected "low-dispersion spectra of the Hessdalen-lights of the blinking type" (Teodorani, Strand and Hauge, 2001, p. 33). Such a light was sighted on August 21, 2001, in a southerly direction (from the Aspaskjolen view point) and was described as "blinking" and "standing still" (Teodorani, Strand and Hauge, 2001, p. 9). Although no data on the actual angular position of the light were apparently recorded, the general direction of the light and its phenomenological characteristics are in agreement with the 2002 recordings. The collected spectrum was shaped as in Fig. 3 (data sampled at 25 nm intervals from the original "intermediate intensity" spectrum).

According to the EMBLA team, "spectra of known lights, like city-lights, car-lights, flash-lights, and lamps were obtained too, as a qualitative comparison". The authors, then, oddly remark that "none 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". However, as shown by Leone (2003a, pp. 19-20), a continuum blackbody-like spectrum should be indeed expected by a typical incandescent car headlamp. The EMBLA team also sees in this spectrum a 6440 K thermal type fingerprint, "a lot of prominent emission lines" and emission bands "subject to a strong intensity variation" (Teodorani, Strand and Hauge, 2001, p. 33). None of these conclusions appear legitimate when the role of the recording instrument is considered.

[8] Teodorani's position is intrinsically unfalsifiable since he could always make recourse to *ad-hoc* choices of multiple LED sources in order to better fit the experimental spectrum. This methodology, of course, doesn't allow him to foresee any new fact. It is, in other words, empirically regressive.

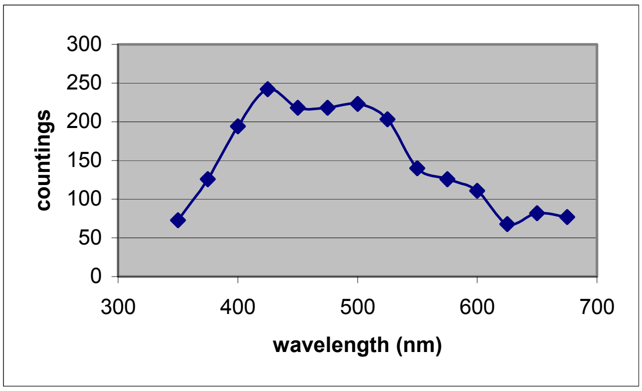
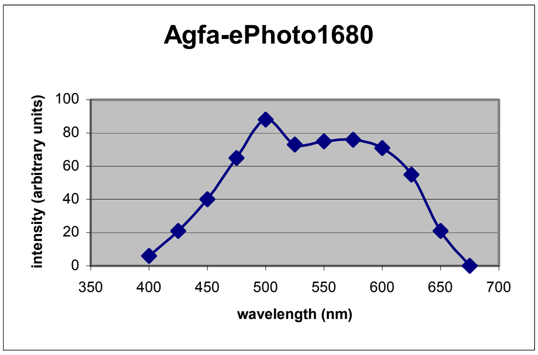


Fig. 3 – Spectrum collected by the EMBLA 2001 team by means of a Canon XM1 CCD videocamera (source: Teodorani, Strand & Hauge, 2001, p. 33).

The Canon's XM1 videocamera incorporates a 3 CCD system. "Each CCD sensor has 320,000 pixels and is dedicated to a primary colour, red, green or blue, to enhance natural colour reproduction with low colour noise" (MacworldExtra, n.d.). While no spectral sensitivity data of the XM1 are presently available, the sensitivity spectrum should resemble that of other 3 CCD system cameras and videocameras. For the sake of comparison with the EMBLA 2001 spectrum, in Fig 4 – 5 are shown the I2S-IEC800 3-chromatic digital videocamera and Agfa-ePhoto1680 3-chromatic camera sensitivity spectra (Antonioli, Fermi, Reverberi, 1999) multiplied by the expected incandescent theoretical spectrum (Leone, 2003b, pp. 22-23).



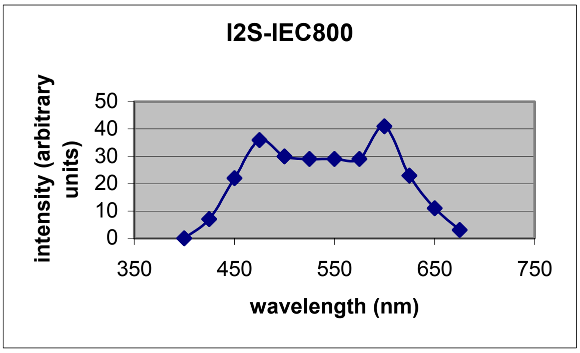


Fig. 4-5 – Spectral sensitivity of 3 CCD camera (Agfa-ePhoto1680) and videocamera (I2S-IEC800) multiplied by an expected 3200 K incandescent spectrum.

Two conclusions are possible. First, the EMBLA 2001 experimental spectrum qualitatively agrees with the expected theoretical spectra emitted by a headlamps source of light corrected by a typical 3 CCD sensitivity spectrum (the shape is similar and only a slight wavelength shift seems to be present). And, secondly, the spectroscopic data recorded during both 2002 and 2001 EMBLA missions are explainable through the vehicle headlamps hypothesis provided that the peculiar effects of the different recording apparatuses are kept into consideration.

Conclusions

Both photometry and spectroscopy agree in pointing at a vehicle headlamps explanation of the light sighted and photographed at Hessdalen in August 2002 (as well as during 2001 EMBLA mission, at least). As already remarked by Leone (2003b, p. 21), "since the whole optical evidence reported by the EMBLA 2002 physics report regards such a specific light, it is legitimate to conclude that the headlamps hypothesis fits all the optical data collected during the August 2002 mission".

As previously cautioned by this author (Ibid., p. 21), notwithstanding this successful explanation, the subject of the anomalous aerial phenomena observed in the Hessdalen valley deserves further attention. However, a continued effort into this subject is not likely to get reliable results unless a serious program of collection of eyewitness testimony and of intensive scientific surveillance for appearance of the alleged luminous phenomenon is set up.

References

Antonioli, G., Fermi, F., and Reverberi R. (1999). *Uso delle camere digitali nella conservazione dei beni culturali*. Retrieved May 16, 2004 from the Department of Physics, University of Parma web site: http://www.fis.unipr.it/beni/Venezia.htm.

ECE Regulation. Addendum 7: Regulation 8. Revision 4 (2002, June). Uniform provisions concerning the approval of motor vehicle headlamps emitting an asymmetrical passing beam or a driving beam or both and equipped with halogen filament lamps (H1, H2, H3, HB3, HB4, H7, H8, H9, HIR1, HIR2 and/or H11). In: United Nations. *Agreement concerning the adoption of uniform technical prescriptions for wheeled vehicles and conditions for reciprocal recognition of approvals granted on the basis of these prescriptions*. [Electronic version]. Geneva: United Nations Economic Commission for Europe. Retrieved January 12, 2003, from http://www.unece.org/trans/main/wp29/wp29regs/r008r4e.pdf.

Johnson, J.C. (1954). *Physical Meteorology*. New York: Technology Press of MIT and John Wiley & Sons.

Leone, M. (2003a, April). *A rebuttal of the EMBLA 2002 report on the optical survey in Hessdalen*. Retrieved May 17, 2003, from the Italian Committee for Project Hessdalen web site: http://www.itacomm.net/ph/rebuttal.pdf.

Leone, M. (2003b, November). *A rebuttal of EMBLA 2002 report on the optical survey in Hessdalen: further comments*. Retrieved February 10, 2004, from the Italian Committee for Project Hessdalen web site: http://www.itacomm.net/ph/leone2.pdf.

Maccabee, B. (1979). Photometric Properties of an Unidentified Bright Object seen off the Coast of New Zealand. *Applied Optics*, 18, 2527-28.

Maccabee, B. (1987). Analysis and Discussion of the Images of a Cluster of Periodically Flashing Lights Filmed Off the Coast of New Zealand. *J. Sci. Expl., 1*, 149-190.

Maccabee, B. (1999). Optical Power Output of an Unidentified High Altitude Light Source. *J. Sci. Expl., 13*, 199-211.

MacworldExtra (n.d.). *Canon XM1*. Retrieved May 16, 2004 from the MacworldExtra web site: http://www.macworldextra.co.uk/showme_detail.lasso?urn=37788.

Moroni, M. (2003, December). *About the Hessdalen debate*. Retrieved February 10, 2004, from the Italian Committee for Project Hessdalen web site: http://www.itacomm.net/ph/Moroni_e.htm.

Teodorani, M. (2003, April). *M. Teodorani's reply to M. Leone's confutation of EMBLA 2002 paper*. Retrieved May 17, 2003 from the "Camelot Chronicles" web site: http://members.xoom.virgilio.it/camelotchr/Download/2003/Re_Rebuttal.pdf.

Teodorani, M. (2004, February). *Some final notes on the "rebuttal phenomenon"*. Retrieved February 10, 2004 from the "Camelot Chronicles" web site: http://members.xoom.virgilio.it/camelotchr/Download/2004/Rebuttals_LastWord.pdf.

Teodorani, M. & Nobili, G. (2002, October). *EMBLA 2002: An Optical and Ground Survey in Hessdalen*. Retrieved February 5, 2003, from the Project Hessdalen web site: http://hessdalen.org/reports/EMBLA_2002_2.pdf.

Teodorani, M., Strand, E.P. & Hauge, B.G. (2001, October). *EMBLA 2001: The Optical Mission*. Retrieved February 5, 2003, from Italian Committee for Project Hessdalen web site: http://www.itacomm.net/ph/embla2001/embla2001_e.pdf.