PROJECT HESSDALEN: NEXT AGE – RESEARCH PLANNING

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Synopsis – Since 1984 Project Hessdalen, together with its several affiliate research groups in the world, can be considered one of the very few pioneering worldwide initiatives in the attempt of instrumented based investigation of anomalous aerial phenomena. Experience has shown what is missing for a full scientific study of this enigma. As a new operational phase is now demanded, in this document a detailed proposal is made with the clear intent of drastically increasing our knowledge of a phenomenon that is going on in this Norwegian area since more than 40 years. Several incremental research steps are proposed and discussed, with their scientific rationale and procedural outline. The main goal is to attempt to give to Project Hessdalen's observatories a more analytic potential, which would overlap with its eminently surveillance-like main characteristics.

1. Introduction

Mysterious light phenomena occur very often in the Hessdalen valley in central Norway. Such lights can be of different colors, most often of spherical shape. They often blink or pulsate and split in more parts. Strange flashes of light often precede the apparition of the lights.

Project Hessdalen has been one of the very first attempts to obtain measurements on this kind of Unidentified Aerial Phenomena (UAP), starting from 1984, when the first observational campaign was carried out using several instruments (Project Hessdalen, website; Strand, 1984; Teodorani & Strand, 2001). The analyzed data showed very interesting anomalies, the most important of which were the following:

1. Many sightings of confirmed anomalous luminous phenomena.
2. Oscillating signals: magnetic (0.5-10 nT and over) and radio (12.5-22.5 dB, range 130-1115 MHz).
3. Several intermittent and sharp radar recordings.
4. Reaction to Laser.

These results triggered the interest of the international scientific community. Congresses and workshops were done (Fryberger, 1997; Smirnov, 1994; Zou, 1995, Teodorani & Strand, 1998). In the course of the years, two observatories were built up, the first of which was the "Blue Box" (Project Hessdalen, website). The second observatory, placed in a subsequent time on Mount Skarvan was used for Science Camps for students (Sciencecamp, website). Collaboration with several international scientific and academic research groups was created and developed along the years (Hauge et al., 2016; Monari et al., 2013; Teodorani, 2004; Vargemezis et al, 2018; Zlotnicki et al. 2012). Several expeditions to the Hessdalen area allowed obtaining some data during fieldwork.

At present, although scientific missions were able to define more precisely its behavior, the Hessdalen phenomenon together with similar manifestations in the world remain unsolved, even if many theories and hypotheses have been proposed to try to explain them (Freund, 2003; Gross, 2013; Pascoli, 2021; Persinger, 1990; Pettigrew, 2003; Puthoff, 2000; Rabinowitz, 2002; Santilli, 2016; Smirnov, 1994; Straser, 2007; Teodorani, 2004, 2022; Tsytovich et al., 2007; Turner, 2003; Zou, 1995). Some of them can be mentioned: mirages and illusions, piezoelectricity and tectonic strain, natural battery, cloud of electric charge, magnetic monopoles, mini-black holes, solar activity, wormholes, electrochemical confinement, quantum vacuum fluctuations, plasma life forms, extraterrestrial visits, alternate dimensions of reality.

Apparently, the phenomenon – characterized by various typologies – is of natural origin, except that sometimes-structured objects also appear in the area (Project Hessdalen, website). The reason of such unusual superposition is not presently known. It is required that a scientific investigation is carried out taking into account all the aspects in which the phenomenon manifests itself. And yet this phenomenology or a very similar one, which is reported also in other parts of the world in a recurrent and localized way (Akers, 2001; Bunnell, 2009; Caton, website; Joplin Spook Lights, website; Kelleher & Knapp, 2005; Kuersten, 2021; Mansfield, 1971; Rutledge 1982; Teodorani, 2014), offers a very big enigma for physics to be solved, in particular the capability of the light phenomenon to remain turned on for long times as if the plasma that constitutes it were confined inside a self-sustained structure without energy losses.

We are going to relaunch the Hessdalen research, by upgrading, in particular, the Blue Box observatory by equipping it with new-generation measurement instruments and supported by a new international research initiative whose goal is to solve the Hessdalen mystery, by using the competences of both physics and engineering.

2. Strategy and Scientific Goals

The intentions of this group are marked by the utmost pragmatism, which means that whatever action must be focused on the highest probability that a scientific result is concretely obtained.

Ideally, a monitoring station must be equipped with different multi-mode and multi-wavelength well calibrated measurement instruments (Loeb & Laukien, 2023; The Galileo Project, website; Watters et al., 2023) whose goal is twofold: a) being an efficient surveillance system able to scan the surrounding environment (both the sky and the ground) 24 hours a day; b) having the capability to analyze in detail the quantity and the quality of the produced electromagnetic emission.

Being able to track an aerial target both at nighttime and in daylight is a fundamental prerequisite in order to allow researchers to obtain real scientific information that can enable them to understand the physics of the problem. In order to reach this task efficiently it is necessary to proceed through several subsequent and incremental phases. The proposed idea is to ask for funding for the first step, and to obtain results so that any further funding request for the subsequent phases is justified. The basic incremental steps are described here:

A. First Level – Reactivating and Refurbishing the Old Instruments

All the standard instruments of the Blue Box are expected to be reactivated, in particular VLF/ELF spectrometer, radar, magnetometer, REG and video cameras, and computers that control them (which might in case be replaced with faster ones). The second observatory, at Mount Skarvan, should be reactivated too as a permanent station for the Science Camp of students and for visiting scientists who want to carry out night watches using their own instruments.

Some improvements should be done, in particular the way in which the acquired data are saved (probably on the cloud) and made available to the scientific community for an in-depth analysis. Data acquired in the past – both from the Blue Box and from the Skarvan station – should be rendered available too both for analysis and for statistical studies. The Hessdalen observatories contain potentially some unexplored data that cannot be left on the back burner.

Links should be established with both Norwegian and foreign scientific and technological institutes, and with the military (especially radar stations and air force), both in view of a possible collaboration and as a high-quality peer review base of all the scientific research done.

B. Second Level – Target Tracking, Video/Photography/Photometry and Triangulation

This phase would be characterized substantially by two main optical instruments: a) all-sky camera and b) pan-tilt unit able to track a CCD or CMOS camera attached to a zoom lens, towards the target both in daylight and at nighttime. Substantially, the all-sky camera system is expected to be able to identify targets of opportunity after AI machine learning (Watters, 2023) has been applied to it on the basis of a complete pre-prepared database of known flying objects (such as airplanes, drones, cars, meteors, birds, insects, etc.), and to order the pan-tilt unit to track the chosen target.

This operation – which is typically preparatory to the next ones – should precede all the subsequent ones in order to assure that the tracking system and its servomechanisms work correctly also for UAP phenomena that fly very fast or in an erratic way. Clearly, in such a way it might be possible to obtain relatively high-resolution images or video footages of flying objects, in order to document them and, above all, to test the pan-tilt tracking system.

Placing a second (or in case a third one) all-sky camera at a distance of at least 1 Km from the Blue Box (possibly at Mount Skarvan) would allow to determine both the distance of the videoed phenomenon and its linear size if the object is extended. In fact, every physical parameter is strictly dependent on the knowledge of the distance, which compared with measured parameters allow to obtain the intrinsic value of physical parameters.

Let us now explain in some detail what we are going to obtain in this step. The measurement of photons emitted from the surface of a UAP can be of fundamental importance in order to try to understand the physical mechanism that is producing light, especially at night. This is normally done in astronomy when extended sources – such as galaxies and planets – are studied. Being all the photonic physics of the problem very well known (Lang 1991), once the distance is known using radar or triangulation procedures, what we are going to measure (Teodorani, 2001) are the following physical intrinsic parameters of the source:

- Superficial intensity – Construction of isophotal contours.
- Point spread function (PSF) – Luminosity distribution across the surface and measurement of the "slope factor" (or intensity gradient) from the center to the peripheral area.
- Total luminosity – Luminosity in a given wavelength interval of the entire surface, once the intrinsic (linear) radius is known after the distance (and in case the temperature too) has been determined.

- Color index – Ratio of luminous received fluxes in several contiguous wavelength ranges corresponding to different filters, ranging from the near ultraviolet to the near infrared (analogous to U, B, V, R, I in astronomy).
- Period of luminous variability – Time variation of total luminosity and superficial intensity, of PSF and of color indexes.

All of these measurements are expected to be carried out if the UAP is illuminated all over the surface.

In the case that the object contains only one or more luminous spots over the surface, then high spatial resolution will allow to resolve the precise location of such spots. A strong dynamic range of the CCD or CMOS cameras will allow distinguishing contiguous areas with weakly luminous and strongly luminous spots.

Compared to conventional photographic emulsion and plates of the past, present CCD and CMOS cameras allow much improved performance in measuring the light of astronomical objects (Walker 1987), especially when weakly luminous sources are considered. The same technique can be used very efficiently to study luminous unidentified objects in the sky, whatever they are, and at any time of the day. A careful study of all the derived physical parameters can allow to ascertain the natural, manmade or non-manmade artificial nature of UAPs, and to understand the physical mechanism that produces the observed luminosity if they are real.

C. Third Level – High-Speed Photography/Photometry and Spectroscopy

This phase would be characterized substantially by two main optical instruments: a) all-sky camera and b) pan-tilt unit able to track a high-speed zoom camera for imaging and a CCD or CMOS zoom camera connected with a spectrographic device, towards the target, assuming that both units of b) system are attached to the same altazimuth mounting.

The camera for direct imaging should be of the type of high-speed video camera/photometer (i-Speed, AOS Technologies, websites), able to acquire at least 1000 fr/sec with integrated buffer memory (or of streaming type, in case), as a good compromise to obtain a sufficient high-time resolution at an acceptable spatial resolution for every frame. The use of this system is threefold:

1) Obtaining a high-resolution image of the phenomenon using only 1 fr/sec at the maximum available focal length (such as 500 mm);

2) Obtaining a time sequence of many low-resolution images of the phenomenon using 1000-5000 fr/sec at the maximum available focal length in order to verify if the phenomenon is rapidly variable in luminosity, color and shape;

3) Obtaining a time sequence of many low-resolution images of the phenomenon using 1000-5000 fr/sec at the minimum focal length (such as 10 mm) in order to verify if the phenomenon is very rapidly moving in the sky (such as 10 Km/sec) in a continuous, jumping or erratic mode. In such a case, a wide-angle mode without tracking would be used, in order to study the kinematic behavior of the phenomenon.

High time resolution will allow ascertaining if possible luminous spots placed on a dark object are rotating, pulsating or moving across the surface.

Clearly, an optimal quality of measurements will be guaranteed if the object is relatively close to the sensors, so that a better determination of the linear size can be done, and/or if it is sufficiently luminous in order to allow to use a high number of frames per second (such as 5,000 to 10,000 fr/sec) using the high-speed camera. Both of these situations will greatly help to study the variability of light with time and with radius across the surface.

In general, quickly variable luminous manifestations cannot be detectable during the acquisition of electronic images or video frames of weakly luminous UAPs, for which a long integration time is actually needed: all possible time variations would be washed out inside the acquired image. However, according to a scientific evaluation of some witnessed cases (Vallee, 1998), UAP's luminosity can occasionally reach very high values (from 500 up to 30,000 MW). In this specific case, due to the very short integration times needed it is possible to use many frames per second and to verify if what to the eye appears as a stable luminosity is in reality the result of a high-speed regular or irregular pulsation that is not ascribable to atmospheric scintillation, absorption or turbulence. This may turn out to be important in order to infer the physics of the phenomenon, let it be natural or not. A regular or semi-regular pulsation – of the order of 10^{-1}-10^{-3} sec just to give an example – or a monotonically increasing or increasing variation of the pulsation rate might furnish some insight on a possible propulsion mechanism or a merely physical mechanism of phenomena of the ball lightning kind, especially if such pulsation is time-correlated with the color, the speed, the acceleration or even the linear dimension of the UAP. As we can verify in high-speed photometry of stars what we can obtain is a very high-resolution light curve of the luminous target. Light curves in astronomy are a crucial measurement that can help to interpret several kinds of phenomena. Exactly the same kind of procedure can be used to investigate unidentified phenomena that are seen in our atmosphere. High-speed luminosity variation can be due to the fast rotation of one or more light spots on the surface of the object, to the pulsation of the object's luminosity, to the intrinsic pulsation of the object itself or to transient photonic events coming from the surface of the object. Theoretical modeling of astronomical kind can be used to deduce which of the possible phenomena is going on.

In order to study fast variations of UAPs, two sensors can be used: a) a multi-pixel photon counter (MPPC) and b) a high-speed camera. In the first case (PANOSETI, website) it is possible to detect transient very short duration luminous events located – just as luminous spots – on an extended surface, using both high-time (up to a nanosecond) and high spatial resolution via a many-pixel CCD detector where every pixel works as a photon counting photometer. This procedure is ideal to have a quantitative description of the emitted photons across a luminous surface and their variation in time, in the case of luminous UAP at night, assuming that the detector is attached to a telescope or to a zoom lens. The same technique is currently used in Optical SETI in order to search for Laser events from other stars. In the second case (i-Speed; AOS Technologies, websites) a camera monitoring system is used with a maximum time resolution of up to one millionth of second; as the spatial resolution of every frame decreases with increasing time resolution, using in practice 1,000-5,000 fr/sec is an optimal compromise between time and spatial resolution. This procedure is ideal to study any possible fast variation at daytime of luminous and non-luminous objects and at nighttime for very luminous objects. Both detectors can be used in wide-angle mode also in order to verify if UAP phenomena are able to move very fast from a point to another of the celestial sphere.

High-speed photometric observations are intended to be simultaneous with spectroscopic ones, where a separate CCD or CMOS detector is used for spectra acquisition.

Let us now pass to spectroscopy. The lens (attached to a CCD or CMOS camera) used for spectroscopy must be of short focal length (such as 50 mm) and high-aperture (such as 100 mm) in order to allow maximum luminosity for typical weak signals coming from spectroscopy, and must be connected to a specific dispersing system that allows medium spectral resolution (R = 2500), wide field and no slit (Masters, 2014). The absence of a slit for light dispersion allows the pan-tilt system to track the target relatively easily. The choice of a medium and not high-resolution spectrograph is just the only possible compromise. In fact, weakly luminous targets may require too long integration times in order to obtain an acceptable signal-to-noise ratio (at least S/N = 10) during the tracking operation, which may increase of a factor 10 as the resolution increases from R = 2500 to R = 10000. Moreover, a medium-resolution system is much less heavy than a high-resolution one. This can help to avoid mechanical inertia during the tracking of targets that move very fast and suddenly invert their direction of motion. A medium-resolution spectrograph allows the acquisition of spectra of light sources that are both point-like and extended. Above all, this kind of spectrograph (Griem, 2013; Lang, 1991; Walker, 1987) is potentially able to resolve blends of spectral lines, to study baseline broadening of spectral lines, to calculate without appreciable error the equivalent width of spectral lines, to detect lines that would be too weak to appear in a low-resolution spectrum, and above all to be able to resolve the typical line splitting effect due to the presence of a strong magnetic field (Zeeman effect) in the plasma constituting the light phenomenon. For instance, if the light source is very luminous (1 MW or more) and if the magnetic field intensity in the plasma is very high (1 T or more) executed calculations show that it is possible to obtain a medium resolution spectrum with acceptable S/N ratio using an integration time of 10 to 30 sec (see Appendix 2). Scientific literature shows that UAP can reach luminosity as high as 500 MW or much more, at some circumstances.

This spectrograph must be equipped with a Lamp able to produce reference spectral lines (of Helium and Argon, for instance) of known wavelength, which are necessary when the obtained spectrum of the target must be subject to pixel-wavelength calibration (RSPEC, website).

Instead of medium resolution, we can obviously use low-resolution spectroscopy, by attaching a diffraction grating to a zoom lens (Teodorani, 2021). In this case we would take an image of both the target and its spectrum, if we use short focal lengths (typically 50 mm), by reaching a spectral resolution R = 100. Resolution can be in case increased – by decreasing the number of Å/pixel – by increasing the focal length (typically 300 mm), so that we might reach the value of R = 500 (which would clearly involve a longer integration time). Of course, the integration time used for low resolution spectroscopy is at least a factor 10 less than the one for medium resolution spectroscopy (Teodorani, 2001: see Formula 1 and Figure 1), i. e. it is much easier to take a spectrum and yet the obtained spectrum – unless it shows lines of particular strength – is not only of low quality but can also induce the analyst to do a wrong spectral analysis (such as confusing quantum fluctuation of the noise with true spectral lines) especially when spectrochemical identification is required if lines are present. Moreover, low-resolution spectroscopy, typically obtained using a diffraction grating, can be used only for point-like light sources, and any spectrum can come out blurred if the target is not correctly tracked. Finally, taking a photograph of the spectrum alone (if we increase R from 100 to 500) demands a manual movement that centers only the spectrum in the view field, or some (inconveniently) complicated software able to do that automatically.

In conclusion, only medium-resolution spectroscopy can be of true scientific (and even practical) relevance. Otherwise, every other spectroscopic operation using low-resolution spectroscopy may result to be often useless in the scientific way, unless we want to study only the continuum (thermal or non-thermal) after proper flux and wavelength calibrations are done.

Indeed, the extremely high apparent luminosity that UAP can often show – also in Hessdalen – is for physicists a really favorable opportunity to perform in particular situations medium-resolution spectroscopy, with at least R = 2500 (Masters, 2014). Assuming that tracking is viable, extremely luminous UAPs (Vallee, 1998) should allow to use relatively short integration times (see Appendix 1), maybe in certain cases short enough to permit to obtain several spectra of the same target in time sequence in order to study time variability of the spectrum's characteristics, especially if a change of color and/or of light intensities and speed occur. Using this spectral resolution, we are potentially able to obtain satisfactory S/N ratios ($\geq$ 10). In such a way, we would have at our disposal a very powerful tool to try to understand the physics of the light source in great detail, especially if spectra are obtained simultaneously with measurements using different instruments, such as CCD/CMOS cameras, RF spectrum analyzers, IR and optical direct imagers and sensors, magnetometers, particle detectors and radar.

In more detail, we can say that the availability of medium spectral resolution would allow obtaining crucial physical information regarding the following:

1. Ability to resolve blends of spectral lines, as for instance the bands of Oxygen in the red part of the spectrum (Teodorani, 2014).

2. Ability to allow spectral identification of some specific chemical elements characterizing materials that are in case occasionally ejected from the UAP. Evidence of this has been recently analyzed in a lab, where some molten-like material was released on the ground by a hovering UAP (Nolan et al., 2022).

3. High accuracy in the measurement of the equivalent width of spectral lines (if present), which would allow to determine the number of atoms that concur in the formation of spectral lines and the excitation temperature (Boltzmann equation) able to cause this (Lang, 1991).

4. Possibility to detect the Zeeman Effect in spectral lines, which would allow to determine the magnetic field intensity which is responsible of line splitting (Lang, 1991). This would be of great importance to help to make inferences on a possible propulsion system (Davis, 2004; Meessen, 2012a, 2012b; Holt, 1979; White, 2013) hypothetically based on extremely high magnetic fields and superconductors able to sustain very intense electric voltage without appreciable electrical resistance and consequent high temperature. However, a Zeeman Effect (or even Stark Effect) might also be a sign of an unknown natural phenomenon of the ball lightning kind (Stenhoff, 1999) whose physics we might want to investigate more in-depth. Such a measurement might be studied in correlation with measurements obtained using a magnetometer having a resolution of 1 nT and a dynamic range of 100.000 nT; in such a case, simultaneous magnetic detections (where the intensity of magnetic field decreases with the inverse of the cube of distance for an electric dipole) would confirm the spectroscopic Zeeman detections (see Appendix 3).

5. High accuracy in studying spectral line broadening at line basewidth (Griem, 2013) and its possible variation with time. This could allow doing inferences on possible fast plasma vortex-like rotation and/or turbulence, or even on more exotic effects such as gravitational broadening. Modeling software can help to decide which effect is more important. Time variability of this effect could be studied if it is possible to obtain many spectra in sequence of very luminous UAPs.

6. High accuracy in studying blue or red shifts in spectral lines, would help to study possible fast plasma ejections and/or collapses at speeds of the order of 1000 Km/sec, in form of a possible P-Cygni-like effect that we often observe in several kinds of unstable stars (P Cygni, wikipedia). Such a measurement might be studied in correlation with measurements obtained using a particle detector. Doppler effects in emission lines might be studied also if a luminous UAP, surrounded by a plasma envelope, is moving faster than 10 Km/sec (Zhilyaev & Petukhov, 2023) and if its direction of (approaching or receding) motion is along the line of sight.

7. High accuracy in studying the slope of the continuum and/or verifications of the presence of LED-like bumps (Teodorani, 2004).

Photographic/photometric and spectrographic operations – which might be coupled in case with a single-lens infrared FLIR system (Boson FLIR camera, website) – can be done simultaneously with measurements that are carried out at the same time using the available EM instruments, such as the magnetometer, the radar, the VLF/ELF receiver+ antenna and the random event generator.

D. Fourth Level – Infrared Monitoring

This phase would be characterized substantially by one additional sensor-unit, based on multiple thermal imaging FLIR (Forward Looking Infrared) cameras, typically operating in the longwave infrared range 8 μm – 14 μm (Boson FLIR cameras, website). The system would consist of an all-sky infrared configuration, with a minimum of 4 and a maximum of 7 cameras aimed at different parts of the sky (Watters et al., 2023), all placed on a separate mounting. The use of this equipment is justified by the need to: a) measure the temperature of the targets that are monitored at the same time by the optical system; b) identify in the sky objects or phenomena that are not seen by the optical system but which potentially alert the EM system and/or the radar system.

E. Fifth Level – Additional Multi-Wavelength and Multi-Mode Measurements

It is assumed that Project Hessdalen is planning to use its still available EM instrumentation, such as magnetometer, VLF/ELF spectrum analyzer, radar, atmospheric station and REG. All these instruments are activated simultaneously with all the others (optical and infrared).

Some new instruments (Watters, 2023) could be added to the standard equipment: particle detector, audio detector (infrasound, sound and ultrasound), VHF/UHF spectrum analyzer, high-power Laser. At the same time, the available radar must be put in a condition to record automatically tracks of anomalous objects.

A long-range (45-110 minutes of duration) surveillance quadcopter-like drone should be introduced inside the available instrumentation, equipped with Thermal/IR night vision (Combo DJI Mavic 3T, website). The idea is to launch it to locations where and as soon as anomalous light phenomena appear on the ground or on water, in order to obtain close-up images. As soon the pan-tilt imaging camera sights a suspect anomalous light phenomenon, it should automatically send the command to launch the drone to the location of interest in order to film it at close range. Of course, this type of drones are programmed to come back automatically to the base after a certain time, before the battery is exhausted. Additionally, the same drone can be used in order to carry out a systematic scanning of all the valley within a radius of 5-10 Km, using the usual thermal imager or an infrared LIDAR sensor (to be attached to the drone, on demand). Drone survey might be also very useful in discovering possible tracks on the ground (Phillips, 1975) which might have appeared, in case, where a light phenomenon have been reported to be very close to the ground by the scientific monitoring system and/or by simple witness report.

Other instruments could be hired occasionally, in the case that the situation requires it. A ground penetrating radar (GPR) might be one of them, in case that it is necessary to scan some areas of the valley (possibly close to mines) where anomalies have been recorded in the past, such as bacteria disappearance, deposition of micrometric Iron particles (Teodorani, 2004) and ground cut in rectangular shape.

A high-power Laser should be used to test any possible phenomenon's reactions (such as change of pulsation rate, color or luminosity) and to verify if possible deflections of the light beam (Teodorani, 2000, 2020) occur due to possible gravitational or to magnetic refraction effects. The pan-tilted zoom camera in use (CMOS/CCD camera or high-speed camera) would simultaneously film any possible event of this kind. Also, the same Laser device could be used in connection with an EEG device to monitor the brainwave of a particular witness, in order to test a possible interaction between the light phenomenon and the human brain (Teodorani & Nobili, 2007).

The presently used magnetometer might be replaced by a more sophisticated one where the dynamic range is at least 100,000 nT and the resolution can reach the value of 0.1 nT. This instrument would be ideal to record magnetic pulsations using a much better resolution than the one obtained in the past (see Appendix 3). All the possible events of electrical blackouts (Rodeghier, 1981) in the instruments must be constantly recorded, especially if they occur in conjunction with particularly striking luminous events that are reported very close to the observing stations, which are related in case with saturation of magnetometer readings.

3. Deduction of the Physical Mechanism

Data must be examined dynamically focusing on the time variability of the observed phenomenon and on possible correlation between physical parameters (see Appendix 4). A physical mechanism can be understood only from an accurate analysis of the dynamics of the problem in terms of time and space variability of physical parameters (Teodorani & Strand, 1998; Teodorani, 2001; Teodorani, 2023). In fact, astronomy-like methodologies, when they are devoted to the study of variable and transient phenomena, can be applied to the scientific study of UAP as well, once multi-wavelength and multi-mode measurement instruments are used in a simultaneous mode. A full understanding of the physics of UAP cannot be obtained from mere static images but rather from the way in which the measured physical parameters vary both with time and with space, and from the way in which they are correlated together. The accurate measurement of physical parameter variability of UAP can bring us to the understanding of the physical mechanism, let it be natural (Fedosin & Kim, 2001; Stenhoff, 1999) or born from some kind of propulsion system (Griffiths, 1984; Meessen, 2012a, 2012b).

Considering that nowadays high-sophistication instrumentation is available (Watters et al. 2022), the past research experience based both on instrumented field missions (Teodorani, 2004, 2014) and on the quantitative analysis of witness cases (Condon, 1969; Coumbe, 2023; Hendry, 1979, Hynek, 1972; Knuth et al., 2019; Maccabee, 1994, 1999; McCampbell, 1976; Nolan, 2022; Vallee, 1998; Zhilyaev and Petukhov, 2023) made us understand quite clearly that our next observational steps in this research should be the following:

1. Obtain a high-resolution image of a UAP, using a dedicated zoom camera tracked to the target by optical and infrared all-sky systems and using the most advanced CCD or CMOS detectors.
2. Calculate the distance and the linear size of the UAP, using triangulation via redundant optical/IR systems, acoustic detectors and/or direct radar tracking.
3. Measure the intrinsic luminosity and its variation with time, once the apparent luminosity is accurately obtained.
4. Obtain high-time resolution images of a UAP in order to measure both possible fast light/color variations (narrow field observations) and fast movements in the sky (wide-angle field observations), using 30-300 mm zoom lenses.
5. Measure the velocity, the acceleration and their variation with time, using also medium resolution spectroscopic methods in case of velocities far exceeding 10 Km/sec (Knuth et al., 2019; Zhilyaev & Petukhov, 2023) by detecting blue or redshifts in spectral lines (if present in the spectrum) produced by “nocturnal lights” whose direction of motion is aligned along the line of sight.
6. Measure the intrinsic magnetic field intensity deduced from a possible Zeeman Effect (Lang, 1991) recorded in a line spectrum (when lines are present) using a slitless medium-high resolution spectrograph, and its variation with time, compared and simultaneous with the measurement in distance using a magnetometer in order to deduce the action of an electric dipole source.
7. Testing a UAP using a Laser beam in its vicinity in order to verify if there is a gravitationally induced deviation (or due to magnetic refraction) and/or (without Laser) if the field stars around the object are displaced by their normal position (Teodorani, 2001, 2020).
8. Search for a correlation between intrinsic luminosity, radio luminosity, radar signature, infrared luminosity, velocity, audio signals, particle emission, magnetic field strength and Laser deflection angle. Do they vary together with time or is there a phase lag?

The most crucial question is if there is a correlation between: a) luminosities of up to 30,000 MW, velocity of 12,000 Km/h or more and accelerations of up to 5,000 g as they were deduced by physical scientists, engineers and radar operators (Coumbe, 2023; Knuth et al., 2019; Maccabee, 1994, 1999; Vallee, 1998), and: b) an hypothesized magnetic field strength of $10 \text{ T} \leq B \leq 1{,}000 \text{ T}$, assuming that in this specific case a magnetically induced Zeeman splitting effect can be detected spectroscopically using a well trackable slitless echelle grating with a resolution of at least R = 2,500. Considering that the predicted magnetic field intensity of ball lightning is expected to be at least a factor 1,000 less than these values (Fedosin & Kim, 2001), the main question is: what kind of flying machine is able to produce such a high magnetic field strength?

In fact, the final goal of this research is to try to deduce from the obtained data the physical mechanism of the UAP phenomenon. This can be due to a natural phenomenon, a manmade object or the effect of some propulsion mechanism of unknown origin. Only an appropriate and accurate instrumented analysis can furnish this answer. Theoretical modelling would follow consequently.

4. Conclusive remarks

The Hessdalen phenomenon represents the most important laboratory in the world to study recurrent anomalous aerial phenomena, being Project Hessdalen probably the most complete attempt of measuring what is effectively observed in that area. During almost 40 years of investigation, a research know-how has been acquired as well as the awareness of improving it (Teodorani, 2009). Evidently, nothing perfect can come out if money funding is not appropriate for this research, and if the scientific and academic community keeps on being biased and prejudicial. The experience acquired and the large quantity of reports collected in so many years speak for itself: the fact that the phenomenon can be able sometimes to produce an enormous quantity of energy should stimulate the physical science, maybe in view of a possible utilization of this energy after reproducing it in a lab once the physics of the phenomenon is fully understood. All this requires an adequate money funding, considering that in the Hessdalen case what is most important is not so much analyzing witness cases but rather to measure that which is within reach of our measurement tools.

It is not yet clear if the Hessdalen phenomenon is a natural/localized peculiarity per se of possible geophysical origin or if it shares the same strangeness that the UFO phenomenon (NARCAP, SCU; Society for UAP Research, websites), in its sense of the term, shows, or if it characterizes both aspects at the same time. In reality, the points in common with the more general UFO/UAP phenomenology are very many, considering that the cases of structured flying objects reported in the Hessdalen valley are not a few, even as a clear minority compared to the more usual unstructured light anomalies. This phenomenon appears by manifesting a very similar behavior in several other locations of the world.

What has been reported and directly observed during so many years shows sometimes an apparent violation of the known physics laws. Should we ignore this – if ascertained by observational data – only because it does not fit the canons of accepted science? Alternatively, should this be an important occasion to us to learn something completely new that might potentially help our scientific knowledge to drastically expand? Scientific rigor obtained from data coming from well calibrated and correctly used instruments, from the exclusion of any possible instrumental noise, and of natural or manmade cases, from the repeatability of the same results obtained by different observers and from a correct mathematical treatment of the experimental data, if not matched with an open mind aimed at scientific exploration, is simply a sterile operation that can gratify only a "clerical" academia but not those who want to go more in depth. We need both approaches – scientific rigor and open mind – maybe having always in mind the enterprises done in fundamental physics almost a century ago, when the clear evidence of an apparently paradoxical reality came out from the calculations of the general relativity theory and, above all, of quantum mechanics. Otherwise, we risk missing out the nucleus of the investigated problem.

REFERENCES

Akers, D. (2001). “Preliminary Report on Magnetic Field Measurements Recorded at Satus Fire Lookout – July 11, 2001”: http://www.leeh.net/polyarts/Archive/01070001.pdf

AOS Technologies – PROMON USB3 High Speed Streaming: https://www.aostechnologies.com/high-speed-cameras/long-time-recording/streaming-camera/promon-usb3-high-speed-streaming-cameras

Boson FLIR camera: https://www.flir.eu/products/boson/

Bunnell, J. (2009). *Hunting Marfa Lights*. Lacey Publishing Co.

Caton, D. – Youtube Channel: Brown Mountain Lights Camera: https://www.youtube.com/@DanielBCaton

Combo DJI Mavic 3T, website: https://store.dji.com/it/product/dji-mavic-3e-and-dji-care-enterprise-basic?vid=123141

Coumbe, D. (2023*). Anomaly – A Scientific Exploration of the UFO Phenomenon*. Rowman & Littlefield

Condon, E. U. (1969). *Scientific Study of Unidentified Flying Objects*, University of Colorado, Bantam Books, New York (USA), Toronto (Canada), London (GB).

Davis, E. (2004). *Teleportation Physics Study*. Special Report AFRL-PRED-TR-2003-0034. Edwards Air Force Base, CA: Air Force Research Laboratory: https://fas.org/sgp/eprint/teleport.pdf

Fedosin, S. G. & Kim, A. S. (2001). “The Physical Theory of Ball Lightning”. *Applied Physics* (Russian Journal), No. 1, pp. 69-87. https://www.researchgate.net/publication/236134349_The_physical_theory_of_ball_lightning#fullTextFileContent

Freund, F. (2003). “Rocks That Crackle and Sparkle and Glow: Strange Pre-Earthquake Phenomena”. *Journal of Scientific Exploration* 17(1), 37-71. https://www.researchgate.net/publication/228778783_Rocks_that_crackle_and_sparkle_and_glow_Strange_pre-earthquake_phenomena

Fryberger, D. (1997). “A model for ball lightning”. *ØIH Rapport* 1997 (5). Høgskolen i Østfold (Norway), pp. 1-82.

Griem, H. P. (2013). *Spectral Line Broadening by Plasmas*. Academic Press.

Griffiths, D. J. (1984). “Electrostatic levitation of a dipole”. *SLAC-PUB* – 3529: https://drive.google.com/file/d/1IPQ4R14UIlJK1OsGANM-PfnKNfmvEDCw/view

Gross, D. M. (2013). "Unidentified Aerial Phenomena (UAP) A New Hypothesis toward Their Explanation”. *Journal of Scientific Exploration*. Vol. 27, Issue 3, pp. 415-453: https://www.researchgate.net/publication/288389376_Unidentified_Aerial_Phenomena_UAP_A_New_Hypothesis_toward_Their_Explanation

Hauge, B. G. ; Kjøniksen, A-L. ; Strand, E. P. ; Zlotnicki, J. & Vargemezis, G. (2016). “Magnetic influence on the unidentified luminous phenomena in Hessdalen, Norway”. *EGU General Assembly 2016*, held 17-22 April, 2016 in Vienna Austria, id. EPSC2016-7638.

Hendry, A. (1979). *The UFO Handbook: A Guide to Investigating, Evaluating and Reporting UFO Sightings*. Doubleday.

Hynek, J. A. (1972). *The UFO Experience: A Scientific Inquiry*. Contemporary Books.

Holt, A. C. (1979). Field Resonance Propulsion Concept. *NASA* https://ntrs.nasa.gov/api/citations/19800010907/downloads/19800010907.pdf

Kelleher, C. A. & Knapp, G. (2005). *Hunt for the Skinwalker: Science Confronts the Unexplained at a Remote Ranch in Utah*. Gallery Books.

Knuth, K. H.; Powell, R. M. & Reali, P. A. (2019). “Estimating Flight Characteristics of Anomalous Unidentified Aerial Vehicles”. *Entropy 21*(10), 939.

Kuersten, H. (2021). *The Dyatlov Pass Mystery: Not a Cold Case*. Amazon Book (including contributions on ball lightning’s theory by Dr. M. Teodorani at pp. 171-177).

i-Speed 3 Series High-Speed Cameras, website: https://www.ix-cameras.com/3-Series/

Joplin Spook Lights (website): https://highstrangeness.tv/articles/joplin/spooklight.php

Lang, K. R. (1991). *Astrophysical Formulae: A Compendium for the Physicist and Astrophysicist*. Springer.

Loeb, A. & Laukien, F. (2023). “Overview of the Galileo Project”. *Journal of Astronomical Instrumention*, https://arxiv.org/pdf/2209.02479.pdf

Maccabee, B. (1994). “Strong magnetic field detected following a sighting of an unidentified flying object”. *Journal of Scientific Exploration*, Vol. 8, No. 3, pp. 347-365. https://www.scientificexploration.org/docs/8/jse_08_3_maccabee.pdf

Maccabee, B. (1999). “Optical power output of an unidentified high altitude light source”. *Journal of Scientific Exploration* 13(2), 199-211.

Mansfield, G. R. (1971). “Origin of the Brown Mountain Light in North Carolina”. *Geological Survey Circular*, n. 646.

Masters, R. A. (2014). “High resolution slit-free direct-viewing multiplexing field spectrograph”. US Patent US8749781B2. https://patents.google.com/patent/US20120287430

McCampbell, J. M.. (1976). *UFOlogy: A Major Breakthrough in the Scientific Understanding of Unidentified Flying Objects*. Celestial Arts Publishing Company.

Meessen, A. (2012a). “Pulsed EM Propulsion of Unconventional Flying Objects”. *PIERS Proceedings*, Moscow, Russia, August 19–23, 2012.

Meessen, A. (2012b). “Evidence of Very Strong Low Frequency Magnetic Fields”. *PIERS Proceedings*, Moscow, Russia, August 19–23, 2012, pp. 524-528: http://www.cobeps.org/pdf/meessen_evidence.pdf

Monari, J.; Montebugnoli, S. & Serra, R. (2013). “Hessdalen – A Perfect Natural Battery”. *ICPH Articles*: http://www.itacomm.net/PH/2013_Monari_et-al-en.pdf

NARCAP, website: https://www.narcap.org/

Nolan, G. P.; Vallee, J. F.; Jiang, S. & Lemke, L. G. (2022). Improved instrumental techniques, including isotopic analysis, applicable to the characterization of unusual materials with potential relevance to aerospace forensics. *Progress in Aerospace Science* 128 (2022) 100788: https://www.docdroid.net/IO2hKxr/1-s20-s0376042121000907-main-pdf

PANOSETI, website: https://oirlab.ucsd.edu/PANOSETI.html

Pascoli, G. (2021). “Are the Hessdalen Lights a Reality, an Illusion, or a Mix of the Two?”. *Journal of Scientific Exploration*, Vol. 35, Issue 3, p 590-622: https://www.researchgate.net/publication/354864502_Are_the_Hessdalen_Lights_a_Reality_an_Illusion_or_a_Mix_of_the_Two#fullTextFileContent

P Cygni, Wikipedia, website: https://en.wikipedia.org/wiki/P_Cygni

Persinger, M. A. (1990). “The Tectonic Strain Theory as an Explanation for UFO Phenomena: a Non-Technical Review of the Research, 1970-1990”. *Journal of UFO Studies*, 2, 105-137: http://neurosciarchive.byethost12.com/1990-Persinger-Journal-of-UFO-Studies-The-Tetonic-strain-theory-as-an-explanation-for-UFO-phenomena.pdf?i=1

Pettigrew, J. D. (2003). “The Min Min light and the Fata Morgana: An optical account of a mysterious Australian phenomenon”. *Clinical and Experimental Optometry* 86(2): 109-120.

Phillips, T. (1975). “Physical Traces Associated with UFO Sightings: A Preliminary Catalog”. *The Center for UFO Studies*, 144 pages.

Project Hessdalen, website: http://www.hessdalen.org/

Puthoff, H. (2000). “Quantum vacuum energy”. *Metanexus*: https://metanexus.net/quantum-vacuum-energy/

Rabinowitz, M. (2002). Little black holes: dark matter and ball lightning. *ArXiv*: https://arxiv.org/ftp/astro-ph/papers/0212/0212251.pdf

RSPEC – Real-Time Spectroscopy, website: https://www.rspec-astro.com/

Rodeghier, M. (1981). *UFO reports involving vehicle interference : a catalogue and data analysis*. CUFOS Report: http://www.cufos.org/books/UFO_REPORTS_INVOLVING_VEHICLE_INTERFERENCE.pdf

Rutledge, H. (1982). *Project Identification: The First Scientific Field Study of Ufo Phenomena*. Prentice Hall Direct.

Santilli, R. M. (2016). “Apparent Detection via New Telescopes with Concave Lenses of Otherwise Invisible Terrestrial Entities (ITE)”. *American Journal of Modern Physics*. 5(3): 45-53: https://www.researchgate.net/publication/304339066_Apparent_Detection_via_New_Telescopes_with_Concave_Lenses_of_Otherwise_Invisible_Terrestrial_Entities_ITE#fullTextFileContent

Scientific Coalition for UAP Studies (SCU), website: https://www.explorescu.org/

Smirnov, B. M. (1994). “Long-lived glowing phenomena in the atmosphere”. *Phys. Uspekhi* 37, 517–521.

Society for UAP Studies, website: https://www.societyforuapstudies.org/

Spaceweather.com, website: https://spaceweather.com/

Stenhoff, M. (1999). *Ball Lightning: An Unsolved Problem in Atmospheric Physics*. Springer.

Strand, E. P. (1984). “Project Hessdalen 1984 – Final Technical Report”. *Project Hessdalen website*: http://www.hessdalen.org/reports/hpreport84.shtml

Straser, V. (2007). “Precursory luminous phenomena used for earthquake prediction. The Taro valley”. Northwestern Apennines, Italy. *New Concepts in Global Tectonics Newsletter*, 44, pp. 17-31.

Teodorani, M. & Strand, E. P. (1998). “Experimental methods for studying the Hessdalen phenomenon in the light of the proposed theories: a comparative overview”. *ØIH Rapport*, n. 1998:5, Høgskolen i Østfold (Norway), pp. 1-93.

Teodorani, M. (2000). “Physical data acquisition and analysis of possible flying extraterrestrial probes by using opto-electronic devices”. *Extraterrestrial Phys. Rev.* 1(3), pp. 32-37.

Teodorani, M. & Strand, E. P. (2001). “Data Analysis of Anomalous Luminous Phenomena in Hessdalen”. *ICPH Articles*: http://www.itacomm.net/ph/hess_e.pdf

Teodorani, M. (2001). Physics from UFO Data. *ICPH Articles*: http://www.itacomm.net/ph/phdata_e.pdf

Teodorani, M. (2004). “A long-term scientific survey of the Hessdalen phenomenon”. *Journal of Scientific Exploration*, 18(2), 217-251. https://www.researchgate.net/publication/228609015_A_long-term_scientific_survey_of_the_Hessdalen_phenomenon

Teodorani, M. & Nobili, G. (2007). “Anomalous Light Phenomena vs. Brain Electric Activity”. *Journal of Consciousness Studies*, Special Number “Quantum Mind 2007”, pp. 109-110: https://massimoteodorani.com/2019/06/08/bioelectric/

Teodorani, M. (2009). “Scientific Inquiry on Anomalous Atmospheric Light Phenomena: Past Research Gaps and New Methodological Goals”. *ICPH Articles*: http://www.itacomm.net/PH/2009_Teodorani.pdf

Teodorani, M. (2014). “Instrumented Monitoring of Aerial Anomalies: A Scientific Approach to the Investigation on Anomalous Atmospheric Light Phenomena”. Invited paper presented at *CAIPAN 2014 Workshop* - CNES-GEIPAN, Paris, France, July 8–9, 2014. http://www.cnes-geipan.fr/fileadmin/documents/24_TEODORANI_full.pdf.

Teodorani, M. (2020). “One more experiment at Skinwalker Ranch?” https://massimoteodorani.com/2020/05/14/one-more-experiment-at-skinwalker-ranch/

Teodorani, M. (2021). “UAP Spectroscopy”: https://massimoteodorani.com/2021/09/13/uap-spectroscopy/

Teodorani, M. (2022). “The impact of physical sciences in the study of Unidentified Aerial Phenomena (UAP)”, in: *Extraterrestrial Intelligence – Academic and Societal Implications*. Cambridge Scholars Publishing, pp. 124-141.

Teodorani, M. (2023). “Investigating UAP Events Using Astrophysical Techniques”. *Limina*. Submitted.

The Galileo Project: https://projects.iq.harvard.edu/galileo/home

Tsytovich, V.; Morfill. G. E. , Fortov, V. E.; Gusein-Zade, N. G.; Klumov, B. A. & Vladimirov, S. V. (2007). “From plasma crystals and helical structures towards inorganic living matter”. *New Journal of Physics* 9, no. 263: 1-11: https://iopscience.iop.org/article/10.1088/1367-2630/9/8/263/pdf

Turner D. J. (2003). “The missing science of ball lightning”. *Journal of Scientific Exploration*, 17, n. 3, pp. 435–496: https://www.scientificexploration.org/docs/17/jse_17_3_turner.pdf

Vallee, J. (1998). “Estimates of Optical Power Output in Six Cases of Unexplained Aerial Objects with Defined Luminosity Characteristics”. *Journal of Scientific Exploration* 12(3), 345-358. https://citeseerx.ist.psu.edu/document?repid=rep1&type=pdf&doi=a59ad8d13f2e66af73708ad5d53363804b692609

Vargemezis, G.; Zlotnicki, J.; Hauge, B. G.; Kjøniksen, A. & Strand, E. (2018). “Near Surface Conductive Zones in Hessdalen Valley (Norway) Inferred by Preliminary VLF Surveys”. European Association of Geoscientists & Engineers. *24th European Meeting of Environmental and Engineering Geophysics*, Sep 2018, Volume 2018, p.1 – 5. https://www.earthdoc.org/content/papers/10.3997/2214-4609.201802511

Von Ludwiger, I. (2000). The “Greifswald Lights”. *MUFON-CES Report*: http://archiv.mufon-ces.org/text/english/greifswald.htm

Walker, G. (1987). *Astronomical Observations – an Optical Perspective*. Cambridge University Press.

Watters, W. A.; Loeb, A.; Laukien, F.; Cloete, R.; Delacroix, A.; Dobroshinsly, S.; Horvath, B.; Kelderman, E.; Little, S.; Masson, E.; Mead, A.; Randall, M.; Schultz, F.; Szenher, M.; Vervelidou, F.; White, A.; Ahlstrom, A.; Cleland, C.; Dockal, S.; Donahue, N.; Elowitz, M.; Ezell, C.; Gersznowicz, A.; Gold, N.; Hercz, M. G.; Keto, E.; Knuth, K.; Lux, A.; Melnick, G. J.; Moro-Martin, A.; Martin-Torres, J.; Ribes, D. L.; Sail, P.; Teodorani, M.; Tedesco, J. J.; Tedesco, G. T.; Tu, M. & Zorzano, M-P. (2023). “The Scientific Investigation of Unidentified Aerial Phenomena (UAP)”. *Journal of Astronomical Instrumentation*. Accepted. In Press. https://doi.org/10.1142/S2251171723400068

White, H. S. (2013). “Warp Field Mechanics 101”. NASA Conf. Proc.: https://ntrs.nasa.gov/api/citations/20110015936/downloads/20110015936.pdf

Zhilyaev, B. E. & Petukhov, V. N. (2023). “Unidentified aerial phenomena. UAPs over Kyiv”. *Research Gate Portal*: https://www.researchgate.net/publication/369529382_Unidentified_aerial_phenomena_UAPs_over_Kyiv

Zlotnicki, J. ; Yvetot, P. & Fauquet, F. (2012). “Existence of electric/magnetic signals related to unknown luminous lights observed in Hessdalen valley (Norway)?”. *EGU General Assembly 2012*, held 22-27 April, 2012 in Vienna, Austria., p. 5967. https://ui.adsabs.harvard.edu/abs/2012EGUGA..14.5967Z/abstract

Zou, Y. S. (1995). “Some physical considerations for unusual atmospheric lights observed in Norway”. *Phys. Scr.* 52, 726–730.

APPENDIX 1 – Feasibility of medium-resolution spectroscopy in UAP research

<u>Question</u>: what is the needed power (energy per unit time) of a light source at a distance of 1 kilometer so that the proposed spectrograph will have a signal-to-noise ratio above unity in each spectral bin that we are recording?

Assuming that, at the direct entrance of the spectrograph, the signal to noise ratio S/N (or SNR) can be expressed as:

$$\frac{S}{N} = \frac{L \cdot \Delta\lambda}{4\pi \cdot d^2} = \frac{L \cdot \lambda}{4\pi \cdot d^2 \cdot R}$$

Where:

L : Energy per unit time

λ : Wavelength of a single spectral line

$\Delta\lambda$: Wavelength Range

d : Distance

R : Spectral Resolution

Assuming that we are using medium resolution R = 2500 (Masters' system), we are able to obtain S/N > 1 only if:

L = 1 MW (S/N = 1.7)
d = 300 m

Or if:

L = 10 MW (S/N = 1.5)
d = 1 Km

Or if:

L = 1 kW (S/N = 1.5)
d = 10 m

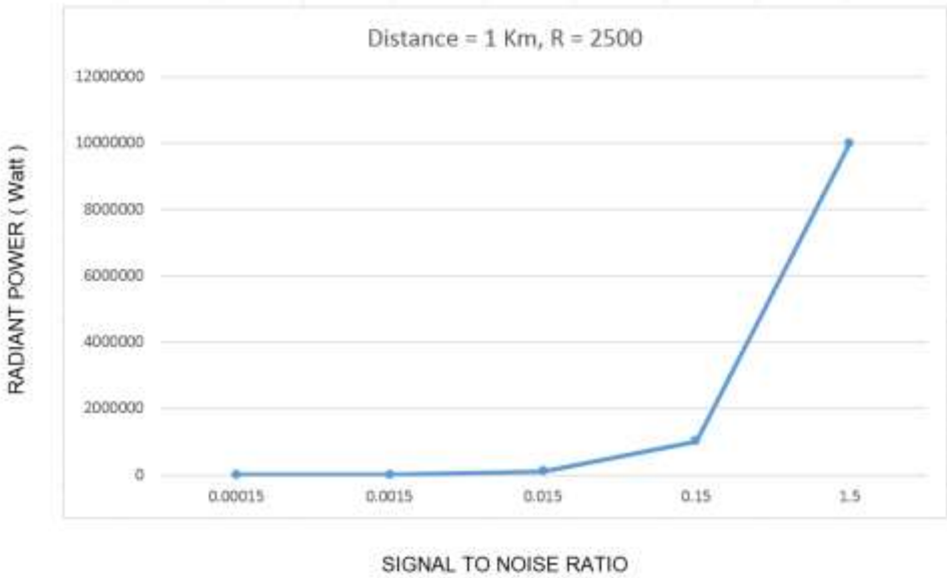

Figure 1. Increase of SNR with the radiant power of a luminous source. If spectral resolution R increases of a factor 10 (High Resolution) the SNR decreases of a factor 10. If distance d decreases of a factor 10, the SNR increases of a factor 100.

Instead, if we use low resolution, with R = 250, all the obtained values increase of a factor of 10. High-resolution (R ≥ 10,000), where all the obtained values decrease of a factor of 10, will not be clearly recommended. Said values for luminosity and distance are not a limitation if $\Delta\lambda \geq 1000$ Å (photography/photometry of continuum spectrum).

In the realistic situation of an observation, we need to use a Lens (or adjustable Zoom Lens), which is very luminous, namely with very high aperture A_L and very little focal length F_L , a detector with high quantum efficiency ε and using a long integration time T_I

At this point, the previous formula becomes:

$$\frac{S}{N} = \frac{L \cdot \lambda \cdot A_L^2 \cdot T_I \cdot \varepsilon}{4\pi \cdot d^2 \cdot R \cdot F_L^2}$$

To make some examples, if we use a lens where A_L = 50 mm and F_L = 5 mm, if L = 1 MW and d = 10 Km, we would obtain S/N = 1.5. While, for L = 1 kW and d = 1Km we would obtain S/N = 0.015 (insufficient); but if d = 100 m, then we would obtain S/N = 1.5. In order to further, increase the number of received photons we need to use an integration time that can be more or less long.

The realistic (and absurd but favorable for us) situation of previously observed UAP in the world shows that very high values of radiant power L, deduced after doing calculations on photos of very important UAP cases (Condon, 1969; Maccabee, 1999; Vallee 1998), do exist:

L = 500 MW; L = 1000 MW; L = 2500 MW; L = 10000 MW; L = 30000 MW

In particular, this important peer reviewed article speaks for itself:

Vallee, J. (1998). Estimates of Optical Power Output in Six Cases of Unexplained Aerial Objects with Defined Luminosity Characteristics. *Journal of Scientific Exploration* 12(3), 345-358.

This means that considering a distance d = 1 Km and using R = 2500, we would obtain a SNR per every wavelength bin (1 Å) respectively given by:

SNR = 75, 150, 375, 1500, 4500

This clearly means that using medium resolution (R = 2500) we can obtain SNR > 1 also when the distance d increases of a factor 10 (10 Km). For example: if we observe a source with L = 1500 MW, we obtain SNR = 2.3.

In addition, for the highest values of the radiant power, it might be possible to carry out high-resolution spectroscopy (R ≥ 10,000) too, for 1 Km ≤ d ≤ 10 Km, being able to obtain a SNR > 1.

Clearly, if we apply an integration time, S/N will increase much more.

We can then conclude that:

- DETECTABILITY – What are the minimum requirements for radiant power per 1 Å bin for obtaining a SNR >1 of a UAP whose distance is d = 1 Km? It is 10 MW in a moonless night.

- OPERATIONAL – If we attach to the spectrograph: 1) Zoom Lens with high A_L and short F_L; 2) CMOS detector with ε = 90%; 3) Using an Integration Time T_I , SNR may increase of a factor 10000 for a (medium) resolution R = 2500, in a moonless night.

- TRACKING – A slitless spectrograph (R = 1000+) has a wide field and can track an object that is standing still, or moving linearly with no strong acceleration, deceleration or erratic movement. Therefore, the execution of T_I is possible. Otherwise, probably it is not. Anyway, tests on birds and/or drone should be carried out.

- REALISM – Transient situations show that a UAP can reach a radiant power of 500 MW ≤ L ≤ 30000 MW (Vallee, JSE 1998). Therefore SNR >> 1 at d = 10 Km +

APPENDIX 2 – Preliminary calculations for medium-resolution spectroscopy

I used the following spectral line: H_β 4861 Å (Hydrogen), because it is more or less close to the center (more luminous) of the optical spectrum's range allowed by the used grating and because I expect that water vapor (H_2O) may be ionized/excited by a heated source, so that we might see H and O emission lines. O lines are typically blended together and mostly in the red part of the spectrum (its less luminous part), not ideal in my opinion to see the Zeeman splitting effect. I approximated the g-factor to 2.5 for an "average line".

Accuracy of a Spectrograph according to Resolution			
Resolution R = $\lambda/\Delta\lambda$	**$\Delta\lambda$ (Å)**	**$V_R = \pm (\Delta\lambda/\lambda)$ c (Km/sec)**	**Note**
100	48.6	3000	
1000	4.86	300	
2500	1.94	119	Standard Masters' spectrograph
10000	0.486	30	Masters' latest version
100000	0.0486	3	

Table 1. Wavelength ranges and radial velocity for different values of spectral resolution.

The spectral resolution that I assumed is exactly R = 2500 (giving a precision of the order of $\Delta\lambda \approx 2$Å) which is the one of the spectrograph that I tested in the field (Masters, 2014). Such a resolution is potentially able to resolve a Zeeman splitting for a magnetic field B $\approx$ 10 Tesla (x 10,000 if in Gauss), and to measure a Doppler intrinsic radial velocity if the UAP is traveling at a speed that exceeds 119 Km/sec or if it ejects or it absorbs gases from its surface.

In the specific UAP case, I expect a B value of magnetic field intensity that could be higher or much higher, such as 100 or even 1000, anyway. After all, we humans, already today, are able to produce magnetic fields up to a value of 1000 T, so far.

Using R = 10000 or more (such as in the CASPEC ESO spectrograph, for instance) requires equipment that is much too heavier and expensive; therefore Master's spectrograph was a very cheap and light compromise, in my opinion.

I used this formula to calculate the Zeeman splitting $\Delta\lambda_Z$

$$\Delta\lambda_Z = \frac{\pi \cdot e \cdot \lambda^2}{m_e \cdot c} \cdot g \cdot B = 4.67 \cdot 10^{-13} \cdot \lambda^2 \cdot g \cdot B$$

Where:

B: Magnetic Field Intensity = 100,000 Gauss = 10 T
λ: Wavelength of the spectral line = 4861 Å
e: charge of the electron
m_e: mass of the electron
c: speed of light
g: Landè factor of the spectral line = 2.5

The calculation shows that a magnetic field in the range 1 T $\leq$ B $\leq$ 10 T generates a Zeeman splitting of 0.28 Å $\leq \Delta\lambda_Z \leq$ 2.8 Å.

In addition, I calculated the Integration Time IT needed to integrate photons in a satisfactory way from a $\Delta\lambda_Z$ **=** 2.8 Å, caused by a B = 10 T produced by a target whose intrinsic luminosity is L_I = 1 MW at a distance of 10 Km, with received luminosity $L_R = 8 \times 10^{-4}$ W/m^2. I obtained IT = 28 min if we want a S/N = 100 (ideal, but not at all realistic), and IT $\approx$ 17 sec if we accept an S/N = 10 (realistic). I assumed an extended light source (10 m in diameter), with a radiating power of L = 1 MW at a distance of 10 Km (realistic), using a focal length of 300 mm and an aperture of 100 mm, plus other indicative instrumental factors, such as sky background noise, seeing = 1", quantum efficiency of an average CCD = 0.25.

$$IT = \frac{\left(\frac{S}{N}\right)^2 \cdot b \cdot \Delta\lambda \cdot F_T{}^2 \cdot \beta^2}{\left(\frac{L}{4\pi \cdot d^2} \cdot \Delta\lambda\right)^2 \cdot \pi \cdot D^2 \cdot A_T{}^2 \cdot \varepsilon}$$

- UAP diameter D = 10 m (1000 cm).
- UAP shape approximated to a sphere with diameter D.
- UAP distance 100 m $\leq$ d $\leq$ 10 km ($10^4 \leq d \leq 10^6$ cm).
- UAP luminosity L (Watts) assumed to be constant.
- Optimum Signal-to-Noise ratio S/N = 100 (a dimensional).
- Sky background noise b = 2.5 x 10^{-6} $n_{photons}$ sec^{-1} cm^{-1} $arcsec^{-1}$ $Å^{-1}$.
- Telescope aperture Dt = 20 cm (of a typical portable telescope of the *Celestron* or *Meade* type).
- Telescope focal length Ft = 286 cm (same as above).
- Disk-like dimension for a point-like source (the "seeing") β = 1 arcsec.
- Photometric CCD detector efficiency factor ε = 0.25.

The conclusion is that:

1. If we want R = 10000 or more we would need a very expensive and heavy instrument (not suitable for our pan-tilt system), which is not practical at all for our necessities.

2. Using R = 2500 (Master's system) is an acceptable compromise, as the system is very light and easily used on a pan-tilt mounting.

3. Using R = 2500, we have a precision of $\Delta\lambda \approx 2$Å, which allows us to measure the Zeeman splitting effect on spectral lines of the order of $\Delta\lambda_Z$ = 2.8 Å, caused by a B = 10 T produced by a target whose intrinsic luminosity is L_I = 1 MW at a distance of 10 Km, with received luminosity L_R = 8 x 10^{-4} W/m^2. This allows us to obtain an integration time of IT = 17 sec, if we (very realistically) settle for a value of S/N = 10.

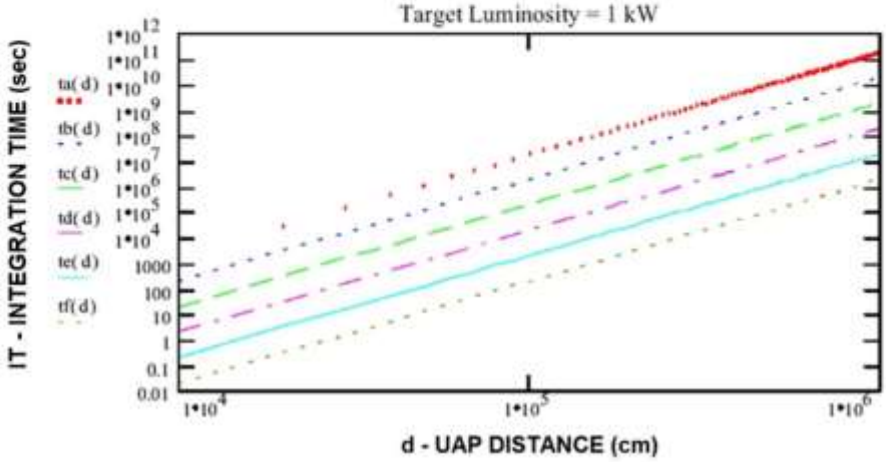

Figure 2. Exposure times for a UAP target with luminosity L = 1 kW, given $\delta\lambda$ = 0.005 Å (ta), $\delta\lambda$ = 0.05 Å (tb), $\delta\lambda$ = 0.5 Å (tc), $\delta\lambda$ = 5 Å (td), $\delta\lambda$ = 50 Å (te), $\delta\lambda$ = 500 Å (tf). Target diameter is assumed to be D = 10 m. Distance d is varied from 100 m to 10 km. Graph is plotted on a bi-logarithmic scale.

It is evident that when the value of $\Delta\lambda$ increases, the integration time IT decreases as well. In fact, when we use low resolution instead of medium resolution spectroscopy the integration time decreases of a factor 10 for a light source with fixed value. When $\Delta\lambda$ is around 1000 Å we enter into the realm of direct imaging, namely (CCD or CMOS) photometry, which obviously allows to obtain extremely short values of the integration time and which, consequently, allows us to carry out high-speed photometry for very luminous sources.

APPENDIX 3 – Important considerations for magnetic measurements

There are some good reasons to hypothesize that the very high values deduced for UAP's luminosity, velocity and acceleration might be correlated with a very high intrinsic value of magnetic field intensity.

According to a very rich amount of reports, very strong magnetic fields related with UAP sightings were responsible of electromagnetic interference with electrical devices (Rodeghier, 1981). In particular, in cars, a high magnetic field might saturate the ignition coil and reduce voltage to the spark plugs, and could cause a momentary halt to current flow or increase resistance in some engine component.

Considering that the received magnetic field intensity produced by an electric dipole or electrical engine of some kind typically decreases with the inverse of the cube of the distance, unless the emitted magnetic field is as high as 100,000 T, what we would be able to measure with our magnetometer at the distance from the source where it is located is expected to be a very low value. Simulation represented by Fig. 2 shows very clearly that beyond a certain distance any possibility of measuring the magnetic field ceases already when the distance of a source of magnetic field B = 10 T reaches 2 Km.

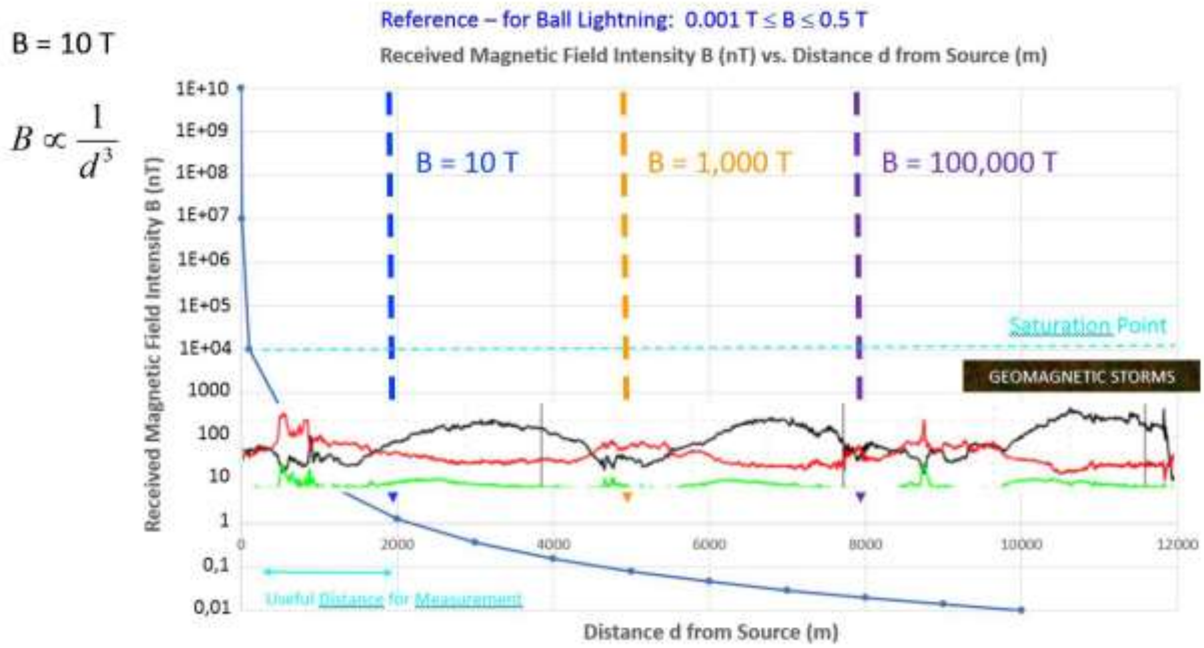

Figure 3. Expected decay of magnetic field intensity with distance from the source if B = 10 T. Comparison with B = 1,000 T and B = 100,000 T is also shown. The effect of geomagnetic storms due to solar activity is shown as well.

If the UAP is some sort of "machine" (manmade or not) very strong values of the magnetic field might be expected (Meessen, 2012a; 2012b). Nowadays our technology has reached the capability to build magnets (in the case for plasma confinement in nuclear fusion experiments) where the magnetic field intensity reaches values of up to 1,200 T. If this is the case for the monitored UAP phenomena then a simple calculation shows that the magnetic field can be still measured at a distance of 5 Km. If the intensity is a factor 100 or 1,000 higher – which human technology cannot produce yet – then the distance limit might reach the maximum range of a general observatory such as the one installed by *The Galileo Project* which is around 12 km (Watters et al., 2023).

Due to their very little size and very short duration, it is highly unlikely that a natural phenomenon of the ball lightning kind is able to produce an excessively high magnetic intensity, which according to theory is expected to be typically in the range 0.001 T ≤ B ≤ 0.5 T (Fedosin & Kim; 2001) and for an extended period of time as it has been observed during previous observations of UAP phenomena. Other natural phenomena such as fireballs, meteor reenters, Chelyabinsk-like events and powerful conventional lightning are expected to be much more magnetically powerful than ball lightning and, anyway, with a much shorter duration than in the case of reported UAP events.

In any fact, the measurement of a magnetic disturbance alone cannot be considered if an optical, infrared, radio and/or a radar counterpart ascribed to an UAP is not recorded at the same time. The same can be said for an electromagnetic (VLF, VHF and UHF) disturbance if it is not accompanied by a UAP manifestation in the sky that is visible in the optical and in the infrared.

In conclusion, due to the law of the inverse of the cube of distance, unless a UAP is just flying very close to the monitoring station (which is highly unlikely, and yet it would generate saturation in the magnetometer's reading), what would be realistically measured is expected to be in the approximate range of 10-100,000 nT, assuming that the effects due to geomagnetic storms, ferromagnetic rocks, internal instrument noise and manmade machinery can be promptly removed. In particular, space weather must be always checked out (Spaceweather.com, website) as soon as a suspect magnetic reading is recorded by the magnetometer: this is a source of noise that must be removed. If at the same time a luminous phenomenon is recorded by the instrumentation, then we would have an overlap of two phenomena together, which must be separately weighed very carefully.

The intrinsic magnetic field intensity of the source can be obtained by extrapolation once the distance is known using radar and/or triangulation. A further and solid confirmation of such a value might come from a possible measurement of the Zeeman Effect (Lang, 1991) in optical spectra of the UAP under investigation, if a relatively high resolution is used, if the spectrum shows emission lines in it and if the intrinsic magnetic field intensity is very high.

The measurement of the magnetic field might turn out to be of paramount importance if what we are observing of an UAP is due to the effect of some kind of propulsion mechanism (Griffiths, 1984; Meessen, 2012a, 2012b), where extremely high electric currents flowing through superconducting devices could be produced. If the surface of the UAP is able to resist to million or billion volts in order to produce very high magnetic fields without undergoing an appreciable factor of electrical resistance and consequent overheating and if this effect is anyway able to excite/ionize atmospheric air around then the flying object might be highly self-luminous, as it has been reported very often. Clearly, verifying if there is a time-correlation between magnetic intensity and other fundamental physical parameters such as velocity, optical luminosity, color, radio brightness, radar signature, and particle emission would give us fundamental insights on the physics of the observed phenomenon, and in particular on the propulsion mechanism.

Reasonably high resolution – not more than 1 nT, but preferably 0.1 nT – would also allow us to verify if the detected magnetic field is subject to pulsations, as it was recorded in the past during previous research (Strand, 1984), and if they are correlated with fast variations of luminosity, color, radio brightness and particle emission. We might be observing a constant or monotonically increasing and/or decreasing pulsation, which can be accurately measured using all of our instruments.

In practice – in the case that we are really assisting to a technological phenomenon of some nature (not necessarily extraterrestrial) – our monitoring operations would take the form of "dynamical back-engineering", by observing a machine by not dismantling it inside an hangar but rather by observing meticulously how it behaves during the flight. Otherwise, if it is not an artificially produced manifestation, we might have the chance to study in detail a high-energy natural phenomenon (not ball lightning like) that we have never been aware of. In both cases, our knowledge of physics could be highly enhanced.

APPENDIX 4 – Important questions for physics

- How does the intensity of UAP's magnetic field strength change over time?
- How is UAP's speed time-correlated with its color and luminosity?
- Does UAP react to Laser beaming?
- Does UAP apparition in the sky alter stars' apparent position and/or luminosity?
- Does UAP disappear from visible wavelength range while seen in infrared?
- Does UAP disappear from sight and from IR while constantly targeted by radar? And vice versa.
- How does the pulsation rate of magnetic field and microwave changes with speed, color and luminosity?
- How is the apparition of UAP correlated with simultaneous electric blackout of some areas?
- Do spectral lines appear when a luminous cloud suddenly surrounds the UAP?
- Does the luminous surface area of the UAP shrink or expand in time, while it stands still?
- Does the UAP (ascertained as anomalous by instruments) start to make the noise of an aircraft?
- Are Doppler effects deduced from radio data (VLF, VHF, UHF) time-correlated with the emission of particles?
- Does a UAP at night increase dimensions of its intrinsic extended surface because it "inflates" or because suddenly a cluster of small lights surround a central nucleus, as seen from large distance?
- Does a UAP change its radar cross section?
- Is the apparition of UAP correlated with intrinsic geophysical anomalies?
- Are "structured UAPs" kinematically and spatially correlated with unstructured "light balls"?
- How do measured physical parameters (suddenly?) change when a UAP suddenly accelerates or does right angle turns?
- What is the timescale of luminosity and color change of a UAP?
- Assuming that, as soon as we have a significant statistics, we want to build up a "Luminosity Function" for UAPs, we need to know the number of UAPs per luminosity interval.
- Do (recorded) semi-regular or regular UAP light pulsations contain a coded message, are they the after-effect of a propulsion system or are they simple light fluctuations of an unusual (BL-like) natural phenomenon?
- Is the radar cross section constant or does it change or disappear when the UAP: 1) is standing still; 2) is moving at constant speed; 3) is accelerating; 4) is changing luminosity and/or color; 5) is disappearing from sight?
- Are the clocks that are piloting the measurement instruments affected by the UAP passage, close and/or in distance?
- Are the horizontal and vertical (both downwards and upwards) speeds/accelerations of a UAP comparable in amplitude or not?
- How does the light and color distribution change along the extended surface of a UAP (disk-like, triangle-like, lozenge-like, etc.)? For instance: the ratio between light intensities in the core and in the peripheral area of the illuminated surface. How - then - does this ratio vary with time, when all the other parameters (in particular speed and acceleration) vary?

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Massimo Teodorani (PhD., Bologna University) is an astrophysicist from North Italy. His Ph.D. in Astronomy from Bologna University is with a specialization in stellar physics. He has been carrying out research on eruptive phenomena in astrophysics, such as supernovas, novas, high-mass close binary stars with neutron star component, black hole candidate binary star systems, strongly eruptive protostars (FU Orionis type), and cataclysmic and pre-cataclysmic stars. He is an expert in photometric and spectroscopic observational techniques. He has been working as a researcher at the INAF (Italian National Institute for Astrophysics) Naples Astronomical Observatory and at the INAF Radioastronomic Observatory in Medicina, Bologna. Being experienced both in optical and in radio astronomy, Dr. Teodorani also has carried out research on extrasolar planets (i.e., the search for 22 GHz water maser line in 57 stellar candidates) and the Search for Extraterrestrial Intelligence (SETI). Dr. Teodorani takes an observational/experimental and interpretative/theoretical approach to his research. He also is an expert in the physics of anomalous plasma phenomena of geophysical interest such as the phenomenon in Hessdalen, Norway and similar recurrent phenomena around the world. On these topics, he has carried out considerable research using astronomy-like strategies and observational techniques and simultaneous multiwavelength and multi-instrument measurements, and he has published his observational and theoretical research. He presently is working on new instrument strategies in this field. Dr. Teodorani recently taught physics at the Bologna University, and he is a well-known science communicator in Italy and around the world regarding subjects such as astrophysics, quantum physics, and anomalistics. He is the author of eighteen science-oriented books including two textbooks, "L'Atomo e le Particelle Elementari – Manuale per Studenti e Ricercatori" (Macro Edizioni, 2007) and "Raccontare l'Universo – Introduzione Divulgativa all'Astrofisica" (Tangram Edizioni Scientifiche, 2020).