

These are our responses to the two referees:

Response #1

Thank you Referee#1 for the interesting and necessary observations. Following your suggestions we have extensively reorganized the manuscript starting from the abstract:

The revised abstract:

In recent years the different methods used to translate data into sound to help scientists to better organise their work have come out of the scientific realm to cross into other areas and achieve purposes other than those pursued strictly by scientific research. The ElectroMagnetic Music, a project born in Italy, fits fully into this area. By transforming into musical pitches the voltage response collected by Transient ElectroMagnetic Method (TEM), a well-known geophysical tool for exploring the subsurface, this novel approach enables to extract musical pieces reflecting the effective geological setting, in a way that any geological site seems to have its own soundtrack (i.e. the “soundscape,” the audio component of a landscape). The soundscape becomes the basis on which a dedicated band improvises jazz music. Besides being a new method for creating music, our project has the ambitious goal to attract people’s interest on Earth sciences and their investigative methods, while raising awareness of the environmental problems that characterize geological sites. The present work refers on the experiences already done by the EMusic as a live band around the world. Reports some preliminary data on people reaction and anticipate some future plans for better assessing the potential of the method as a good science communication tool.

As for your suggestions:

1 - The introduction does not adequately frame this work in the either the context of the wealth of sonification projects or in the field of TEM analysis. At present this section reads like an extended abstract, which is confusing to readers. While the authors do provide examples of datasets which have gone through sonifications, nowhere is a definition of sonification in general given neither is the diverse number of approaches to sonification (such as direct audification, mapping datapoints to MIDI instruments based on values, model- vs data-based sonification etc.) discussed. These are crucial aspects required in order to better understand the work presented.

We have rewritten the introduction following your advices, concentrating mainly on reviewing some research on sonification and audification. We have underlined in what we believe EMusic is original compared to the other projects based on sonification.

We write: “The EMusic (ElectroMagnetic Music) in this trend is certainly the first one utilizing the EM response of the Earth, being the first case of sonification strictly related with the geological structure of the subsurface”

Further: “What distinguishes our project is a real dedicated band that improvises jazz on a musical basis obtained through the sonification process”.

We also added a paragraph specifically dedicated to our objectives:

2 Objectives

The EMusic has been conceived to translate into “music” data acquired by a specific scientific instrument, normally used for many geoscience applications. We believe that this technique has a great potential in terms of science and art communication capability. To get a first taste of these potentials, in a first phase, our agenda included mainly live events in several geo-sites. We performed all around the world in close cooperation with musicians to promote the EMusic. We also used the net to spread our method of sonification, the events performed, and the ones scheduled. In the near future we intend to bring the project in schools to involve students in Earth sciences, planet sustainability while introducing them to a different approach to music.

For the time being, as a live band, we are satisfied since the project obtained great interest by the scientific and musical communities. The EGU General Assembly in Wien invited us to play twice (2017 and 2018). Geoscience Australia invited us to play in Canberra and Perth; AGU Centennial Grant awarded us with a 5 hours sound installation based on Airborne EM data collected in Colorado Mountains; Under the patronage of the City of Naples, the Geological Survey of the Campania District and in collaboration with the National Park of Vesuvius, we played on the top of Vesuvius Volcano; We also performed at the INGV (Istituto Nazionale di Geofisica e Vulcanologia) Open Day; we carried out a tour of 7 stages “Sounds from the Geology of Italy”, based on the sonification of EM data collected in some of the most beautiful natural and cultural sites, involving famous international jazzists, like Enrico Rava and Francesco Cafiso.

This paper describes in details our method of sonification and refers on the events performed in collaboration with INGV. We describe also the potentialities of the methods from a science communication perspective even if so far we didn’t conduct an evaluation. Nevertheless, as previously said, we preview in a near future to experiment the method in schools to have the opportunity to extensively evaluate its efficaciousness in terms of attracting students’ interest in geosciences while sensitizing them to planet sustainability. To this aim we are at present implementing a project named Georisonanze.

2 - Section 2 enables readers to better understand what the data behind this project actually represents. However, many questions still arise. Figure 3 is presented in the text as being standard TEM

data, but appears in the figure and caption itself as a sonification. Could the authors provide the TEM data in the raw format that would be the usual for a scientific publication within the field, perhaps labelling so that those from other fields can understand it. Merging this figure with the sonification so early in the manuscript merely confuses the readers and perhaps two separate figures are required, or at least two different panels?

The process of the sonification itself is not adequately described. A flow chart would be very helpful in this regard along with technical details, any choices made by the authors and how these were justified. For example, what choices of maximum and minimum voltages were made and how were these determined? What are the limitations with these choices given known ranges of TEM events in the literature? And what audible frequencies / notes were these voltages mapped to? Were considerations made based on different musical instruments?

Following your instructions we have renamed the par. "Data sonification" in "Methods" and we have subdivided the paragraph into three sub-paragraph:

3.1 TEM methods

3.2 Data sonification

3.3 How EMusic show are organized.

Regarding Fig.3 is indeed a "geophysical" representation of the data, i.e. voltage values vs acquisition time. We have specified in the caption what are the axis units. Close to the "raw data" we inserted the pitches deriving from the sonification of each acquisition gate of the instrument.

In "Data sonification" we have provided details about the procedure and we tried to reply to all the comments by the reviewer (e.g. definition of min/max values, audible frequencies, etc.). As we have pointed out, we extract pitches that can be played by any musical instruments: indeed the "Sound of the earth" is described by the different pitches, the intervals among them (i.e. scales, modes) rather than absolute musical notes.

3- Interaction with musicians and composers seems like it deserves a section of its own. How were these collaborations established, what were their initial thoughts to the sonified TEM transients? Were they involved in the design of the sonification or only approached afterwards? These are important considerations within the scope of the journal.

Some of the claims have been addressed in the Method Section. A paragraph that particularly discusses the interaction with musicians have been inserted:

4. Engaging with musicians

4 - The sections devoted to events also lack a lot of required information. What the format/sessions within the EGU General Assembly are not currently clear, and for readers unfamiliar with this conference a discussion of the types of attendees and presentation methods is required (e.g. a PICO is not described). Further, how the different sessions operated is not explained. What were the purposes of the different sessions? Were the musical performances used to explain, or did they simply follow the explanations? Similar considerations are required with the other events described, where it is not clear who these sessions were aimed at (scientists, geoscience-interested publics, non-science audiences?), how they were targeted, and what different considerations to the presentations were made to be appropriate to these different audiences.

A dedicated paragraph to the events (5. EMusic Live events) has been added with the following brief introduction:

In the following, we describe the main EMusic shows performed in collaboration with INGV. In each occasion we had the opportunity to interact with different audiences: scientists, geo-tourists, children and families. From the description of the following events, it is clear that the events may not always follow the same line-up. Sometimes the geology of the place of data acquisition is discussed during the concert, in other cases, as the Vesuvian concert, it can even be introduced before the concert begins.

The paragraph has been subdivided into three subparagraph describing The EGU events, The Vesuvian Concert and the INGV Open day.

To meet the reviewer's requests, in the EGU events sub-paragraph we have added:

“The General Assembly is the annual venue of EGU, the greatest in Europe gathering geoscientists from all over the world. The Assembly includes also outreach sessions, and since 2015 also a session on Earth sciences and Art. So, we arranged the presentations in order to capture the attention of a wide public.”

And also:

“But it was only in 2018, that we had the possibility to give an immediate taste of the EMusic to the scientific community when we presented in the Earth sciences and Art PICO session. The PICO is a recently born way of presenting at a scientific conference. Compared to a poster session, a PICO is more suitable for a presentation including Art. It allows you to have a couple of minutes to introduce your work. Then you reach an interactive screen to receive anyone interested and show your work in detail.”

For the Vesuvian Concert (par. 5.2) details have been added on the different arrangement of the event:

The sentence “In another occasion we had the opportunity to arrange the performance in a way different from the show in Ferento previously described. It was a show halfway between geo-tourism and a musical concert.” Introduce the paragraph stressing the fact that in this occasion a part of the public was constituted by geo-tourists

While in the Open Day (5.3) details have been added on the appreciation of the whole day and on the informal interaction with the public of the concert, in this case formed by students, families and researchers.

5 - It is clear that no formal evaluation of the activities has been performed, which is a real shame. While the authors claim audiences "greatly appreciated" the events, without even a description of how professional observations were made these claims are unfounded. Instead I would urge the authors to be more honest and instead present their "feedback" section more as a critical reflection of their own practice and as future plans for this project, detailing how through evaluation they aim to understand the impact these sonifications may have on different audiences, because at present no claims can be made about this.

To meet the reviewer’s requests, at the place of the feedback paragraph a more articulate session now appears.

6. Discussion

Here a hint to some studies on the field of sonification from the perspective of social sciences has been added. In particular, a study by Supper (2014) of interest for our particular case:

“As a project based on sonification, we can already count on a series of studies already performed on what makes this technique so compelling to the public imagination. Sonification has already attracted the interest of scholars in the social sciences and humanities (Stern and Akiyama 2012; Schoon and Volmar 2012; Harenberg and Weissberg, 2012; Rumori 2012). Further studies discuss the experience of sonification in terms of its promise to create sublime experiences of science (Supper, 2014). As far as we stay as a live band performing music created in the interaction between science and art, we can in all respects fit into what Supper, reporting the thought of Born and Barry (2010) defines the logic of accountability and the logic of ontology. Accountability is referred as art and art-science initiatives used to legitimate scientific research. As Supper observes, reporting several examples of such collaborations in the sonification field, such legitimation is not always a one-way street. Rather than art making science more accountable to the public, art and science are involved in an act of “legitimacy exchange”. In our particular case, who knows if the EMusic will help increase the audience of jazz and improvised music. As for the logic of 375 ontology, Born and Barry explains that it is referred to “altering existing ways of thinking about the nature of art and science, as well as with transforming the relations between artists and scientists and their objects and publics”. In this sense, the EMusic surely suggests new ways of creating music, stressing the role of improvisation, while making the relationship with scientists essential in this area.

Par. 6 is then subdivided in other two sub paragraph:

6.1. A preliminary feedback

6.2 Future plans

In the preliminary feedback we have extrapolated data from our web channels and social media (EMusic is present in you tube, Spotify, facebook and linkedin,) The analysis was intersected in some cases with the media coverage.

“Concerning the impact of the EMusic on the public at present we can count on some data extrapolated from our web channels as you tube and Spotify. The data can just give indications on the interest aroused and on the liking. We report them knowing that they are purely indicative having never made an advertising campaign, given that such an action requires a budget. On some occasions we received media coverage that contributed to raise the interest of people before and after an event...”

In the par. “Future plans”

We have outlined some ideas on how to conduct future evaluation non only in the case of the heterogeneous audience participating in the show. A project for school, Georisonanze, is on its way, and the evaluation will be conducted following the experience already done for other school projects including art already carried out at INGV.

Response #2

Thanks for the detailed review Bernardo Feldman. Your contribute as musician was really appreciated and gave us the chance to greatly improve the paper. Following your suggestions we have extensively reorganized the manuscript.

You wrote:

No explanation YET as to how exactly the sonification took place. Did the musicians translate the data by providing their own personal interpretation? Were voltages used to assign amplitudes (loudness/dynamics), frequencies (pitch values), lengths of individual sounds to create rhythmic patterns? There is no clarification given to the reader who might not know what sonification exactly is.

We added a detailed paragraph in which we explain in detail the rules of sonification, based on rigorous scientific criteria, so that any musicians who would follow our methodology would achieve the same pitches collected in the same site. Once the pitches are drawn the musicians can work on them in different ways, as explained in the text.

You wrote:

If the intention of the project is to bring awareness to our planet, it really doesn't matter how literal the translation of the data provided by the voltages is. Evidently, as the title of the article clearly states, it is intention to attract people's interest to geoscience while, in the process sensitizing us to planet sustainability. If, in the other hand, the sonification can to be used as a tool to "prevent risks" and assist in the reading of a particular phenomenon occurring at a certain part of our planet, there has to be a consistent array of sounds or textures that could quickly and easily be understood by people, scientists in particular. I would equate these as type of "sonic fingerprints" mentioned in line 145 of the article. I presume that there already many other tools are in place to measure potential earthquakes, eruptions, pollution of aquifers, seawater intrusion along the coastlines, seismic risk, drought and permafrost melting, etc.

We added a paragraph named “Objectives” where we have explained better what we aimed at: we are not interested in any device for preventing risk, but simply to use Music to sensitize people regarding global emergencies. Rather than a single frequency/pitch, we are sure that a cluster of pitches, that can be assigned to a scale and hence to a mood, can arise emotions and curiosity for the listener.

You wrote:

What exactly are they looking to find through these experiments in schools? Are they looking to measure how students respond and get sensitized in regards to planet sustainability? Is it by simply bringing

attention to the subject?

We focus more this in “Objectives” paragraph

You wrote:

Although it is stated that fixed values are used to assign to the various transient’s particular pitches in an objective manner, it is not quite clear how these pitches are arrived at. The analogy comparing it with edges of a color scale does help to assume that gradations have been arrived with a certain logic, most likely translating numerical values into audible frequencies that retain precise intervallic relationships.

The explanations right below help in confirm that amplitudes (louder sounds) will come from the stronger responses and vice versa, and that higher frequencies (pitches) will correspond to stronger responses. Inasmuch as I tried to find a clear correspondence between the pitches given in Figure 3, arrived at as transformations of the voltage’s responses, and the so-called “score” utilized by the saxophonist to interplay with these collected sonified transients. Although there is no explanation as to how the player choose these particular chords as the basis for his improvisation, while listening to the two elements interacting with each other, I found that the performer did utilize pitches that beautifully harmonized and complemented the clusters created within the sonified textures. While crossfading, alternating pitches within the sonification produced a

sense of chromatic movement extending beyond the traditional harmonizations found in “traditional” Western music, and closer to the textures of musicians experimenting with pure intonation and microtonalism.

In “Data sonification” we have reported more details about the sonification rules.

Regarding “Selinunte” we corrected a mistake about the grouping of the pitches (it’s not by 4). Here is the corrected text:

As the saxophonist Marco Guidolotti played during this reversed part of Selinunte piece, the relative score has the form shown in Figure 4 (notice that the pitches are translated into an Eb instrument, while the sonification produced notes in the C-key). The musician chose to fix some chords that can be assigned by grouping the pitches so to get some chords.

Hence, the saxophonist plays the exact pitches derived from the sonification, but starting from the end of the transient in Fig. 3, so that to reproduce the travel from the greatest depths to the surface.

It is important to emphasize that we don’t want to keep the musicians in a cage: they can handle the pitches as they wish, in any order: the most important thing is to remain into the scale and the different moods provided by the local geology.

We have edited our manuscript by considering both of them, but it’s complicated to detail any single modifications. We cannot produce a marked-up version, as we have markedly modified the paper for wide parts, sometimes by completely replacing new sentences.