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HESSDALEN
A PERFECT "NATURAL BATTERY"

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INTRODUCTION

Hessdalen is a small, but nowadays quite famous, valley. It is located in the central part of Norway, a couple of degrees in latitude far from the Arctic Circle.

This valley is well known not only for its natural beauties, but also for its "lights" – a phenomenon that has been observed by hundreds of people, including valley dwellers, tourists, curious passer-by people. These lights have never been associated to a clear identification; since the '80s they have been literally defined as UFOs.

Following the several extemporary observations dating back to those years, researchers, technologists and scientists have been alternatively trying to measure and understand the phenomenon.

It consists in luminous spheroids, varying in size, shape and hue, showing faint or bright luminosity. They sometimes move slowly, in other occasions they appear darting and following a random path. Such heterogeneous features make it particularly complex to comprehend their nature.

It is mainly thanks to a Norwegian researcher, Erling Strand – working for the Østfold College University in Sarpsborg – that the phenomenon does not get to swell the tank of the "exotic and exoteric mysteries".

Strand gathered researchers from the USA, Russia, China, UK, Germany and, finally, France and Italy.

These scientists are acquainted with phenomena showing similarities with the lights observed in the valley. They are experts in ionized plasmas, globular lightning, seismic lights, etc.

The Italian teams have been visiting the valley since 1996, when the *EMBLA Project* was started in cooperation with the Norwegian technologists of the *Project Hessdalen*. The Italian group is composed by researchers working at the Medicina Radiotelescope Station. They are skilled in the design and construction of instruments for Astrophysics in the radio domain. Since 2001, they have been supported by a private group, the *Italian Committee for the Project Hessdalen* (CIPH).

Hessdalen thus became the first area in the world where a methodical study of this anomalous atmospheric light phenomenon takes place. This approach, based on scientific measurement, differs from the one usually chosen by ufologists, who tend to rely more on witness than on quantitative indications.

The valley has been monitored for decades, thus it was possible to start a scientific debate on these mysterious light phenomena.

So far, no convincing solutions have emerged in spite of the large datasets acquired during many observing campaigns, which have spanned more than 12 years as they started with *EMBLA 2000*. In that year the Italian researchers

of the (ex-CNR) Institute of Radioastronomy installed some devices, which they had derived from instruments in use for astrophysical research in the radio field, thus starting a multi-wavelength study of the phenomenon. It was the first time that scientific instruments were used to analyse the intimate physical mechanisms of these strange “luminous globes”, exploiting the same techniques employed in astrophysics. The goal was to scrutinise the valley phenomena as if they were “stars in the atmosphere”.

This dissertation does not aim to provide a solution to the origin of the Hessdalen phenomenon. It simply presents a collection of physical considerations, relative to the nature of the observable facts, based on field measurements. These thoughts may hopefully inspire deeper investigations by part of experts in different scientific branches.

A NEW MODEL TO EXPLAIN THE PHENOMENON

After 12 years of thorough research, we believe we added an important element to the comprehension of the mysterious phenomenon.
The valley shows electrical anomalies, moreover it has peculiar geological and mineral characteristics. Such features have helped us to formulate a working hypothesis on what we here call “natural battery”, an electrochemical model that could be tested conceiving proper experiments and field measurements.

Four different categories of phenomena have been taking place in the last years, all of which can be traced back to the ALP (*Anomalous Luminous Phenomena*) definition:

- close-to-ground phenomena. They consist in seemingly non-structured lights, up to large sizes, showing a typically long lifetime (> 10 seconds);
- randomly flying phenomena. They show no structure and have a medium-to-long lifetime (1-10 seconds);
- micro-flashing phenomena. They happen both in the proximity of the ground and in the lower atmosphere, with a very short duration (< 1 second);
- flying phenomena apparently showing an inner structure.

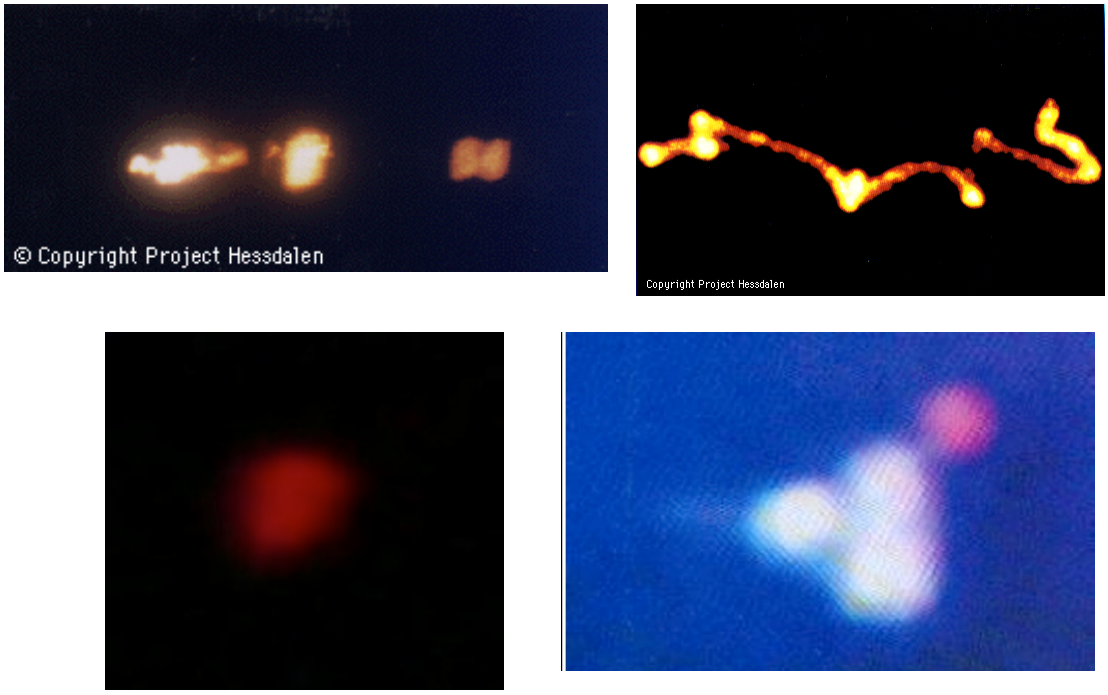


Figure 1: Examples of the Hessdalen lights. Starting from top left: close-to ground, randomly flying, micro-flashing and structured phenomena.

This discussion will not deal with the phenomena of the latter category, as they have not been documented by instrumental observations during our campaigns. Indeed they are seldom reported and are mainly present in a context of "UFO testimonies".
Our hypothesis specifically refers to the first three categories, which can be led back to the "plasma physics" domain. Plasmas are ionised gases, i.e. globally neutral ensembles of ions and electrons.
In this framework, several questions arise:

- how can plasmas form within the valley?
- What is the nature of the forces confining these charges?
- How can these ALP move so fast inside the valley?
- Where does the energy that generates the light phenomena come from?

Several hypotheses have been formulated to answer such questions, some of them reaching the border line of science as they invoke magnetic monopoles, mini black holes or even space-time gates.
As claimed in the XIV century by William of Ockham, philosopher and Franciscan friar, it might not be useful to formulate more theories than the ones strictly necessary to explain a complex phenomenon. This principle, called "Ockham's razor", still inspires many modern scientists. The razor metaphor expresses the idea that, from a methodological point of view, it is appropriate to eliminate with "razor cuts" – and by means of successive approximations – the most complicated hypotheses, so that in the end, factors being equal, the simplest explanation is to be preferred.

We are convinced that this principle confirmed its validity even in the case of the Hessdalen phenomenon.

FROM COLD PLASMA TO ION BUBBLES

The term “plasma” defines an aggregate of charged particles that globally keeps neutral, as the densities of positive and negative ions are equal. These free charges make the plasma a good conductor, strongly affected by electromagnetic fields.
Without dealing with the details of the physical dissertation, it is sufficient to know that the typical temperatures we experience on Earth (which are cold with respect to other environments meaningful to plasma physics) allow for the formation of low-density plasmas. In these conditions, the forces and interactions among ions become weaker as the plasma sphere grows in size. This might explain why the shape of the Hessdalen lights is neither homogeneous nor well structured.

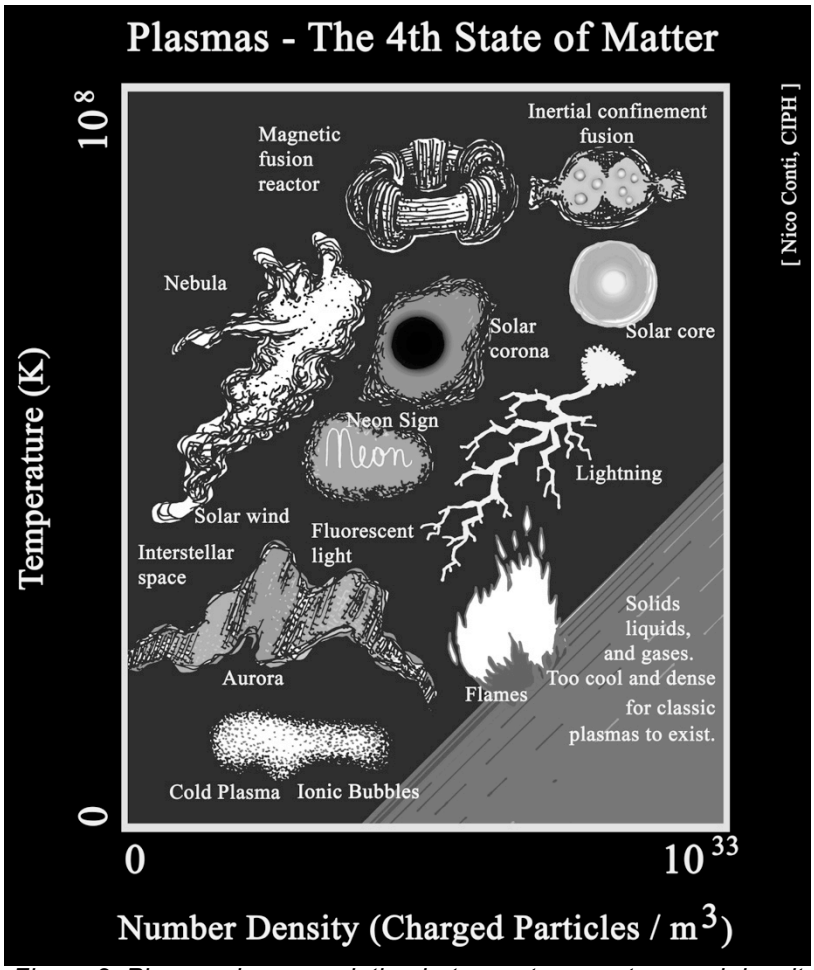


Figure 2: Plasma classes; relation between temperature and density

When cold plasmas are excited by energy, originating internally or externally to the globe (as it will be discussed), they can emit energy in the form of electromagnetic radiation, including light. Vice-versa, they can remain in an practical “invisible” state because the energy emitted is so low to be detected

only by means of radar devices, as the free charges composing the plasma interact with the transmitted electromagnetic waves. For these reasons, these cold plasmas can be labelled as “ion clouds” or “ion bubbles”.

HESSDALEN AND THE “NATURAL BATTERY”

As hypothesized by Bjorn Gitle Hauge back in 2006, so far without any confirmation, the geological nature of the valley might have a decisive bearing on the origin of the phenomenon.
Geographically, the valley is split in two parts by the Hesja river. Geological maps indicate a peculiar segregation of metals and mineral in the area: zinc and iron are located in the western section, while copper is present in the eastern side.
As it is well known in electro-chemistry, those two sections might work as the electrodes of a galvanic element, where the anode is defined as the electrode where oxidation takes place (the zinc-iron section), while the cathode is the electrode where reduction occurs (copper area). In order for this redox reaction to happen, the two elements must be immersed in a solution (electrolyte) whose function is to transport the charges from one electrode to the other.

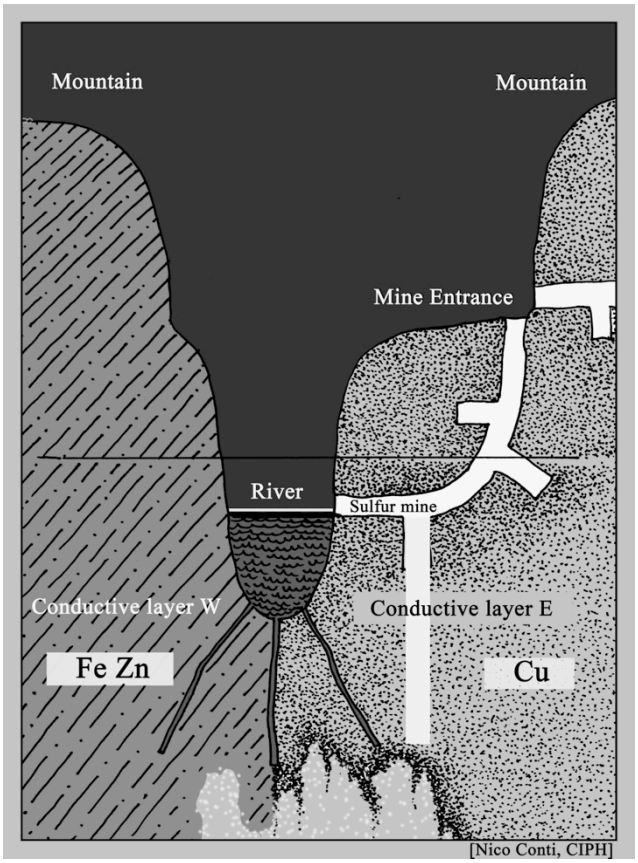


Figure 3: The Hessdalen valley shown in section.

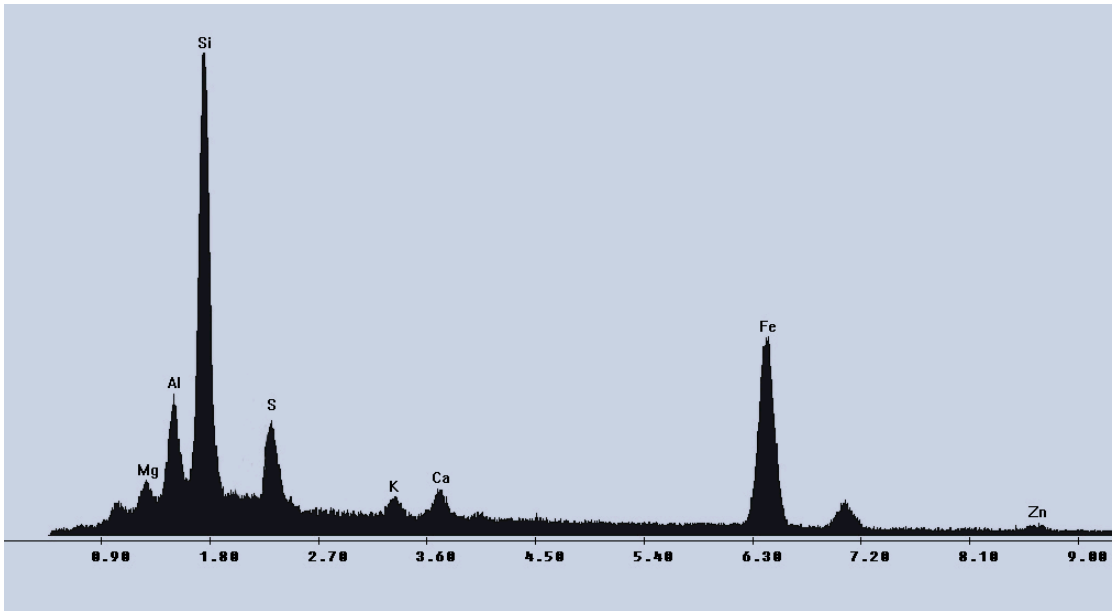


Figure 4: Electronic scan (with SEM/EDAX) of the minerals sampled in the western area. The zinc (Zn) and iron (Fe) abundances can be noticed.

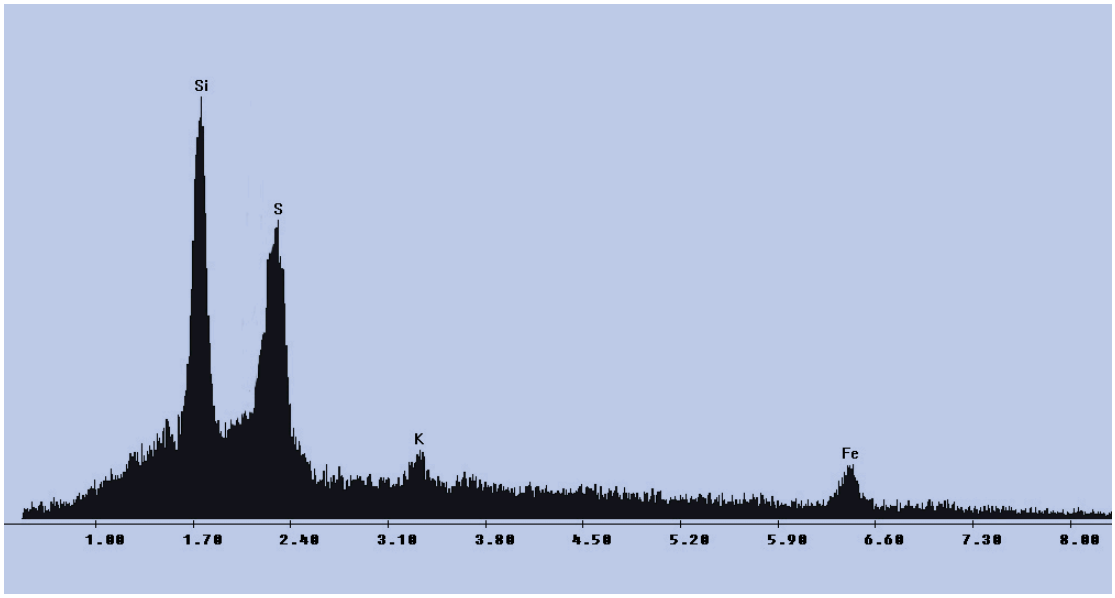


Figure 5: Electronic scan (with SEM/EDAX) of the minerals found in the central area, in the proximity of the river. The richness in sulphur (S) is evident.

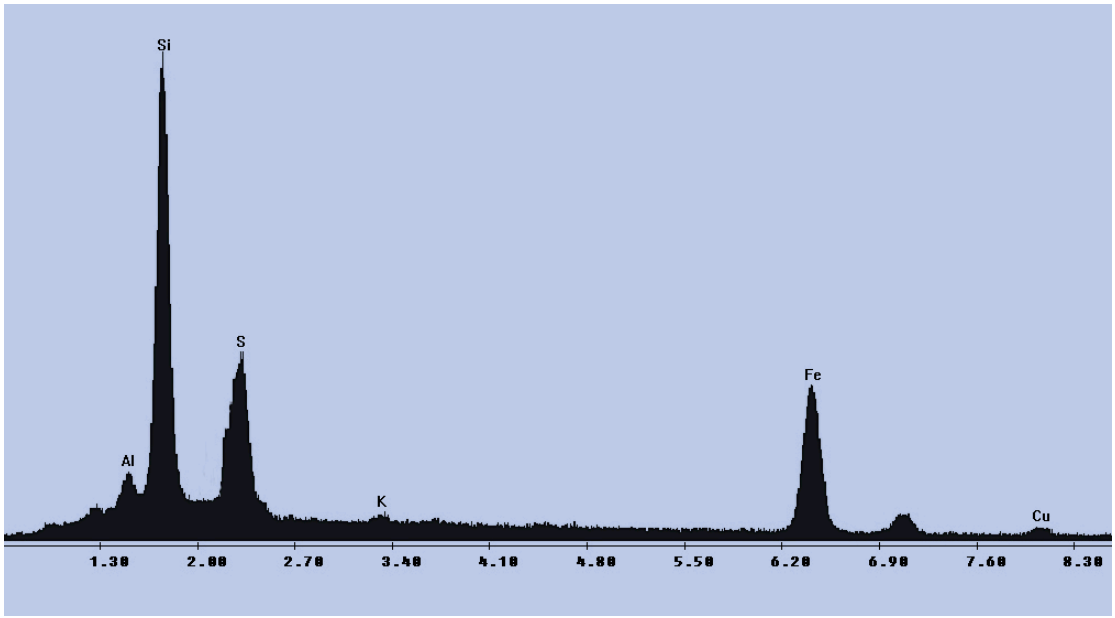


Figure 6: Electronic scan (with SEM/EDAX) of the minerals picked up in the eastern side. Here the presence of copper (Cu) can be noticed.

The missing piece to support the "natural battery model" was identified in 2012, with the re-discovery of the local sulphur mines: active until 1933, they were closed because the mining company bankrupted. Once back to Italy, we pondered on the contributions those mines might give to the chemical profile of the valley. We now hypothesize that the torrents flowing out of the mines and into the Hesja river might contain sulphuric acid (H_2SO_4). On site, we had hints about the presence of this substance:

- when entering the mines, our skin distinctly itched;
- the Hasja river seems to be in some part lacked of fish;
- copper sulphate was present in the mines.

We thus believe that a key step will simply be to perform the chemical analysis of the Hasja waters, in order to assess if they contain sulphuric acid. The presence of H_2SO_4 in flowing waters is indeed an already known, thought rare, occurrence.

If this scenario were confirmed, it would support the idea that the valley behaves like a huge galvanic cell, where sulphuric acid works as the electrolyte that generates the redox reactions between copper and zinc-iron, located on the opposite sides of the river.

How can act an entire valley it is very complicated and nobody knows, but probably the geological complexity of Hessdalen and the interaction between all mining structures can ensure that it behaves like so many mini-galvanic cells in series and then, they can generate a field not negligible and measurable.

Anomalies in the electric field, possibly generated by the "natural battery", were measured in 2010 by means of an EFM (*Electric Field Meter*) installed at the so-called "Peder's Farm".

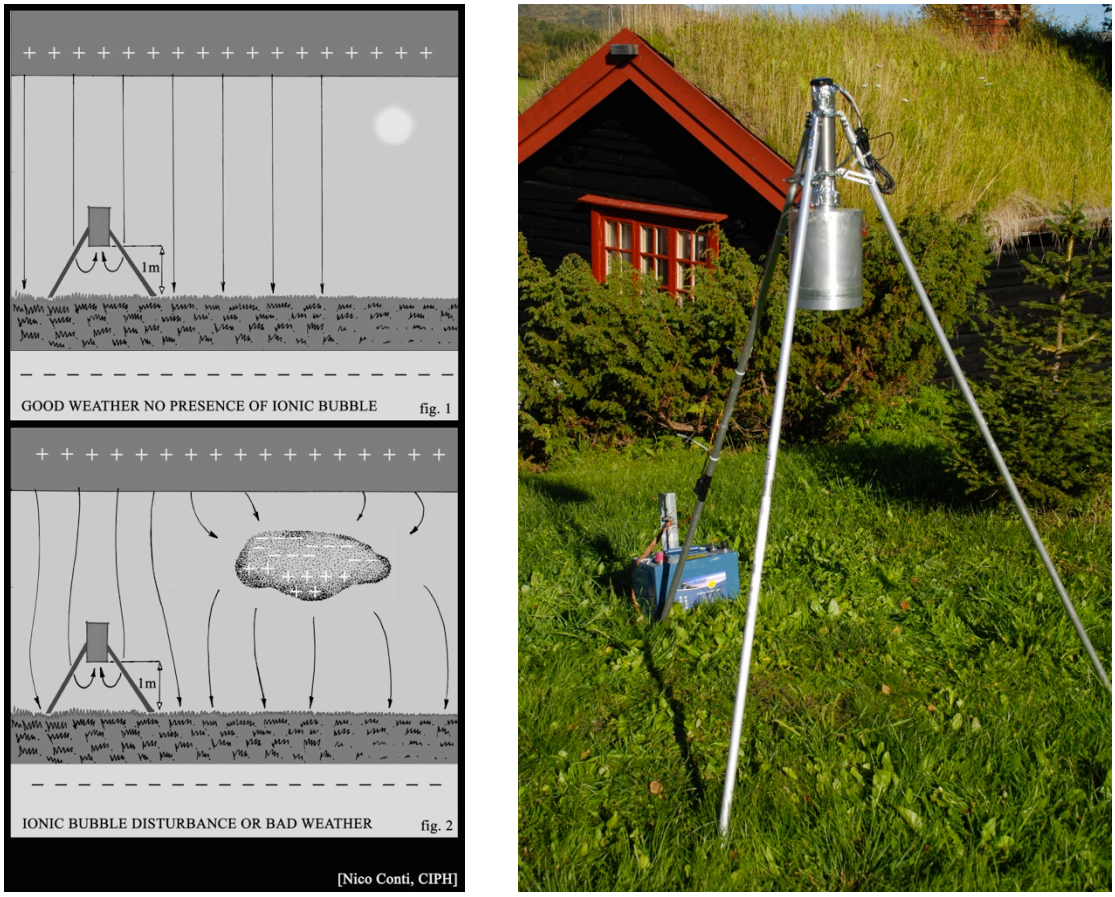


Figure 7: Left – Scheme showing how the Electric Field Meter works in normal conditions and in presence of an ion bubble. Right – The EFM installed at Peder's Farm in 2010.

The intensity of the quasi-static electric field permits to evaluate the potential difference (at a given altitude) between the ionosphere and the ground, as if they were the plates of a capacitor. Weather phenomena, like incoming storms, can influence the electric field value in the range of 24 hours but, generally, it can remain constant for days.
In 2010, the EFM was installed at the farm (altitude about 600 m) in order to understand if the ion bubbles could reveal themselves by means of the production of local anomalies in the electric field, as metals do when they are immersed in it. Measurements were carried out for one week, and they revealed no evident variations in the electric field intensity. The average field value, though, was very different from what expected. This indicated the possible presence of an "external" source of potential difference.

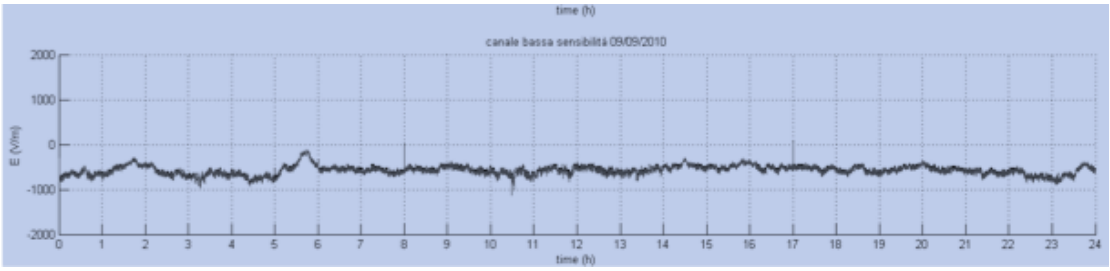


Figure 8: Electric field intensity measured in September 2010 at the altitude of 600 m. The average value (-500 V/m) is different from the expected one (-650 V/m).

The future installation of a permanent network of EFM sensors will allow the monitoring in the long term of the electric field anomaly, perhaps due to the "natural battery", and confirm the possible formation of ion bubbles.

WHICH CHEMISTRY FOR THE ION BUBBLES?

All the phenomena generating charges that are commented in the following section fall into a single category called *ion current*.

This current is ubiquitous: it exists at any given moment and at any place in the world, of course with an intensity that varies with the site. It serves to rebalance the terrestrial electro-dynamic system produced by natural lightning.

16 million storms occur each year on our planet, i.e. there are 44,000 storms every day. Lightning trikes the earth 100 times per second. This accumulation of charge on the earth must be compensated through the ion current, which flows in the opposite sense, because of the charge conservation. The current can produce concentrations of ions, i.e. cold plasmas and/or ion bubbles.

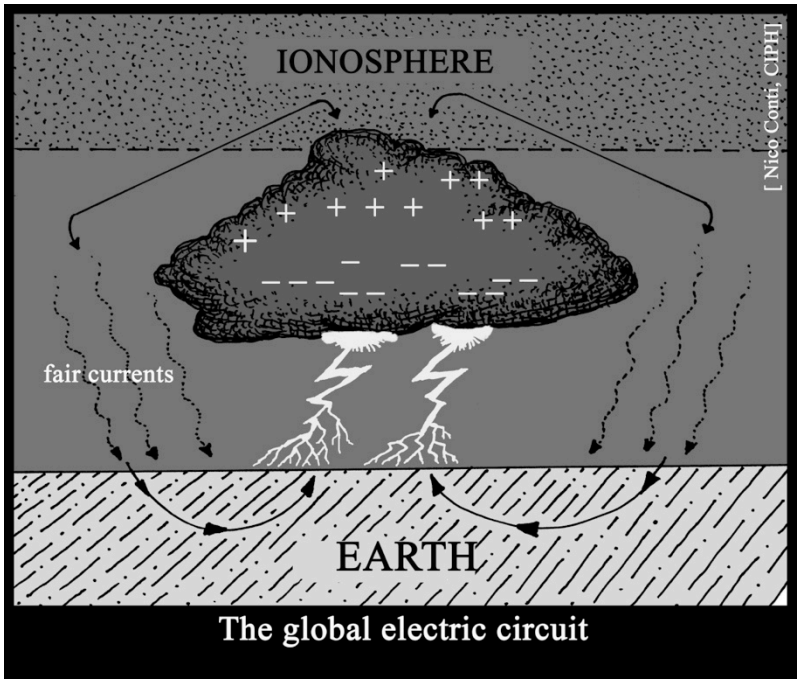


Figure 9: Scheme of the global electric circuit.

Some researchers have hypothesised that cold plasmas might originate from micro-earthquakes taking place deep underground (Paiva and Taft, 2010). In particular, the model assumes that the quakes produce ionized dust, the so-called “Dusty Plasma”, whose micrometre-sized solid particles are immersed in a cocktail of electrons, ions and neutral particles.
The ionized dust generates when the seismic event stresses the minerals and quartzes in the soil.

It is very likely that certain ALPs taking place in several sites around the world, as the “telluric lights”, might originate from such effects. Nonetheless, no significant earthquake has recently been recorded in the Hessdalen valley, while the lights were being monitored, thus no connection between the two phenomena can be appreciated.
For this reason, and given that in 2012 we reconsidered the presence of sulphur mines under the valley, we hypothesise that the cold plasmas/ion bubbles in Hessdalen are ionised aerosols occurring when the sulphur gaseous emissions (H_2S, SO_2, SO_3, coming from the subsoil) meet the persistent humidity of the valley.

Figure 10: The entrance of the sulphur mines. At the top, copper sulphurs are visible.

In such an environment, the stability of the formed ions would be granted by the polar properties of water.
The size of the bubble depends on the amount of aerosol contained in the cloud. The ion cloud can be in a non-excited state (not emitting light,

detectable only with a radar), or in an excited state (when appearing as a luminous globe).
In any case, the ion bubbles can move along the electric field lines of force, due to the “natural battery” in the valley, or stay still where the electric potential is at equilibrium. They can form very large sacs near the ground or small patches in the sky, originating – in peculiar conditions – micro-flashes like the ones recorded in 2003. These extremely brief flashes can be produced by discharges inside the small ion bubble, in turn caused by the voltage due to the natural battery. It is the same functioning principle of the “neon lamps”.
The formation of wide regions of ion bubbles can explain the radar echoes recorded in 2002. During that campaign the instrument, which worked in the UHF band at the frequency of 415 MHz, recorded that something anomalous was approaching Peder’s farm, without any visible counterpart.
Radars work in a quite simple and intuitive way. The instrument measures the signal flight time, i.e. the time interval between the transmission of a monochromatic signal and the detection of its potential reflexion (echo). As the transmitted wave propagates at the speed of light, it is easy to translate the flight time into the distance of the reflecting object. It is then possible to estimate the radial velocity of the object, simply measuring the variation of its distance along time.
In that occasion, the radar measured the incredible speed of 8000 km/h.

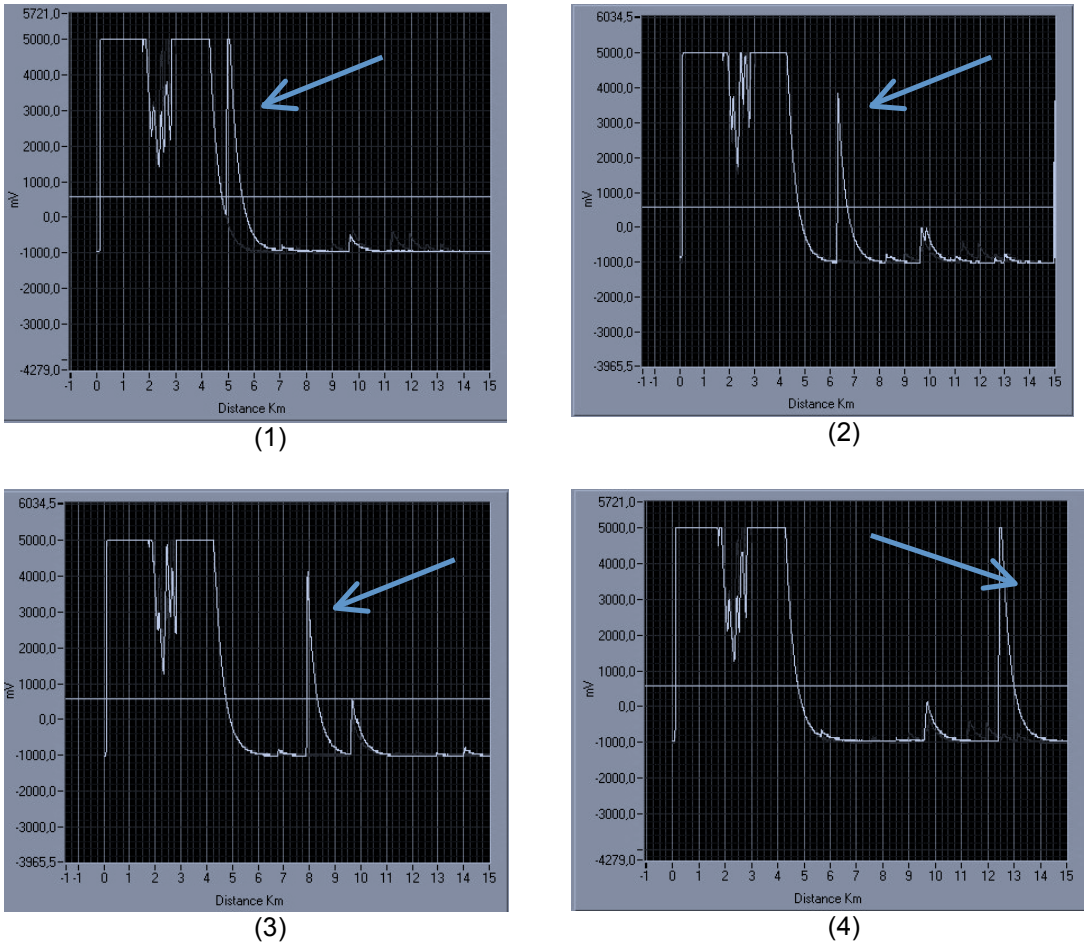


Figure 11: from 1 to 4 the peak (echo) is clearly moving. The estimated speed is 8000 km/h.

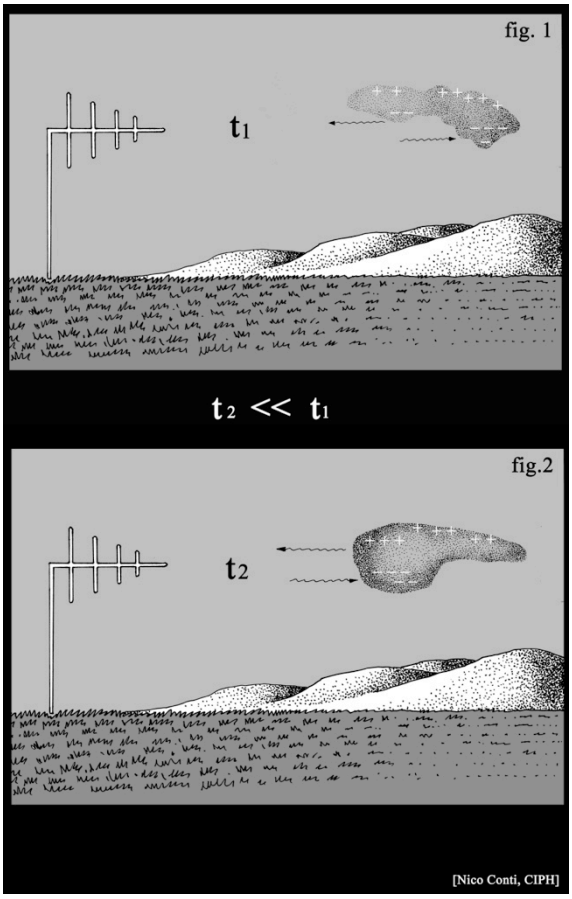


Figure 12: Principle of the ion bubble deformation, which might explain the incredibly high apparent speed measured by the radar.

The unexcited ion bubble model can explain a similar measurement, which might result from multiple reflections, taking place in slightly different moments, while the bubble is changing its form. The echoes produced by the deforming cloud can be mistaken for a motion, which actually is fictitious.

RADIATION MECHANISMS FOR THE ION BUBBLES

Supposing the intuition about the ion bubbles to be true, it is now possible to model the radiation they produce.
Mechanisms causing a plasma to emit light are well known:

- *Line emission* by part of neutral or ionized atoms;
- *Free-free or Bremsstrahlung (deflection) emission* by scattering of electrons on ions.

As the most salient characteristic of the Hessdalen phenomena is their luminosity, how can the above mechanisms be triggered?
Line emission might be attributed to ion recombination, triggered by solar wind or cosmic ray particles almost reaching the ground, whose effect is the emission of photons in the visible range. A possible correlation between aurorae – produced by the interaction between solar wind and the high-altitude layers of the atmosphere – and the appearance of the Hessdalen lights had already been hypothesized. The high latitude of the location, which brings the magnetic field line of force closer to the ground, is favourable to the occurrence of the phenomenon.

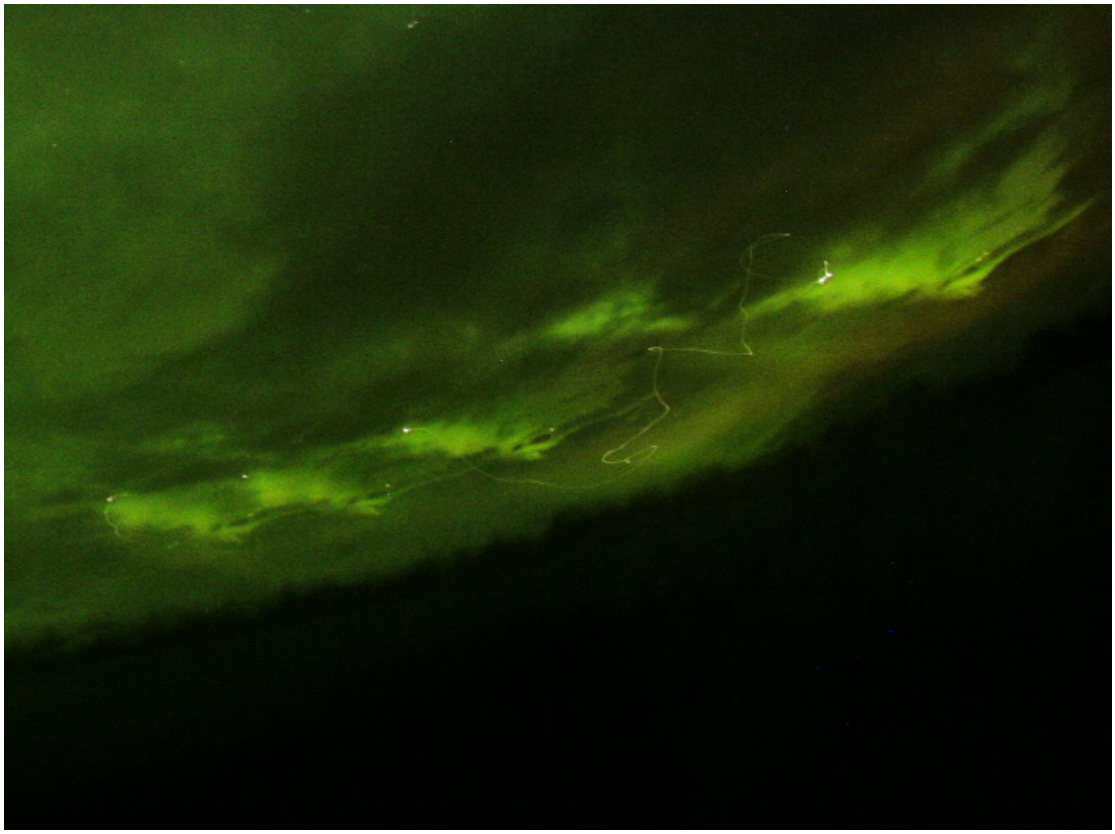


Figure 13: Picture by Gilberto Forni (member of the "Museo del Cielo e della Terra", S.G.Persiceto - Italy). Aurora borealis, 2012 (exposure time 30 sec): inside the aurora emission, the trace left by a moving Hessdalen light can be clearly seen.

The recombination/line emission scenario is not supported by the spectral data acquired in 2007. There is no conclusive evidence of emission or absorption lines in these spectra, and this would suggest a free-free origin for the radiation, but it is not possible to draw conclusions, taking into account that:

- the spectral resolution is poor;
- most spectra are seemingly saturated;
- the spectral response of the camera sensor is limited to the 450-600 nm band;
- the lenses might have filtering effects.

To better investigate this working hypothesis, future campaigns will have to focus on the acquisition of wider and higher-resolution fully calibrated spectra, exploiting the professional instrumentation usually employed in astrophysical observations.

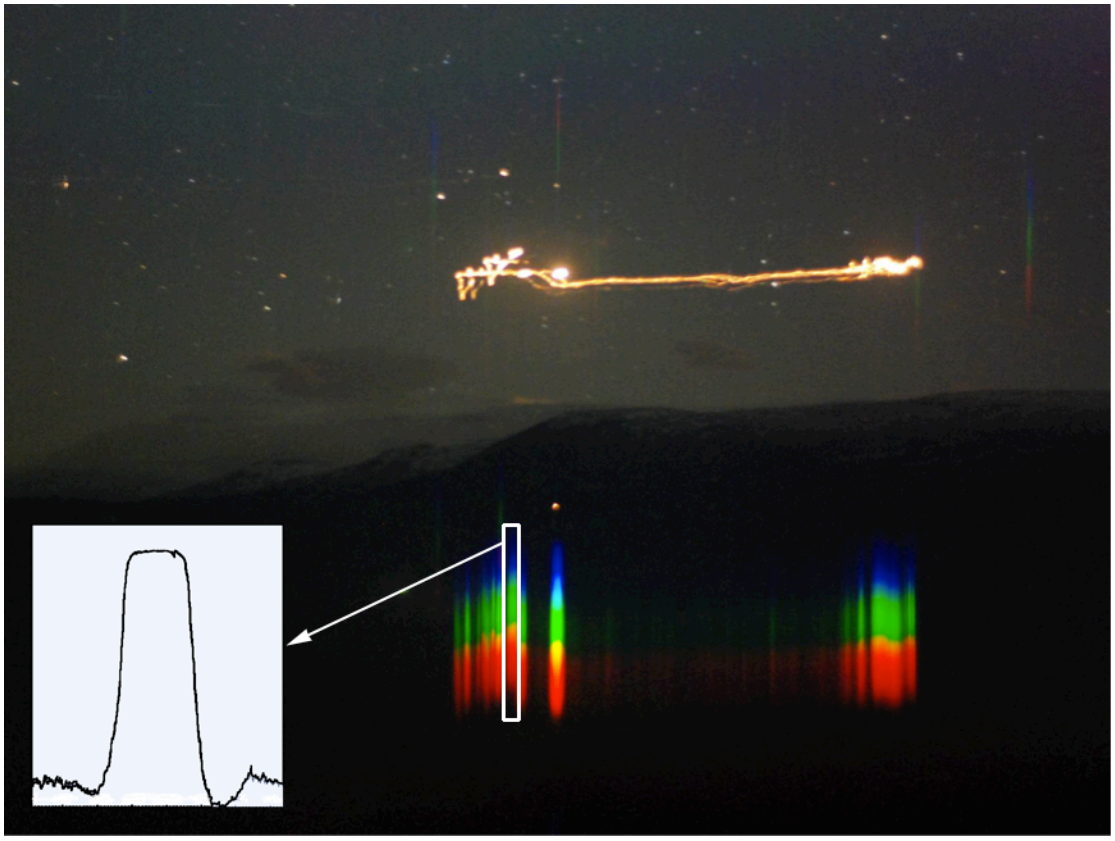
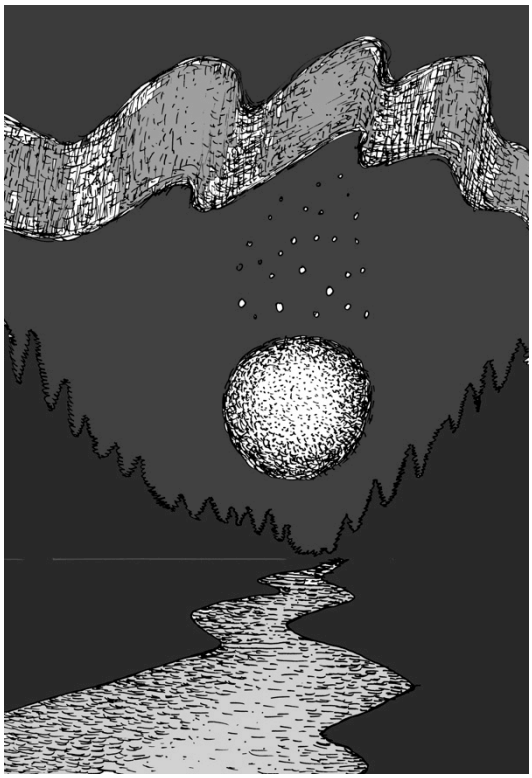


Figure 14: Picture by B.G. Hauge, 2007, showing the optical spectrum of the Hessdalen phenomenon. The inlet illustrates a "slice" of the spectrum highlighted by the white box, i.e. the intensity vs. frequency (both quantities are not calibrated).

As the energies involved in the case of a cold plasma are not very high, it is plausible that other manifestations lie in lower frequency portions of the electromagnetic spectrum, in particular the infrared and radio bands. This might explain why many witnesses reported to have noticed, during the light phenomenon, disturbances to the electrical and radio equipment.
For this reason, we aim to carry out measurements, as broad-band as possible, in the sub-visible spectrum during the forthcoming campaigns.

CONCLUSIONS



This brief article proposes a working hypothesis for the development of a physical model to explain the origin of the Hessdalen phenomena.
It speculatively suggests that the local characteristics of the valley lead to the production of cold plasmas and/or ion bubbles, by means of chemical effects and thanks to the self-consistency due to the polar properties of water.
Plasmas/ion bubbles move along the lines of force of an electric field produced by the “natural battery”, which in turn originates from the peculiar geology of the valley.
The cold plasmas excitation and emission might be generated by a recombination mechanism, triggered by solar wind/cosmic ray particles.
Conversely, the emission might come from free-free mechanisms, interactions between the bubble particles and the natural battery electric field. The latter hypothesis seems to be preferred, yet the available measurements are insufficient to draw conclusions.
All these theories must be tested with dedicated observations, to be carried out in the radio, infrared and visible bands with high frequency resolution, wide-band instruments.

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