

# ARCHAEOACOUSTICS II

## The Archaeology of Sound



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Including a Bonus Report on Sogmatar

Edited by Linda C. Eneix

Prologue by Fernando A. Coimbra

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# New Technologies of Analysis in Archaeoacoustics

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**ABSTRACT:** Building on previous research where EEG was used to measure the effect on brainwave activity, SBRG (Super Brain Research Group) have been developing a new protocol to further evaluate physical phenomena found at many archaeological and other sites. Equipment from the field of forensic imaging and remote sensing has been utilised to enable greater understanding of the inclusion and utilisation of resonance as a deliberate feature utilised by the architects. At the same time we analyzed the effect on the human body of these phenomena using established methods such as electroencephalography (EEG) and more recently the TRV camera. Over the last two years SBRG's archaeoacoustic research has focused on making visible vibrations and natural magnetic and electric fields which interact with the human body, that until now had only previously been measured by microphone, spectrum analyzers or similar devices. This new method is based on using a combination of ultrasensitive digital sensors and computer software, to identify micro variations in the environment. Vibrations and environmental micro-movements are made visible and a value given to their corresponding frequencies through a photographic process that creates a photographic composite from a series of time-lapse images. Electromagnetic fields can be made visible, by using the "scattering phenomenon" of light reflecting from steam water molecules whose magnetic field is invisible to the human eye on the one hand, but detected by computer using a modified camera in the UV field. Ancient sites analysed by SBRG to date, have exhibited the presence of certain phenomena that have a direct influence on the human body, thereby creating a new method of analysis in the field of archaeoacoustics.

**KEYWORDS:** Archaeoacoustics, UV photography, TRV camera

## Introduction

**A** Traditional approach in Archaeoacoustics is to record environmental sounds to study the architecture of the site to better understand if natural or engineered acoustical properties

are present. In such an approach, ultrasensitive microphones and digital recorders are used [2,3,4,5,6,8,9,10,11,12,15,16]. The equipment used by our group to record sounds consists of a dynamic high-end recorder, the Tascam DR-680 (extended in the ultrasound and infrasound field with a

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<sup>1</sup> SB Research Group (SBRG) is an international and interdisciplinary project team of researchers, researching the archaeoacoustic properties of ancient sites and temples throughout Europe ([www.sbresearchgoup.eu](http://www.sbresearchgoup.eu)).

maximum sampling rate of 192 KHz). Use of gain control in recording devices is very delicate. In quiet locations, the maximum gain for recording is used; in more noisy environments gain is determined with 0,775V/0dB AES/EBU standard. The microphones used have a wide dynamic range and a flat response at different frequencies (Sennheiser MKH 3020, frequency response of 10Hz - 50.000Hz) with shielded cables (Mogami Gold Edition XLR) and gold-plated connectors [2,3,4,5,6,8,9,10,11,12,15, 16].

A medical-anthropologic approach extends archaeoacoustic analysis to include the relationship between the human body and archaeological sites using new forensic methodologies. Our preliminary results from several ancient sites, in which we used this approach suggest a deep knowledge by ancient civilizations of the resonance phenomenon and particular sound

frequencies which affect brain activity [7,10, 14, 16]. These questions were our starting point:

- > Do archaeological sites have an effect on the human body and brain?
- > Do any vibrations that may be present have a direct effect on the human brain?
- > Are there other naturally enhanced phenomena that can affect brain activity?

For several years we have continued the research of Ian Cook [1] and Robert Jahn [17] on the effect on brain activity of particular resonance frequencies found at various archaeological sites, recognising the strong connection between ancient structures and the human body [7,10, 14, 16]. In 2013 we started a laboratory study with a group of volunteers exposing them to the same range of frequencies found in well known archaeological locations in an absorbing sound room [7].



Fig. 1 – The adsorbing sound room during EEG research

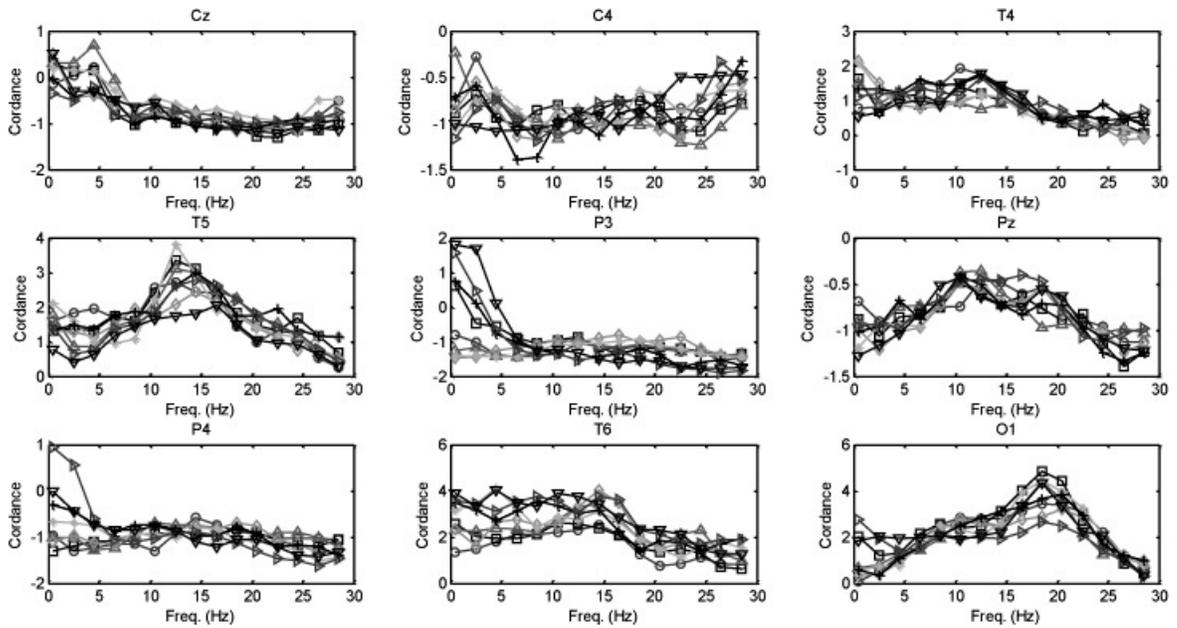


Fig. 2 – The EEG cordance aspect of different tones (on the volunteer in Fig.1)

During this investigation we observed that the exposure to these frequencies during meditation or prayer can create a brain activity response which differs depending on whether or not the volunteers are trained in meditation techniques. This lengthy research has yet to be concluded, but early results indicate that the aspect of brain waves measured by EEG are totally different.

In particular we can observe two or more peaks of brain wave frequency in some areas during the emission of tones between 70-140Hz, this is not usually possible under normal conditions. Usually, (but not with a pathology), such frequencies are found, i.e. during sleep, or another frequency, i.e. when we are awake, it is not ordinarily possible therefore for two frequencies to be experienced contemporary, (i.e. to be asleep and awake at the same time). However these results showed this is possible if the volunteer is trained in meditation or prayer techniques and is exposed to particular

tones. This creates an oneiric experience (one of visions or ideas), with total consciousness but without the use of chemical substances.

Previous results in 2014, found there is no common tone which everyone is sensitive to, but between the ranges of 95–110 Hz, it was discovered everyone has one, two or more frequencies to which they are very sensitive and which affect their brain activity [7]. The volunteer in figure 4 for example, has a strong sensitivity at 120Hz and with a low sensitivity at 105Hz. While volunteers untrained in meditation or prayer, had a different sensitivity to sound tones, the volunteer in Figure 3 had a great sensitivity to 105Hz but low for 95Hz.

Subsequently the laboratory research was extended to a Neolithic structure, Cividale del Friuli Hypogeum in Italy, where drums were used to obtain the same frequency and vibrations used in the laboratory.

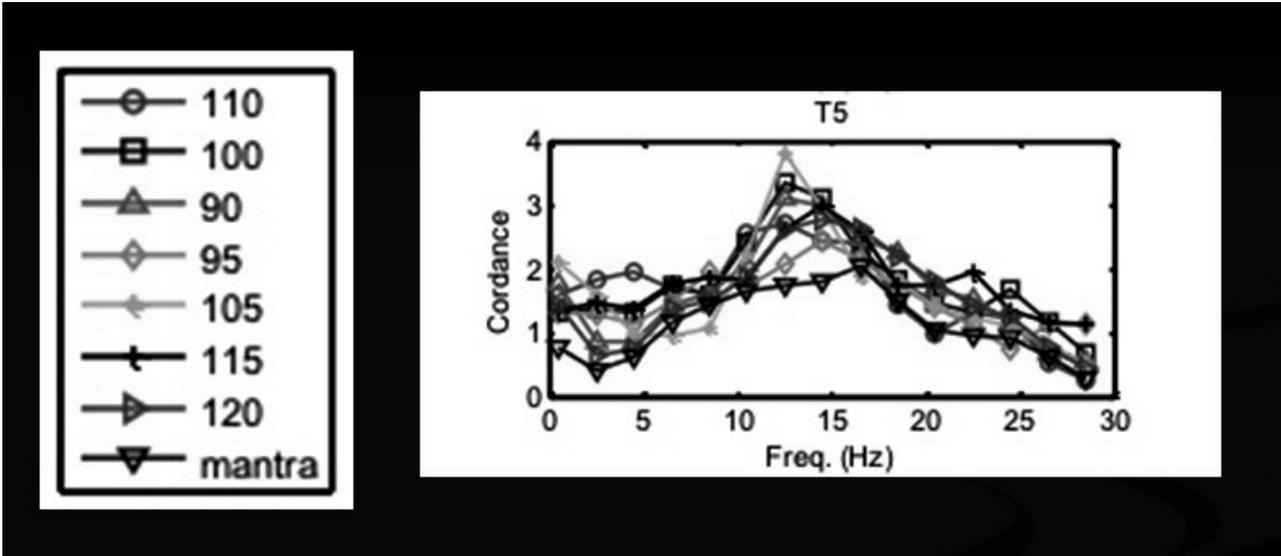


Fig. 3 – Aspect of EEG in T5 area for a volunteer not trained in meditation or when exposed to different tones.

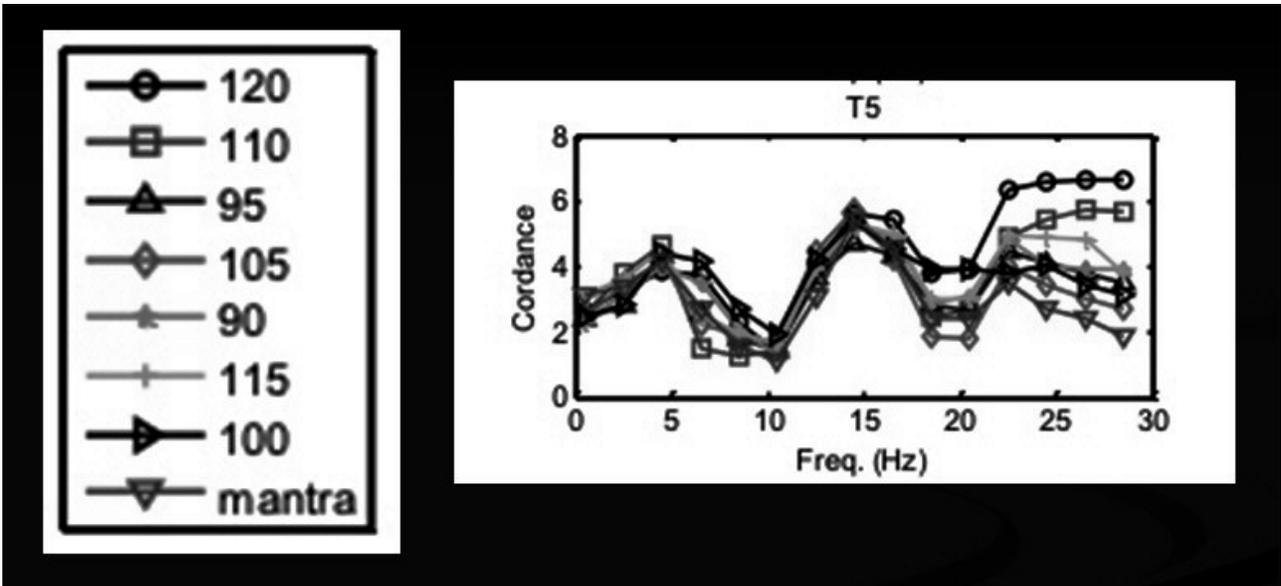


Fig. 4 – Aspect of EEG in T5 area for a volunteer trained in meditation or prayer when exposed to different tones. It is possible to see more than three peaks of brain wave frequency, in particular at 120Hz.



Fig. 5 – The use of EEG in Cividale del Friuli Hypogeum (Italy) in 2014



Fig. 6 – Two operators wearing helmets are required to place electrodes on the volunteers in this narrow space.

However, there was a big difference in how the EEG equipment functioned between the two environments. In common with many underground structures, the humidity was very high and created shorts circuits in the EEG device. Two operators are usually required to place electrodes on the head of the volunteer, but in a narrow and dark environment such processes took much longer to obtain reliable data than in the laboratory. This and the humid conditions also meant there was a greater risk of short circuits in the cabling for the equipment.

The resulting data that was obtained, required a skilled and experienced technician willing to dedicate considerable time to analyse the results. As this proved difficult to achieve, alternative less complex methods were sought, specifically those that could evaluate the emotional state of volunteers along with any subsequent altered states of mind from vibrations. It was decided to work with the TRV camera and UV imaging in this respect.

### TRV Camera

“TRV technology” (Variable Resonance Imaging Camera) is something we have been working with over the last three years [10,16]. As this is new technology, it requires an explanation as to how it was applied in our research and how it might be applied within the wider archaeoacoustic field. TRV equipment shows there is a direct correlation between emotional and functional states of the human body by measuring precise parameters of controlled motion reflection. Until recently, quantitative parameters and efficient information of the movement of the human body had not been established. Bernstein and Lopez (psychodiagnostic miokinetics) [18] studied the micro-mobility of the human body and found that it represented a sophisticated mathematical problem. For example, it has been shown that the vertical

balance of the human head is controlled by the vestibular system, described as a reflex function, but the balance of the head can also be considered an extension of locomotor activity (micro-mobility of the head) controlled by this system. The analysis of this and other types of reflexes which control the body’s mobility provide a lot of information on the physiological state of any subject examined. From a physical point of view, the mechanical oscillations of the head are a vibrational process, whose parameters provide a quantitative correlation between energy and mobility of the object. Information on the integral parameters of head mobility can be obtained using video analysis TRV (Variable Resonance Imaging Camera) technology, which provides quantitative information of the periodic movements of any part of the imaged object.

In the image provided on the primary monitor (represented by pseudo-colours), each point represents the mobility parameters in the frequency of the examined subject. As in other biomedical imaging (ultrasound, NMR, IR, X -ray), the TRV is a method of image analysis that is based on data of micro-mobility models and introduces a new term, emotional vestibular reflex or “*reflection of vestibular energy*” (RVE). This indicates that the coordination of the movement depends on the emotional and physiological state of mind affected by these factors. To date, the system has primarily been used in the security and anti-terrorism field, whereby people in an agitated or stressed state of mind have a different color around them compared to those in a normal state, which helps to identify them amongst a group of people.

The TRV image analyser system is used to monitor vibrations in normal or altered physiological states. In a little square on the PC screen the image of the subject is shown using a spectrum of false colours, with a

graph corresponding to the initial position. Later the software shows through a variation of image colors, a transition to an altered physiological state of conscience which sometimes results in a change of colour to a single color tone or the total disappearance of the image itself. The change from the initial multicoloured image to a single color state indicates that the vibrations have passed from a wide spectrum to a narrow spectrum of frequencies, which indicates a state of coherence in the examined subject. It is possible to state that the detected frequency spectrum changes completely when the examined subject enters into an altered state of conscience. All the parameters are analysed and stored from

moment to moment by the camera's software. At the end of the trial a "report" can be generated showing the spectrum of vibrations, which shows the depth of brainwave state achieved along with any fluctuations of intense vibration in the body of the subject examined.

The picture below (Figure 8) shows a distribution of horizontal colored stripes around the vibrating objects (rows show obtained individual frequencies). These represent the spectral distribution of vibrations in a band between 0.1 and 10 Hz according to a scale of pseudo colors from purple to red.

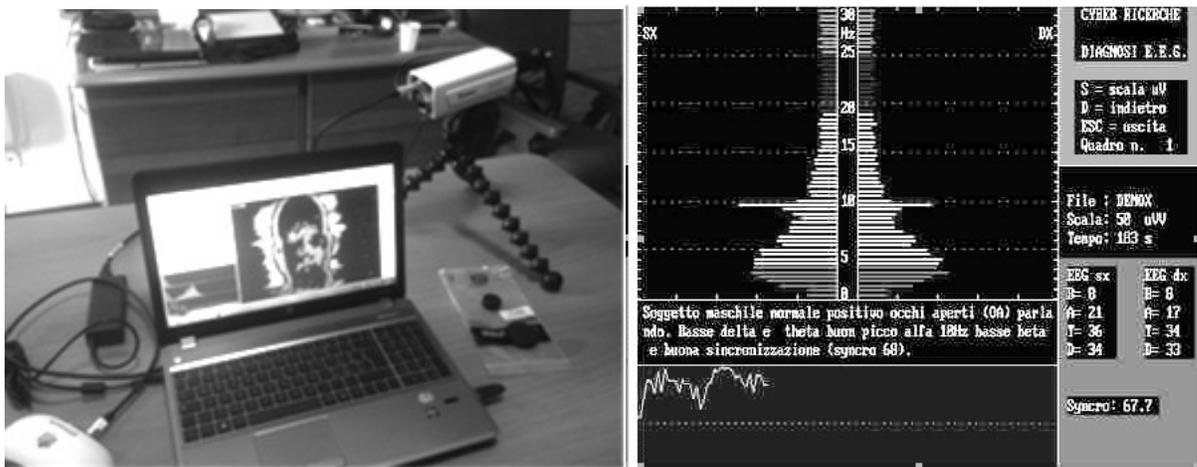


Fig. 7 – On the left: analysis by TRV system; on the right: analysis by EEG



Fig. 8 – Images converted to a scale of pseudo colours in relation to body frequency (low vibration) in Hz.

The vibrations generated throughout the human body vary continuously both in amplitude and in frequency. On the computer screen a large panel shows someone with horizontal coloured lines of varying lengths surrounding them, highlighting the vibrations detected (Figure 9). The frequency is represented using colour scale (Figure 8). Another panel in the bottom left of the screen, shows the spectral characteristics on three graphs.

The TRV system aims to study the functional state of the human body through recognition and mapping of the emotional state. The algorithms for determining this are based on a mathematical statistical system, the coordination of movement principles and the logic of behaviour psychology using comparative tests.

The TRV system's camera has a common CCD backlit, with a three MegaPixel sensor. The protective anti-aliasing filter was removed to extend its vision beyond visible light into the infrared (IR) and ultraviolet (UV) range. It has a system of rotating LEDs from infrared to visible light which generates ultraviolet light and synchronises it to the lights rotation at will from 1 Hz to 10 KHz. The lens is a 25 mm quartz-fluorite with passband from 200nm to 1800nm. It is connected to a PC, but videos can also be saved to internal flash memory.

This system was developed by the secret services to test the emotional state of terrorist suspects under police interrogation. Furthermore this special technology is used by airport security staff to evaluate the emotional/stress condition of passengers. Any subject planning a terrorist attack who is in a stressful condition, can be immediately identified by the red/orange colour painted by software around the subject taken by security video camera.

We utilised a TRV camera and software derived by Russian technology, the same used at Sochi Winter Olympic Games in 2014 (known as the Defender System X in Japan and Merlin Camera in Italy) which analysed almost 2,500,000 people before they entered the venues. It was deemed a real success, because no terrorist attack occurred.

The TRV cameras software makes clear immediately the emotional state of the volunteer, in fact human vibrations are pointed out by the colour and extension. We used this method in the archaeoacoustic field in Italy in the site of Alatri<sup>[10]</sup> and in Cividale del Friuli hypogeum<sup>[16]</sup>.

We used this system not only to evaluate the emotional state of volunteers, but also to visually confirm the vibrations detected in archaeological sites, because this device is also capable of identifying low vibrations from the environment. This extended application is open to criticism, because it is not the original intended use for which the device was invented, but the preliminary results in such studies were confirmed by other more conventional methods such as microphones and digital recorders, geologic devices<sup>[10]</sup>.

For example in Cividale del Friuli (Italy) hypogeum, the TRV system recorded perfectly the transition to an altered state of consciousness of the volunteer, which occurred when the entire chamber began to vibrate at the same frequency as the subject during chanting. Initially this was captured by the camera and software as a transition to one color, until the image of the person in the foreground totally disappeared, indicative that the frequencies moved from a broad range to a narrower range<sup>[16]</sup>.



Fig. 9 – TRV image taken by airport security staff



Fig. 10 – The change of emotional state of a subject. In few seconds it is visible a change of extension and colour of false aura, as depressing thoughts (on the left) to positive and happy thoughts (on the right) are experienced.



Fig. 11 - Variation of emotional states during meditation at a “sacred” site. This is visible from the colour and amplitude of the false aura around the volunteer



Fig. 12 – This phenomenon of “vanishing” occurred when one of the chambers of Cividale del Friuli hypogeum begins to vibrate at its resonance frequency when the volunteer is chanting at the same frequency of the site. Read progressive images from left to right.

In Cividale del Friuli hypogeum this altered state of consciousness was achieved by simply repeating a mantra for approximately 8 minutes, as documented by an audio recording which was taken at the same time. Ultimately the male voice or percussion instruments tuned on the right resonance frequency confirm by TRV camera that a "mystical" state can be reached after a few minutes by those who are subjected to the resonance phenomenon inside the hypogeum chambers [16].

### FUTURA Camera

This camera was born from the idea of SBRG associate researcher, Daniele Gullà, who projected this device on the basis of his experience in the field of legal crime scene analysis for the Italian police and also as an expert appointed by the judge in Italian courts and in cyber crime.

In the forensic field and also in anthropology the research in ultraviolet band gives a lot information normally not visible by the human eye [13], but it has not explored sufficiently in the extreme UV band [14]. So for the futura camera a very high sensitive sensor, normally used for Scientific and Medical Imaging and Microscopy was chosen. This is the CCD42-40 NIMO back illuminated CCD sensor by Canadian E2V Factory. It has full-frame architecture, 2048 by 2048 pixel format of 13.5  $\mu\text{m}$  square pixels. Back illumination technology, in combination with extremely low noise amplifiers, makes the device well suited to the most demanding applications requiring a high dynamic range. To improve the sensitivity further, the CCD is manufactured without anti-blooming structures. There are two low noise amplifiers in the read out register, one at each end. Charge can be made to transfer

through either or both amplifiers by making the appropriate R1 connections. The readout register has a gate controlled dump drain to allow fast dumping of unwanted data. The register is designed to accommodate four image pixels of charge and a summing well is provided capable of holding six image pixels of charge. The output amplifier has a feature to enable the responsivity to be reduced, allowing the reading of such large charge packets [14].

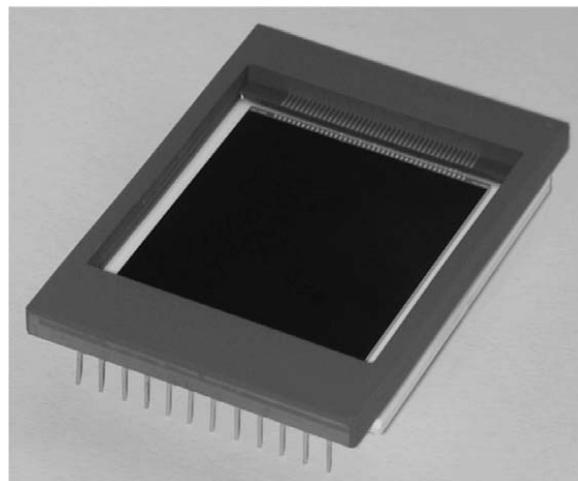


Fig. 13 – The CCD42-40 NIMO back illuminated CCD sensor by Canadian E2V sensor

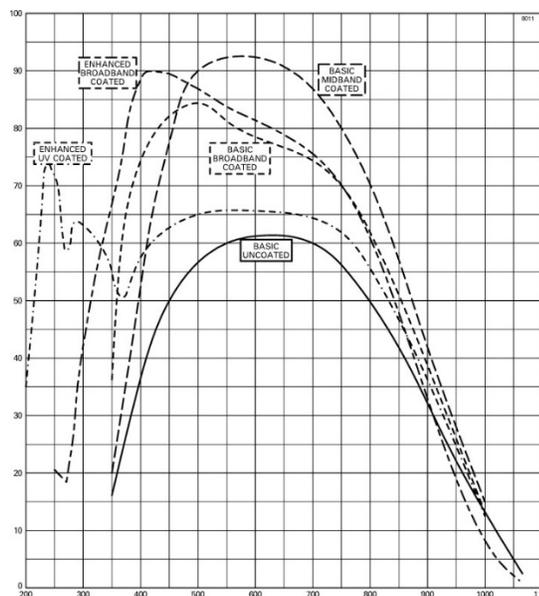


Fig. 14 – Typical spectral response of CCD42-40 NIMO sensor. On abscissa axis the wavelength in nm, on ordinate axis the quantum efficiency in %

Because in the extreme ultraviolet band (UV) the absorption of lenses of normal optics is very strong, usually a normal optic is unable to allow electromagnetic waves below 320-350nm to pass through. We needed scientific optics for our camera. Optics with calcium fluoride and quartz lenses for forensic use (200-1.300nm) were chosen and in particular a Cerco 2073 “UV lens” optic, designed for intensified CCD video cameras with UV photocathode (diameter 18 or 25 mm). This lens allows 200nm of UV light to pass through at 85%, so the attenuation in the extreme UV band is really low. This UV optic achieves the best luminous efficiency for ultraviolet imaging, thanks to its F/1.8 aperture and multilayer antireflective coatings [14].



Fig. 15 – Cerco 2073 UV lens

The main characteristic of the TRV camera is its multispectral extension over standard photographic cameras. Inside the camera’s box is a disk upon which are fitted eight filters encompassing a number of ultraviolet, visible light and infrared pass bands. This disk rotates in front of the sensor enabling rapid changing of filters without

the need to move the camera or optics. It is therefore possible to choose a specific light band to analyze and if the camera is placed on a tripod, the researcher can choose the bands he wants to examine enabling a number of different images to be captured on the same photograph, or on separate photographs to enable comparison of the different results [14].

No. Filters	Type of filters inserted in the multispectral camera		
	Filter passband	nm	Extension band
F 1	Empty, for all spectrum		
F 2	Extreme UV	220	50
F 3	UV	250	50
F 4	UV	300	50
F 5	UV	350	50
F 6	Visible light	514	10
F 7	IR	850	50
F 8	IR	950	50

Tab. 1 – Filters available for multispectral images



Fig. 16 – The external aspect of the multispectral camera (FUTURA).

The multispectral camera also has an active beryllium filter on the sensor. When this filter is activated the camera can only photograph X-rays, gamma rays, cosmic rays and neutrons. The camera is portable as it has an internal battery with a TFT screen. The CCD with microcells of Peltier has a self cooling to -60°C. The downside of this sophisticated device is that it weights almost

3.2 kg and can only be used on a tripod. This camera can be extended also in other fields of archaeology, for example in rock-painting, art restoration and deteriorated manuscript.

The use of this device in sacred sites is based on research by J. N. Hansen and J.A.Lieberman which shows the human body can emit non-visible light (extreme UV emissions) from the microtubules of neurons at specific levels of consciousness (this appears in many ways as a glow of light around the head),.

They proposed that brain waves recorded by electro encephlography (EEG) originate from the vibrations of the brain neurons microtubule structure. Penrose and Hameroff consider that also thoughts could originate from this system and quantum vibrations are orchestrated by synaptic connections (Orchestrated Objective Reduction or “Orch OR” theory) <sup>[19]</sup>. The discovery by Hameroff and Penrose (2014) of quantum vibrations in the microtubule architecture located within the cerebral cells influenced our choice to add this method to SBRG research. So we decided to utilize this method also in archaeoacoustics to evaluate the emotional state of volunteers in ancient sacred sites and their behaviour after exposing at these last <sup>[14]</sup>.

In particular we tested 10 volunteers by FUTURA camera and observed that human light emissions resulting from the vibrations of the neuron microtubule system are only visible in the UV band. Usually images taken in the UV band have the appearance of black and white photographs. To more easily distinguish between different UV

light bands, coloured images were developed. Images of the emissions around the human body were set up using a three band (F3, F4, F5) RGB composition (Table 1). The coloured images were set up in three coloured bands: the BLUE colour was taken by F3 filter until 250nm, the GREEN colour by F4 filter until 300 nm and the RED colour by F5 filter until 350nm. Over the red band at 350nm, it was not possible to see any light emission around the volunteer.

All the images from FUTURA camera are free from interpolation or modification and do not appear to be an artifact from this technique. Such emissions are more visible in people who have practiced meditation or yoga for several years, where it is possible to find a larger halo around their heads. As in other our EEG research <sup>[7]</sup>, brain activity reacts differently if the volunteer is regularly practicing meditation or prayer, whereby the halo surrounding the head is more expanded. It is important to point out the FUTURA camera’s sensor directly reads the light emitted from the subjects head without any stratagem to highlight the halo.

The second important result is the fact that in sacred sites this halo is easily expanded after a permanence of some minutes, as the environment could have a direct effect on the emotionality of the volunteer or is able to reinforce his capability. This results were all repeatable, also if our results need to expand the number of trial samples from 10 to a larger number of volunteers. But we are not the first researchers who found this halo, also other researchers found it by various sophisticated equipment <sup>[20]</sup>.



Fig. 18 – A ‘halo’ around the head of a volunteer during meditation in an ancient sacred site in the UV band. This light emission is also evident during deep meditation in trained people around their bodies too, but at another (lower) frequency of UV light



Fig. 19 – Several volunteers were photographed. The difference of the halo around the heads was very evident.



Fig. 20 – A volunteer before (left) and after exposition in a sacred site (right). It is evident the expansion of the aura after the permanence in a sacred site. This subject kept the expanded aura until two hours after prayer in a sacred site for a half an hour.

## Computer Technology for Making Visible Magnetic Fields Affecting the Human Mind

Among the phenomena affecting the human mind there are also magnetic fields. Normally by various devices it is possible to measure a magnetic field and say if it is present in a particular location or not, but obviously it is not possible to see it.

To make visible the shape of the magnetic field placed in an ancient site it is possible to use UV photography, together with vector programs for computers (PIV – Particle Image Velocimetry). It consists of a modified digital camera <sup>[13]</sup> with its anti-aliasing filter removed or by TRV camera. By the modified camera it is possible to perceive the movement and the behaviour of dust suspended in the air and gas flow as water steam which orientate themselves as a dipole in the magnetic field.

We used the Particle Image Velocimetry (PIV) program for PC by Dantec Dynamics from Denmark. It was the software used to analyse this movement in the UV video and photographs taken in various sites. PIV is used in industry as an intuitive measurement technique to measure two or three components of velocity in a variety of flows. The application of PIV in research and industry is widespread, due to its ease of use and accurate data representation. As easy and intuitive as PIV is, it involves many cross-disciplinary challenges, from classical optics and imaging to the use of dedicated state-of-the-art digital electronics and lasers. The principle of PIV working is very simple: two consecutive shots illuminate a slice or volume of a flow field with particles suspended in the flow. The scattered light from the particles is recorded in two consecutive images on one or several digital cameras. The images are sub-divided into

smaller areas for calculating the mean particle displacement between two corresponding sub-areas. The particle displacement is calculated using cross-correlation or Least Squares Matching techniques. Since the time between the shots is known, the particle velocity can be determined.



Fig. 21 – A sacred site in North of Italy dedicated to sylvan deities in ancient times, nowadays it is overlooked by a Catholic church built in the Middle Ages. It is visible in the middle of the flat space a strong magnetic field by PIV software.



Fig. 22 – The same church from another point of view. Also from this sight the magnetic field is highlighted by PIV software in the same place

Taking into account the magnification of the optical setup, the absolute velocity field can be derived. The velocities calculated from an image pair are an instantaneous snapshot of the flow viewed by the cameras. PIV results are an accurate representation of the flow presented to the user and viewers in an easy to understand and visual manner. The presentation is aided by advanced soft-ware post-processing. Dantec Dynamics is the leading provider of laser optical measurement systems and sensors for fluid flow characterization and materials testing.

### **Discussion and Conclusion**

In three years of research using new technologies we are a long way from any definitive conclusions. Despite amazing results we need to study more deeply the relationship between ancient sites and people who spend considerable time inside them. We understood that ancient civilizations did not build their temples just anywhere, but in particular locations where natural physical phenomena were able to modify the state of conscience of the people during a ritual. New technologies together with well known methods, i.e. EEG, showed this in our studies. We can say through our technologies and methods that ancient populations have a good knowledge of the human brain: empiric for sure, but effective.

We can conclude that new photographic and imaging technologies open new roads for better understanding this aspect by researchers in the archaeoacoustic field. Archaeoacoustics should therefore not only consider analyzing the acoustic properties of the site, but also all the associated physical phenomena which are not perceived by the ears, but which could potentially influence a population and their perception of a particular site as being sacred. Using such technologies, we observed a change of

emotional state in various volunteers after they remained for some time in sacred sites especially by vibration, audible (as a chant or a drum), particularly in connection with resonance phenomena or not audible vibration (natural infrasounds, ultrasounds).

It looks as if mechanical vibrations are only one aspect of the possibility for affecting the human mind, because also magnetic fields can do the same. We can also say that without studying the relationship between environment and the human mind, study in archaeoacoustics appears somewhat limited. In our researches we demonstrated that some physical phenomena (vibrations, magnetic fields) present at such sites, can influence brain activity [7,9,10,11,16]. To analyze altered states of consciousness at particular locations, we suggest the use of musical instruments or the voice, re-creating an original ancient environmental situation for stimulating the resonance, whilst volunteers are monitored using electroencephalography (EEG)<sup>[7]</sup>, TRV camera<sup>[10,16]</sup> or FUTURA camera<sup>[14]</sup>. It is also necessary to conduct a deep archaeological analysis of the site, because archaeoacoustics without an archaeological background is only acoustics; archaeology without studying human emotionality connected to that site is a vain effort to understand an ancient environment as dumb (silent) stones.

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