The Interpretation of Sound on the Basis of the Differentiated Structure of Three-Dimensional Space

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It is shown that the experimental data of sound, obtained by the investigation of H. Fletcher and W. A. Munson [4], can be physically described on the basis of the differentiated structure of three-dimensional space (DSS), showing an analogy to the physical interpretation of the process of human vision. The analysis of the experimental data indicates that the process of hearing at frequencies below 800 Hz depends on the differentiated structure of the space related to air. Furthermore, it has been shown that the existence of sound at frequencies higher than 800 Hz is the result of quantization phenomena of the differentiated space-related state of the air, revealing to be an analogy to the quantum effects of the differentiated structure of space of the quantum-Hall-effect (QHE). The presented results about sound, considered with respect to the findings of the QHE, the Hubble-effect galaxies and the process of seeing, result in the fundamental statement that the human ability of the observation of being refers exclusively to the existence of the differentiated structure of three-dimensional space.

1 Introduction

The discovery of a macroscopic quantization in the field of solid state physics, called quantum-Hall-effect (QHE) or Klitzing-effect [1], which was first experimentally observed by K. von Klitzing in 1980, opened the door to a new interpretation of various physical phenomena, such as the origin of the category time or dynamics in the field of mechanics, or thermodynamics and theory of heat [2], but also to some human-related biological processes [3]. The experimental findings of the QHE provided basic indications of the possibility of the existence of a specific space state, characterized by a division of three-dimensional space into a clearly separated, independent 2-D and 1-D dimensional space, called *Differentiated Structure of Space (DSS)* [2, 3]. This separation is recognizable e.g. by the simultaneous existence of two different forms of electromagnetism, effective not only in the context of MOS transistors, but also in the observation of the Hubble-effect (HE) galaxies, a process that is even reflected in the process of human vision, among other things. As shown in [3], the fundamental investigations into the existence of HE galaxies lead to the physical realization that the vision of humans, and to some extent also of animals, depends on the given DSS-state of space. The fundamental importance of the DSS-space state for humans becomes additionally apparent when we discuss the sound process physically. The experimental data of the investigations of human hearing carried out by H. Fletcher & W. A. Munson in 1933 [4], which show the relationships found between the sound pressure, the sound intensity and the loudness level on the one hand and the sound frequency on the other hand, presented here in Fig. 1, have so far been interpreted as biologically caused effects [5–7]. In contrast, the presented work shows that all the dependencies measured by Fletcher & Munson [4] (except for the conditions at the initial and final frequencies of human sound sensitivity are almost exclusively of physical origin, since, as is shown, they are due solely to the existence of the DSS-state of the air atmosphere.

Based on the data in Fig. 1, it must first be pointed out that for the investigation of sound intensity and sound pressure at the boundary condition of approximately 20° C and a sound velocity of $v_s = 343$ m/s, the frequency of $f_0 = 800$ Hz proves to be a suitable boundary condition, since the physical processes involved in the realization of sound, arising at frequencies $f_x < f_0$, differ considerably from the processes at frequencies $f_x > f_0$. Therefore, we divide the physical analysis of the sound process into Part I and Part II.

2 The analysis of the Part I area of sound

Sound generation and its transmission are based on the properties of air. The air molecules as components of the air, which we may evaluate as an ideal gas in the closest approximation, are mainly subject to the influence of earth gravity. Since these forces can be regarded as constant in wide areas above the earth's surface, there is the special possibility of not paying attention to the gravitational forces when analysing the origin of sound. Following this idea, we can therefore assume that in our case the kinetic energy of the air molecules and their variability can be considered as purely electromagnetic in nature, which, however, as the experimental data show, is causally related to the temperature of the environment, i.e. more precisely, the fundamental electromagnetic energy of the air molecules is indirectly proportional to the ambient temperature, observable especially in the variable value of the speed of sound. This in turn means that the air can be considered a so-called Boltzmann gas, i.e. the electromagnetic energy of the air molecules can be put into a causal

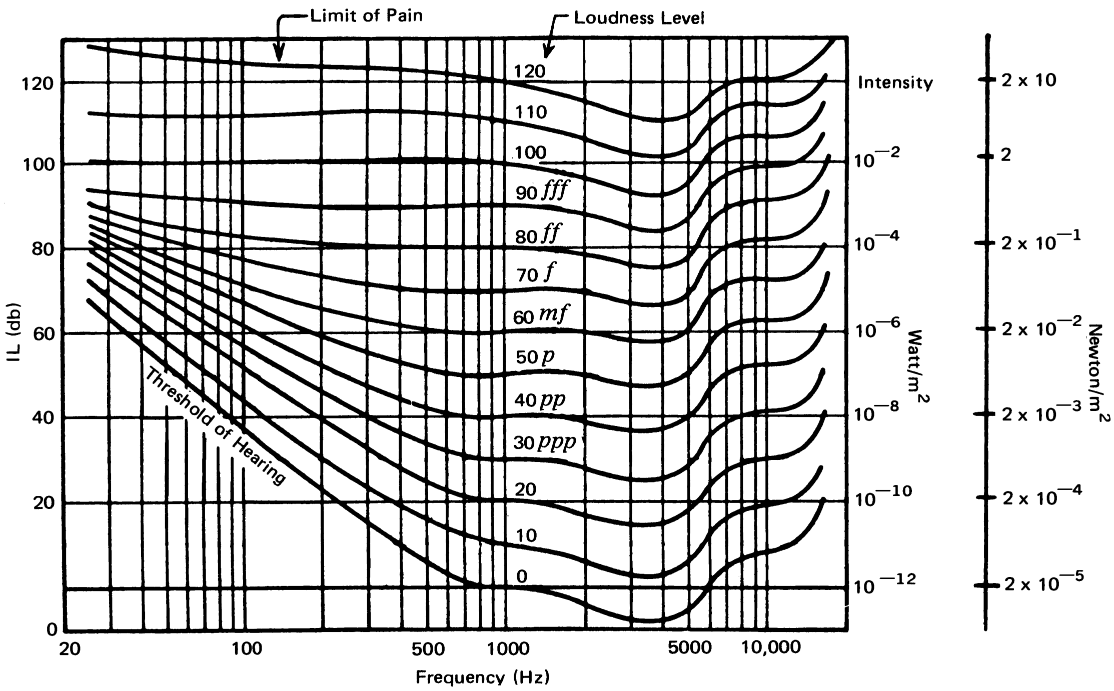

Fig. 1: Curves of equal loudness (Fletcher and Munson [4]). Reprinted from [6] by permission from *Springer Nature* (`https://rd.springer.com/chapter/10.1007/978-1-4615-9981-4_3`). This figure was first published by the *Journal of the Acoustical Society of America* and later adapted and expanded by *Springer Nature*.

relation to the Boltzmann energy kT. Based on these considerations and on the experimental data of the sound investigations of Fletcher & Munson, the following basic equation is formulated for the analysis of sound:

$$\frac{kT}{hf_x} = n_{B,x}\, v_s \frac{p_x}{I_x} = n_{B,x} \frac{E_{p,x}}{E_{I,x}} \,. \tag{1}$$

Here, k is the Boltzmann constant, T the temperature of the environment, h the Planck constant, f_x the given frequency, v_s the speed of sound, p_x the sound pressure, I_x the sound intensity, and $n_{B,x}$ the number of air molecules corresponding to the given frequency in order to reach the so-called hearing threshold, as shown in Fig. 1 [4]. The index x in (1) refers to the given frequency f_x for all quantities. The sound intensity energy $E_{I,x}$ occurring in (1) is given by $E_{I,x} = I_x/f_x$, and the corresponding sound pressure energy by $E_{p,x} = p_x l_x$, taking into account the sound velocity of $l_x f_x = v_s = 343\,\text{m/s}$, l_x represents the so-called sound length.

As can be seen from the definition of a so-called Boltzmann relation of sound presented in (1), this relation at the frequency f_x is given by the relation of the corresponding energies, which in turn can be determined by the indirect proportionality between the sound pressure p_x and the sound intensity I_x. In order to be in accordance with the experimental findings, the energy relation was, as shown in (1), additionally modified by the number of molecules $n_{B,x}$ considered at the given frequency f_x in order to be able to causally represent the variation of the energy relation. The fundamental importance and necessity of the introduction of the number $n_{B,x}$ will be presented in the following analysis, because this number $n_{B,x}$ is not only of decisive importance in the description of the course of the (human) hearing threshold at the frequencies of approximately $20\,\text{Hz} < f_x < 800\,\text{Hz}$, but it is the essential factor that helps to physically fathom the process of sound realization in nature.

In the following it is shown that the special form of the Boltzmann relation equation formulated in (1) can and must be used as a starting point for sound analysis.

3 The relationship between sound and the air-related DSS-condition

The experimental results of Fletcher & Munson [4] are not only fundamental for the description of human hearing, but, as is shown, are generally valid and therefore fundamental [5–7]. In the analysis to interpret the realization and propagation of sound, the following experimentally observed facts must be considered:

1) The sound intensity I_x and the sound pressure p_x are in a mutually causal relationship at any volume (indicated in phon*) and at any observed frequency. Special attention must be paid to the finding which reveals that a constant connection

*The phon is a unit of perceived loudness of pure tones, indicated in Fig. 1 as "Loudness Level".

is given between the square of the sound pressure, i.e. p_x^2, and the sound intensity I_x. This physically conditioned circumstance, which is valid for each sound intensity I_x and for each corresponding sound pressure p_x, namely at each frequency f_x [4], see Fig. 1, can be described by

$$\frac{p_x^2}{I_x} = \text{const.}\,. \tag{2}$$

This means that with an increase in sound intensity I_x (phon strength), the increase in sound pressure p_x must always be smaller than the increase in the associated sound intensity I_x

2) It should also be noted that the curves of equal loudness dependent on f_x, shown in Fig. 1 in phon, do not touch each other, i.e. the intensity distances, independent of the frequency(!), have almost the same values, i.e. the increase of the I_x-phon distances is almost always constant at a given frequency f_x. This important experimental finding indicates that the so-called loudness of the sound refers solely to the sound intensity I_x.

These two experimental findings show that the energy values characteristic of the air molecules, expressed in purely electromagnetic form using $E_{I,x} = I_x/F_x$ and $E_{p,x} = p_x l_x$, can be recorded and expressed in two different ways when sound is observed.

Here are a few remarks: The specific type of the DSS-air-state (Differentiated Space Structure state of air), seen in terms of the boundary conditions of the existence of the Hubble-effect (HE) galaxies [3], is to be sought in the theoretically possible cancellation of the gravitational effect of the Earth as a boundary condition for the emergence of the specific type of the DSS-air-state, described in the beginning of Part I.

The essential consequence of this cancellation is that the variability of the sound-related energies of the air molecules is limited to changes of electromagnetic nature alone. This means that, in contrast to the states observed in the HE galaxies, the molecules of air in the given DSS-state in this case show only purely electromagnetic variable effects, and that within the framework of our common three-dimensional understanding of space, they are separated into a so-called 2-D and a 1-D "space".

The special feature of this insight is that it clearly reveals for the first time that, "spatially" considered, air molecules as energy carriers can be observed in two different forms, i.e. "spatially" differentiated, whereas in our common, i.e. classical understanding of space, on the one hand the $E_{I,x}$-energy refers to the two-dimensionality of this energy, i.e. to the 2-D "space", which is interpreted as intensity energy, and on the other hand the $E_{p,x}$-energy refers to the one-dimensionality, i.e. to the 1-D "space", which is interpreted as pressure energy. However, the possibility of the existence of such a special state is only given if we may consider nature, evaluating in spatial categories, as differentiated, recorded as DSS-state. This specific spatial state was first discussed in 2017 in [2, pp. 33–34, 45, and 49–50], based on the analysis of the experimental findings of the quantum-Hall-effect published in 1980 by K. von Klitzing et al. [1], and its unusual existence was again proven by the analysis of HE galaxies [3]. Seen in this context, the analysis of the Fletcher & Munson data shown in Fig. 1 and its conclusion are of extraordinary importance, because they show that the possibility of sound formation is only given when this specific "differentiated space state", unusual to our daily understanding of space, is given in the air and thus the boundary condition for the formation of sound is real. The correctness of such an unusual model, which was presented on the basis of the specific electromagnetic DSS-state of the air, can be confirmed impressively and convincingly by a further detailed analysis of the experimental data of Fletcher & Munson.

The essential functional significance of the number of molecules $n_{B,x}$ given in (1) at the given intensity I_x is to guarantee the DSS-state of the air in the form of (1) and (2), which physically reflect the limit value of the hearing threshold as equations. This in turn means that, for the experimentally given values of sound intensity I_x and sound pressure p_x, we can use (1) to write the specific magnitude of the value $n_{B,x}$ as a function of the frequency f_x, where we have to define the frequency f_x, normalized in relation to the reference frequency f_0, as the relation $n_{f,x} = f_x/f_0$. And in order to be able to mathematically record the homogeneity of the air in the DSS-state, it is also necessary to define the relation $n_{p,x} = p_x/p_0$, i.e. to set the sound pressure p_x in relation to the standard value of the air pressure p_0 by means of the number $n_{p,x}$. Starting from the limit values $I_0 = 1 \times 10^{-12}\,\text{W/m}^2$ and $p_0 = 2 \times 10^{-5}\,\text{N/m}^2$ given in Fig. 1, for every frequency we then obtain the constant value $(n_{B,x}/n_{f,x}\,n_{p,x}) = 1.122$. The constancy of this value, which captures the homogeneity of the air condition, and above all the small size of this dimensionless value 1.122 suggests the possibility of replacing this value by the number 1, followed by the associated necessity to modify the experimentally given values I_x and p_x accordingly. In order to minimize the change of the value p_x^2/I_x, the validity of which must be maintained, it is sufficient to reduce the value from $I_0 = 1\times10^{-12}\,\text{W/m}^2$ to $I_0 = 0.9\times10^{-12}\,\text{W/m}^2$, while keeping the value $p_0 = 2 \times 10^{-5}\,\text{N/m}^2$. The smallness of the correction of the I_0 value is fully acceptable, as it is within the given measuring accuracy.

If we now try to represent a causal connection of the values $n_{B,x}/n_{f,x}$ to the experimental values $n_{\exp,x} = I_x/I_0$, which are given by the known data of [4], by means of an equation, an extraordinarily meaningful connection, valid for all frequencies $f_x < f_0$ emerges, which can be described by

$$n_{\exp,x} = \left(\frac{n_{B,x}}{n_{f,x}}\right)^2 . \tag{3}$$

Using a simple calculation, it can be shown that (3) is a compellingly necessary causal consequence of the hearing process (1) and (2).

Since in the framework of the DSS-model, the values of $n_{\exp,x}$ readable in Fig. 1 can be unambiguously related to the specific energies of the 2-D space, i.e. to the sound-intensity radiations I_x, but the relation values $n_{B,x}/n_{f,x}$ within the framework of $(n_{B,x}/n_{f,x}\, n_{p,x}) = 1$ can be related to the specific energies of the 1-D space, i.e. with the sound-pressure values p_x, the simple and clear form of (3) proves that every frequency $x < 800$ Hz must be the condition of the differentiated state of space. Furthermore, (3) testifies that this DSS-state is necessary as a boundary condition in order to reach the sound limit by means of the I_x and p_x limit values, i.e. to generate and transmit sound in our environment of the earth's surface.

The number $n_{B,x}$ in (1) is also of great importance for non-physical reasons: As shown, it is necessary for the realization of the DSS-state and thus brings the mental development of man to fruition. The analysis of the sound indirectly shows clearly that the acoustic communication between humans is solely caused by the existence of this DSS-state of the air. In fact, an interesting analogy to the process of seeing and thus to the human perception process in general can be seen, because the process of seeing, as shown in [3] and explained by the existence of specifically suitable uvula and rod cells, is also based on the existence of the DSS-state, as it were, in the field of optics, i.e. light.

4 The analysis of the Part II region of sound and the analogies to the integral and fractional quantum-Hall-effect

On the basis of the sound interpretation model presented in Part I, it is clear that sound mediation at frequencies f_x above the limit value f_0, i.e. at $f_x > f_0$, must be fundamentally different from the process presented in Part I, because once the sound intensity value I_0 is reached, there should be no further normal possibility of reaching the DSS-state for the production of sound. In fact, however, it is observed that initially, with increasing values from f_0 to approximately $f_x = 1300$ Hz, the hearing threshold limit value of I_0, given by approximately 1×10^{-12} W/m^2, remains quasi-constant in order to reach a new minimum in I_x of approximately 2×10^{-13}W/m^2 at $f_x = 3200$ Hz. Afterwards, starting at $f_x = 3200$ Hz, an increase in the hearing threshold limit values I_x is observed with increasing f_x values, followed – which is particularly important – by an indication of a small decrease in the I_x limit values at $f_x = 1.28\times10^4$ Hz. After that, a strong increase of the curves of equal loudness is measured further on with increasing frequency, and to stop at $f_x = 1.6\times10^4$ Hz, at all phon levels. In order to be able to interpret these experimentally observed complex I_x-f_x-dependencies, we have to assume the existence of two different processes which, as we will show, relate to the 2-D space component on the one hand and to the 1-D space component on the other.

One process concerns the interpretation of the minima of I_x at $f_x = 3.2x10^3$ Hz and at $f_x = 1.28\times10^4$ Hz: They can be interpreted as the consequence of an area quantization given in the two-dimensional space part, describable with the quantum number 4 and 16. With this, it is postulated here that – despite the sound limit value of $I_0 = 1\times10^{-12}$ W, as explained in Part I – also at higher frequencies, i.e. at $f_x = 3.2\times10^3$ Hz and $f_x = 1.28\times10^4$ Hz – which is due to this experimentally observable macroscopic 2-D quantization – an air-related DSS-state can be present, which means that in nature it is possible to also generate sound at $f_x > 8\times10^2$ Hz.

An analogous macroscopic quantization related to two-dimensional space, namely the quantization discovered by K. von Klitzing, was renamed in later years to *Integral quantum-Hall-effect* (IQHE), observed at the quantum numbers 2, 4, (6), 8, 12 and 16 [2, 8, 9]. In order to be able to consider the assumed two-dimensional surface quantization for sound as physically acceptable in comparison with IQHE quantization, some additional remarks are necessary: In the IQHE, the magnetic field B is in causal interaction with the electron density N_e, i.e. in the DSS-space model with the 2-D space state. In the so-called Fractional quantum-Hall-effect (FQHE), discovered for the first time by D. C. Tsui et al. at GaAs–$Al_xGa_{(1-x)}As$ heterostructures [10], the magnetic field B_x corresponds to a frequency f_x. This model of the different functioning of the magnetic field, given on the one hand by the IQHE and on the other hand by the FQHE, could actually be indirectly confirmed by targeted measurements within the QHE, as shown in [11, pp. 34–42]. This means that the magnitude of the magnetic field, which is expressed in Tesla units in the MKSA unit system, can also be expressed simply by the quantity "frequency" in the MKS unit system, which makes a possible analogy of the process between the sound effect and the QHE appear possible.

As already mentioned in [3], the QHE state is always present in the DSS-space state. As a consequence, IQHE quantization is to be interpreted as a 2-D space quantization, in contrast to FQHE quantization, which can be interpreted as a 1-D space quantization. This insight leads us to the additional conclusion that the discovery of the length-related harmony theory, which stems from Pythagoras, actually reflects a 1-D space quantization, which is today presented in every musical harmony theory as a consequence of the existence of overtones that always belong to the fundamental tones. But this important insight must be further expanded by the discovery of the existence of deep harmony tones associated with each fundamental tone, recognizable by the existence of the so-called deep combination tones, see [6, p. 38]. It is evident that the existence of these deep harmony tones can be understood as an analogy to the existence of FQHE quantization. This leads to the conclusion, which is important for our analysis, that the unexpected sound generation at frequencies $f_x > 8\times10^2$ Hz according to our model must be a consequence of the existence of 2-D space and 1-D space quantizations associated with the given fundamental tones, a model which is fully consistent with the extensive experimental findings of both the IQHE and the FQHE. In addition, an interesting fact can be seen that the QHE, where the observation of the FQHE was initially completely unexpected, fully reflects this "unexpectedness" when listening to deep harmony tones [6]. The relatively small probability of low combination tones therefore means that a strong increase in the hearing threshold limit values I_x is to be expected with increasing frequency, which, as Fig. 1 shows, was actually observed.

The found sudden stop of sound generation at $f_x = 1.6 \times 10^4$ Hz at all phon values can only be interpreted in such a way that in humans in the cochlea there are no stereocilia for these high frequencies that would process such electromagnetic signals. This means that we can only speak of a physiological effect in this case of the general cessation of sound sensitivity at extremely high frequencies. The same reasoning can be applied to the description of the sudden occurrence of hearing ability observed at all phon levels, which occurs in humans at about 20 Hz. This means that the onset of hearing must be physiological and therefore cannot be attributed to a physical effect. Otherwise, as explained, the sound data of Fig. 1 observed by Fletcher & Munson can be attributed to physical processes, which all, without exception, indicate the existence of an air-related DSS-condition.

5 Summary and conclusion

Based on the analysis of experimental data of the quantum-Hall-effect [1], it was found that in nature, spatially speaking, a specific state can exist, called differentiated structure of three-dimensional space (DSS-state) [2, 3]. Based on this discovery not only a novel description of the category "time" as a consequence of localized, i.e. 1-D related electromagnetism could be presented [2, page 45], but also the background of the existence of the Hubble-effect galaxies as well as the process of human vision based on the DSS-state could be physically described [3]. This visual model, which associates the rod cells with the specific 1-D space state and the uvula cells with the specific 2-D space state, does not differ in any essential point from the process of human hearing based on the process of the DSS-state, as the analysis of the Fletcher & Munson data reveal, revealing also the analogy between the processes of sound generation and those of the quantum Hall effect. Thus, within the DSS-model, the air molecules are the "carriers" of both the 1-D space structures in terms of sound pressure p_x, and the 2-D space structures in terms of sound intensity I_x. The detailed analysis of the Fletcher & Munson data also clearly indicated that the limit of the hearing threshold is determined by the existence of the DSS-air-state. This experimental discovery is a fundamentally important discovery from a physical point of view because it proves that the process of hearing is conditioned by the existence of the DSS-state of the air molecules. Consequently, it can be concluded that the DSS-state as the basis of hearing, but also of seeing, as shown in [3], is the fundamental state that enables human kind to mentally recognize what is happening in nature, i.e. all being. But this also means that the DSS-state is the fundamental physical background which is the starting point for all human evaluations and interpretations of both static and dynamic, i.e. time-related processes in nature [2, 3, 11] and should therefore always be taken into consideration additionally.

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