Sounds from Noise: Negative approaches to structure in Xenakis' music and Quantum field theory.

The twentieth century has seen the uprise and celebration of themes like noise, complexity, indeterminacy. This is true for many disciplines, including science and music. This article investigates the implications of this development for our concept of structure. In particular, in assuming the fruitful applicability of such an investigation across disciplines, the compositional practice of the modern composer Iannis Xenakis is discussed and the resulting concept of "negative structure" applied to the interpretation of the quantum field theoretical vacuum.

1 The embrace of noise

The embrace of noise, or the disordered and complex, is a phenomenon characteristic of the twentieth century, whose origins may be placed at the fin du siècle and reaction against a culture of overly simplifying reductionist practices in the 19th century (Daston and Galison, 2007). Examples of it are abundant across the cultural and scientific spectrum, for example in the paintings of Pollock, music concrete or chaos theory and cybernetics. In 1971 Arnheim (1971, 11) wrote that while entropy, a measure of noisiness, "during the last century still served to diagnose, explain and deplore the degradation of culture, it now provides a positive rationale for "minimal" art and the pleasures of chaos." Two flavors of noise can be distinguished: Firstly, there is the distractive, pejorative noise, the dissonance and manifestation of Nietzsche's Dionysian in art. This is also the industrial noise that is aestheticised and politicised in Russollo's (1916) futurist manifesto "L'arte dei rumori" or the music concrète movement (Hegarty, 2007). For Voegelin (2010, 43), it is the noise that "lives out the traumata of the beginning of the twentieth century". Secondly, there is an overwhelming noise, product of an awareness of the superficiality of order and certainty. This "background noise" has been poetically described by Serres (1995, 13) as

> the ground of our being. . . .[It] never ceases; it is limitless, continuous, unending, unchanging. It has itself no background, no contradictory. . . As soon as a phenomenon appears, it leaves the noise; as soon as a form looms up or pokes through, it reveals itself by veiling noise.

It is this second flavor that lies in the focus of this article, because I believe that it urges a revision of our concept of structure. This can be motivated by a discussion of how background noise figures in Xenakis' compositional practice and quantum field theory.

1.1 Sound from noise

Iannis Xenakis (1922-2001), who originally trained as engineer and had worked in the architectural bureau of Le Corbusier before going into musical composition, is one of the most influential modern composers. Noise, or "ataxy", is a key component of his very formalised approach to musical composition. While this is evidenced by dense tonal dynamics that figure *au font* in many of his compositions (e.g. Bohor, Diamorphoses, Nuits, La légende d'ér), for some pieces the concern with background noise is explicitly traceable by looking at Xenakis' compositional approach.

A prime example for this is Concret PH, conceived for the inauguration of the famous Phillips Pavilion that Xenakis had developed together with Le Corbusier for the EXPO 1958. It was produced by cutting short chunks of tape recordings of cracking coal and burning material and then reassembling these noisy fragments into textures of differing densities. What is important here is the intention behind this technique and the tension between peaks as structural extreme and their collective constitution of disorder:

> Not by chance, then, is the overall form of the piece so simple and static: simplicity at the macro-level allows the listener -and the composer himself - to turn his/her attention to the morphology of the scraps of sound this music is made of, to the shortest processes by which matter is transformed into energy [...H]ere the model of sound material is a mixture of manipulative procedures through which [...] *noise is transformed by learning into a sign* (Di Scipio, 1998, 213, my italics).

Another example, Gendy3, was produced with the GENDYN (génération dynamique) program. GEDYN was written by Xenakis in 1992 in order to produce waveform distortions according to markovian stochastics (Hoffmann, 2000). This procedure served Xenakis to produce genuine noise, defined by him as "a curve with no smoothness at all, and no periodicity" (Xenakis, 1996, 152), i.e. without the successive addition of sine tones to form a noisy spectrum. By applying the algorithm onto previous runs, musical characteristics of a piece emerge only from random processes at the bottom level (Di Scipio, 1998, 226).

What is important to notice in both these pieces, is how the notion of a background noise has replaced that of a background silence, a tabula rasa or vacuum, on top of which things happen. An important consequence of this substitution is that structure, or order, is understood as the divergence from noise. In other words, structure here becomes a negative quality, something that is characterised by what it is *not* rather than the other way around. Thus, in his analysis of Xenakis' compositional techniques, Di Scipio (1998, 237) concludes:

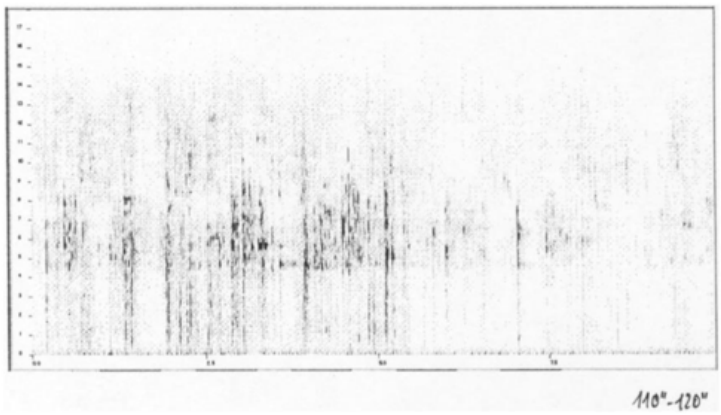

Fig. 2.1: Loudness vs. time for an excerpt (110"-120") in Xenakis' Concret PH. Source: (Di Scipio, 1998)

> His work reflects a world no longer describable in terms of the order-from-order principle [...] but a world animated by the order-from-disorder principle, a world where things are incessantly put in order, warding off the ever-deeper abyss of entropic disorder.

It is exactly this negativity that Serres alludes to when he says that an appearing phenomenon "reveals itself by veiling noise". Of course, such language may awake suspicions of it as an act of sophistry: Surely, every negative statement can be expressed in its logically equivalent positive form. Therefore, no genuine difference should follow from substituting the blank canvas with the Pollock, one might say. In the next sections, the possibility of such a genuine difference, and its locus, will be discussed.

2 Negative structure

To do so, one first needs to distinguish two independent kinds of background noises at play in Xenakis: Noise by virtue of complete unpredictability and noise as a form of total saturation. For example, in Concret PH, the former noise is given by the complete uncertainty as to whether the next moment will contain a click or not (Fig. 2.1), while the latter noise corresponds to the fact that every single "slice of sound" will contain the whole spectrum of frequencies with more or less equal amplitude (Fig. 2.2). To appreciate this distinction, the information theoretic concept of (Shannon) entropy is very useful. Being formally defined as

$$H(A) = -\sum_{a} p_a \log_2(p_a)$$

for some variable A with outcomes a and respective probability p_a, it is a measure of the global uncertainty about the state of a system (being closely related

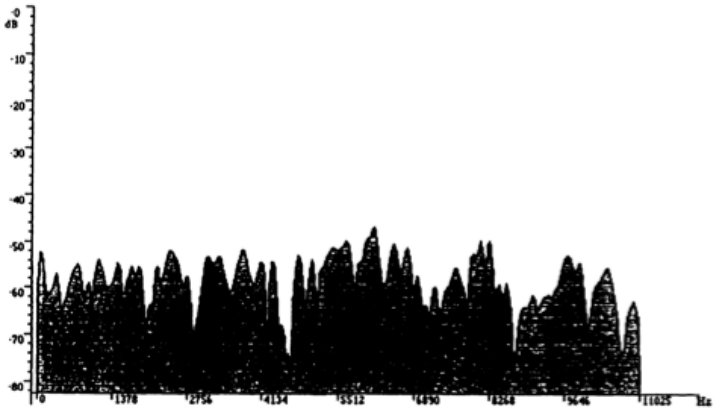

Fig. 2.2: Amplitude vs. Frequency for a single slice of sound in Concret PH. Although different parameters are mapped, the similarity and noisiness of the figures is evident. Source: (Di Scipio, 1998)

to the thermodynamic entropy). As can be seen from the formal definition, the entropy of a system will be maximal, if all p_a are the same, i.e. when there is no good reason to believe that one thing will be the case rather than another. What entropy is entirely insensitive to, are the specific outcomes and their properties, for example noisiness. Thus the first noise is an entropic noise, since it is concerned with the global uncertainty in the dynamics of a system, while the second noise is that of a single slice of a state.

Concerning the entropic noise, skepticism regarding the novelty of understanding structure negatively is justified. The reason for this a clear epistemological symmetry between noise and silence in that they are equally redundant as a means of conveying knowledge (as a form of information): If somebody was to guess a visual structure, sending either a blank canvas or a completely noisy picture would equally constitute completely pointless "hints". Therefore, negative structures contain just as much information as their positive counterparts.

However, for the second background noise, there is a clear asymmetry. This noise differs from the entropic noise in making a statement about the world in a single state. What is special about a noisy state is that it saturates: It is the actualisation of possible being in every degree of freedom of a system. As such, Arnheim (1966, 125) describes noise or disorder "not as the absence of all order but rather the clash of uncoordinated orders". Because such a clash cannot possibly exhibit them, structures become negatively defined because they are given by which degrees of freedom are *not* realised. The crucial difference to positive structures here is that negative structures result from interaction with noise. Xenakis (1992, 94, my italics) thematises this in his opus magnum, "Formalized music", where he says that the intrinsic value of a structured system

> lies in the fact that it must manifest itself, be. The perturbations

> which apparently change its structure represent so many negations of this existence. And if we create a succession of perturbations or negations, on the one hand, and stationary states or existences on the other, we are only affirming mechanism Z. In other words, [...] *we confirm it negatively by opposing it with perturbative states.*

The perturbations that Xenakis alludes to, clearly reflect a characteristic of background noise. Thus, structure can be understood as an effect of a system's resilience to the dissolution by its environment and invariant over external perturbations. An equivalent account of structure obviously cannot be made by a positive account, where the structure is the only thing that there is. The moment of repetition that drives this approach also explains why this asymmetry is not present in entropic noise: Information theory is insensitive to the fact that "the effect and meaning of the single unit varies with the number of its repetitions" (Arnheim, 1971, 17). This account of structure also implies an important change in perspective as to what structure tells us: Given the second law of thermodynamics, which states that the global entropy never decreases over change, all interactions of a structure with its environment imply an increase of the structure-environment system and, thus, effectively work towards the dissolution of the structure, its death. "The repetition of an event, its reproduction as faithfully as possible, corresponds to this struggle against disappearance [...] As if the entire universe fought desperately to hang onto existence, to being, by its own tireless renewal at every instant" (Xenakis, 1992, 267). By describing structure relative to its inevitable decay, we change the focus of our description: Structure becomes an expression of the success of Maxwell's demons, who work against the second law by putting things in order. This matches well with Xenakis' interest for and application of self-organising structures such as cellular automata (Hoffmann, 2010; Solomos, 2005) or "relative automata" (Xenakis, 1985, 68) such as the fugue: Their structure is the result of their capacity to produce resilience to environmental decay more or less autonomously.

3 Lessons for physics

As was stated earlier, background noise appears in physics as well. Prominently it arises in quantum field theory from Heisenberg's notorious uncertainty principle. This principle, in generalised form, states that the product of the statistical uncertainties of measuring certain pairs of observable properties on a system can never be zero. Relevant here is that energy and time are two such "incompatible" observables: Their uncertainties obey an anti-proportional relationship. But this implies that a system can "borrow" an increasing amount of energy if the time uncertainty is only short enough. This has fundamental consequences for a quantised field theory in that it means that particle-antiparticle pairs can be produced as manifestations of the borrowed energy as long as they vanish within the time uncertainty (Barrow, 2000, 215-41). The recognition of this possibility for spontaneous particle pair production has fundamentally changed our idea of the universe at the Planck scale: What seemed to be a vacuum is

now an overwhelming pool of particles that incessantly come into existence and vanish. These dynamics are actually maximally entropic in that it is impossible to predict whether a certain sample of space-time contains particles or not at any time. Importantly, although most of these particles are treated by physicists as "virtual", they can produce effects, such as Hawking radiation, where one particle of the created pair is swallowed by the black hole, or the Casimir effect (Rafelski and Müller, 2006).

Given the discussion above, the obvious question to ask is: Can the structures of the quantum field vacuum be understood negatively as well? A first step to answering the question is to see whether the negative approach can evade Ockham's razor: This is because background noise arguably is ontologically more involved than background silence. But given the self-imposed ontological parsimony of science, unless a "negative" quantum vacuum scores higher than its counterpart in some respect, it represents an unnecessary metaphysical commitment. In favor of this line one can invoke the information theoretic symmetry between noise and silence discussed above. However, two candidates for higher scoring can be suggested: First of all, negative accounts of structures make statistical fluctuations in the form of particle-pair creations possible to explain with the noisy perturbations that produce them. For positive structures, such an explanation almost necessarily requires some kind of problematic "intrinsic properties"-account. Furthermore, a procrastination of such problems to the "hidden variable-perturbations level", in the negative approach, need not be the case, since the properties of a system may arise from the relationship *between* the levels of perturbation and emergent structure, an option unavailable to positive accounts. Secondly, the negative approach may be regarded as highly economical in that its laws need specify only what may not be the case. They are of the form "Everything is possible except..." as opposed to "Nothing is possible except..." While for a finite number of global possibilities statements of the above forms are logically interchangeable, the negative approach recognises the possibility of the infinity of possibilities, or at least avoids the unnecessary risk of assuming its finiteness. This applies, of course, to the quantum vacuum, where already all particle processes are allowed as long as they obey simple quantum number conservation rules (baryon number, CPT symmetry, etc.) (Redhead, 2002).

4 Conclusion

In wrapping up, the (ongoing) rise and embrace of noise into culture and science over the past century was shown to come in many shades that can, to a certain extent, be differentiated and treated independently. The use of one such shade, an all-saturating background noise, in the work of Iannis Xenakis suggested a revision of structures not positively, as a given, but instead negatively, as the result of an ongoing and dynamic interaction between multiple and complex entropic perturbations. This negative approach to structure already yielded an interesting view of the quantum theoretical vacuum and, I believe, promises to

be fruitfully applicable to other fields in both science and art.

word count: 2497

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