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ORDER: GOD'S, MAN'S AND NATURE'S

Order, Disorder, Noise[1]

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Prologue

A few years ago an interesting exhibition took place in Cambridge (and London) under the title 'N01SE'.[2] The title recalls of course the word 'noise' but written as 'N01SE' it also refers to the binary code (with the two numbers 0 and 1) which is the basic language of calculators - from the simplest to the most sophisticated, (eg. contemporary computers).

The title of this exhibition could then be read in two ways. On one side, by playing with the word 'noise/n01se', we are presented with the idea that there might be a core of information in any situation of noise, provided that there is a context, an interpretation, a point of view which allows us to identify such information and to decode it. On the other side, we are prompted to reflect critically on the assumptions and goals of the revolutionary field of contemporary digital technologies, whose promise is indeed that of a complete removal of any sort of noise. Is such a promise achievable? At what costs? Should noise, any form of noise, be removed? Is noise inevitably the dark side of any form of information? Is it the opposite of order? Are there contexts in which we can value its presence? Can noise turn into its purported opposite?

Attendance at the Cambridge exhibition is what originally prompted some of the thoughts and ideas I explore in this paper.

Preliminary thoughts: what is 'noise'?

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[1] A version of this paper was presented at the VIII International Symposium on 'Disorder Systems: Theory and its Applications', Karaburun, Izmir (Turkey), September 2008. I am grateful to the participants in the symposium for their useful comments. I am also grateful to Nancy Cartwright for reading drafts of this paper, to Jordi Cat for some advice on literature sources, to Adam Spray for assistance with picture reproduction, and to the Templeton Foundation for sponsoring research time to write the present version.

[2] For an online catalogue of the exhibition see: http://www.kettlesyard.co.uk/noise/

The term noise covers a rather diffuse and for certain aspects ambiguous field of meaning. In the dictionary we find a large range of synonyms, from the more specific (outcry, hubbub, clamour, protest) to the more general (disturbance, interference). Noise is what a tumultuous crowd produces, or more cheerfully, what a group of students on holiday makes, or a flock of migrating birds: in all these cases, noise is something that others make and that we unwillingly suffer, something that we perceive as an invasion of, or an interference with, our perceptual space.[3] A loud conversation or loud laughter are 'noisy', if we are reading a philosophy article or we are performing a physics experiment or we are concentrating on a yoga exercise.
Noise is associated with an idea of impediment, or obstacle – an element of distraction that prevents us from accomplishing the very task we are focussing on.

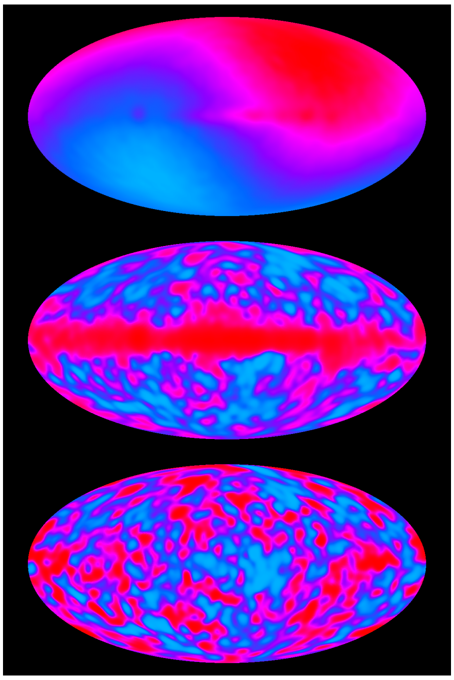
The negative connotation of the term noise more specifically relates to an idea of indistinct 'rumour'. Indeed, the first domain we associate noise with (though as we will see shortly, it is not the only one) is that of sound – or better, excess of sound. Via this route noise appears mainly as a source of disorder, or an impediment to order or, even more, the opposite to order. There is no structure in noise, no recognizable information or pattern, no meaning: it is just fuzzy interference. Noise is precisely what, for example, digital technologies try to keep at bay.[4] Digital technologies are all about purity, stability, perfection, orderly structure. In the field of music reproduction, the promise made by the latest technologies is to offer absolutely intact sound: no scratches, no static, no noise ('Perfect sound forever' a Sony publicity recites). Most importantly, these technologies promise no decay. In Bangladesh religious manuscripts disintegrate, victim of insects and humidity. If we could only record them in digital form, they would be immune from rotting.

[3] Noise is a legally recognized form of pollution or of public nuisance, and as such is addressed by various parts of common law.
[4] Some of the examples and illustrations in this introduction, and further on in the paper, are taken from the catalogue of the 'N01SE' exhibition.

The underlying recipe for the execution of these technologies is relatively simple:

- complex and convoluted strings of sound or of image are decomposed in discrete units
- the units are repackaged in such a way that transport of information is made easy
- the units are finally recomposed in 'cleaned up' versions, much better and purer than the original ones.

Digital technology goes then even beyond expectations: it does not simply produce a perfect reproduction of an original (this was the old concept of 'high fidelity'). It actually produces a better version of it (a digitalised version).



A map of the whole sky captured by the Cosmic Background Explorer (COBE).
(http://lambda.gsfc.nasa.gov/product/cobe/cobe_images/phys_today_cover_big.gif)

Ryan’s Eye is about 100 atoms wide and was recorded on a grain of salt by Tom Van Sant using an ultra small focused electron beam. (http://www.tomvansant.com/id17.html)

It is in this way that pure ‘digitality’ achieves perfection: it separates sound (signal) from the natural process which brings it into existence – a process full of interference, potential corruption, noise. A process of construction is the opposite of perfection. God is perfect because He creates without being created. Asking questions about how something has come into being is, in some sense, acknowledging its lack of perfection.

Still, this does not mean that digital (re)production is absolutely free from discrepancy or irrelevant signals. In fact, pure digitality is never really achieved. However, one of the extraordinary aspects of digital circuits is their capacity for containment. They are able to control discrepancies in order to prevent that they propagate themselves. The memory in our laptop is refreshed at least 60 times per second, in order to avoid the information packed in our machines sharing the same destiny of the religious manuscripts in Bangladesh. When a signal becomes a possible source of disturbance, the signal is reconfigured, cleaned up, and reintroduced in the system – while maintaining the digital illusion that nothing has happened behind the scenes.

Is noise then only a negative, interfering residue to be eliminated any time it appears? Is the elimination of noise a most relevant way to achieve or preserve order, and to keep potential sources of disorder at bay? There are at least two issues we should reflect on before attempting to answer these

questions, in view of possibly giving noise a different, not necessarily negative, connotation.

Purportedly beneficial effects

Noise is not only associated with sound. It is a widespread phenomenon in nature – in fact, more widespread than we might expect. If we take noise to stand for any form of interference on a signal or information, we find it in different forms in different types of systems: biological cells, quantum measurements and information, non-equilibrium systems, the stock market, etc. Interestingly, by looking at the effect that noise has on these different systems, we do not necessarily infer that noise is a source of disorder, an undesired interference on the intended operations. For example, in biology noise is important in that cells not only seem to perform their several tasks in noisy environments (to the point that it has been suggested that biological systems might have evolved to perform at their best precisely because they are confronted by levels of 'external' noise), but also they possess degrees of 'intrinsic' noise; that is, differential amounts of thermal fluctuation which are inherent to the cell system itself. Noise might then fulfil a beneficial function when it is discovered to be one of the intrinsic features of an organic system.[5] An idea which has been claimed to contribute to changing our perception of noise is that of *stochastic resonance*, that is the observation that when random noise is added to a system, the system reacts as a consequence with a change in its behaviour. The change is for the better rather than the worse, namely the quality of, say, a signal's transmission or of a system's performance increases rather than decreases (as we would expect, should noise be only a factor of interference).

The idea of stochastic resonance was first put forward in the 1980s by some climatologists to account for the occurrence of ice ages. [6] Interest in the

[5] Marchesoni, F. (2009) 'Order out of Noise', *Physics*, 2, 23

[6] Here is how Marchesoni describes the explanation in question: 'Thirty years ago climatologists asked their physicist friends to explain the almost periodic occurrence of the ice ages, or how a small change of one parameter out of many in the earth orbit around the sun can cause a shift of the climate as dramatic as the ice ages. (…) the physicists' puzzling response was thought-provoking. Climate supports two stable states, one at a lower temperature (an ice age) and one at a higher temperature (…); fluctuations attributable to geodynamical events can cause random transitions between the two states. The external small, periodic modulations of the earth orbit bias the random transitions towards times where

positive effects of noise in physical systems is, however, much older than this idea. It is claimed, for example, that noise plays a crucial role in Einstein's belief in the existence of atoms.

In 1905 a young Einstein published a number of papers in which he further developed a statistical molecular-kinetic theory of heat as already presented in his doctoral dissertation, and which he then applied to liquids in another series of papers published between 1906 and 1908. In the latter he claimed that so-called Brownian motion was caused by the irregular thermal movement of the molecules of the liquid.[7]

In 1828 the botanist Robert Brown had observed how tiny bits of pollen suspended in water move in an incessantly irregular, jiggling way. However he did not know how to explain what caused this movement. Einstein was able to predict that if the molecules and atoms of water (or more generally of a liquid) would irregularly collide with larger particles, a resulting random motion (the motion noticed by Brown) could be observed under a microscope. In such a way he was able not only to explain Brownian motion but also to support the view of the existence of molecules and atoms – a highly debated and disputed view in his days (a notable sceptic was Mach, and for a while Planck). The pollen grains were not bouncing around out of their own steam. Their observable movement was caused by their collision with unobservable molecules and atoms collectively and randomly impacting on the grains with random strength and from random directions in every instant of time.
Most importantly for us, Einstein showed that what keeps individual molecules in a state of constant agitation is their thermal energy. He then described

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such transitions are most likely. If the fluctuations are too small, the transition occur too infrequently and out of tune with a given modulation of the earth orbit; if the fluctuations are too large, the random transitions would be too frequent and, therefore, also out of tune. Hence, at an optimal amplitude of the fluctuation, depending on the modulation frequency, periodic transitions can be driven by random noise, a phenomenon known as stochastic resonance.' Marchesoni, F. (2009), 'Order out of Noise', *Physics*, 2, 23. See also Gammaitoni, L.- Hanggi, P.-Jung, P.- Marchesoni, F., (2009), 'Stochastic Resonance: A remarkable idea that changed our perception of noise', *Eur.Phys. J. B*., 69. Although the explanation above was not supported by subsequent data, the idea of stochastic resonance continued to develop and to gain recognition in other fields of research.

[7] Cassidy, D. (1995), *Einstein and Our World*, Humanities Press; reissued Amherst, NY: Humanity Books, 1998.

Brownian motion as the "white noise"[8] of random molecular movements due to heat. What we now call 'Gaussian White Noise' is then the very same noise that causes Brownian motion. Thermal noise acts here constructively: it sustains a form of fluctuating movement in nature and, as an explanation of such a movement, it can be used to model such a movement as a random process.

Einstein can then be put on an ideal list of seminal work on noise, which would also include Maxwell, Boltzman, Planck, Langevin, Bachelier, Johnson and Nyquist, Wiener… all the way to contemporary researchers on 'quantum noise'.[9] The fact that semiconductors produce inherent noise, the fact that the bandwidth of light in lasers is due to fluctuations or noise, the fact that a vacuum is never empty but always fluctuating (and therefore a random process), all this and more identifies noise as an important phenomenon to investigate, and quantum physics or quantum optics have become crucial areas for the understanding of its nature and functions.

One further mention to two 'applications' of noise is in order. In electrical engineering, the vacuum tube was crucial in developing the technology of radio, television, radar and computers, among others.[10] Vacuum tubes, like all electronic and electrical devices, produce random noise, so studying the forms that this noise takes was a way to understand how these devices work and how they could be improved. Vacuum tubes, for example, produce thermal noise, but also what is known as flicker noise (a noise which decreases with frequency) and separation noise (which occurs when some current 'chooses' to follow the path of the screen grid rather than that of the plate, producing a slight random variation in the plate current).

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[8] White noise is, literally, a type of noise made up of a combination of sounds at all frequencies with equal intensity. It is called 'white' in analogy with white light, which is also a combination of all different colors (frequencies) put together.

[9] See Cohen, L. (2005), 'The History of Noise', *IEEE Signal Processing Magazine*, 20. Of course in an ideal list of purported 'noise studies' we could not omit the mathematician and engineer Claude Shannon, considered to be the father of information theory. His name is attached to research on the relation between noise and bandwidth in communication channels, and on information transfer rate.

[10] A typical example of a vacuum tube is the electric light bulb. Current passing through the filament heats it up so that it gives off electrons. These, being negatively charged, are attracted to the positive plate. A grid of wires between the filament (or cathode) and the plate is negative, which repels the electrons and hence controls the current of the plate. Harper, J. (2003),' "Tube201" - How Vacuum Tubes Really Work', http://www.john-a-harper.com/tubes201/

In physics the device known as 'matched filter' was invented during the Second World War by Van Vleck and Middleton as a way to detect possible signals in a background of noise. The underlying idea of this device was to correlate a known signal with an unknown one in an attempt to detect a similarly known signal in the unknown one. Studying the types of noise which can be added in order of disguising a signal is part and parcel of this technique.[11]

So, against the background just discussed, a first issue to reflect on is that noise – either intrinsic to natural systems or artificially/intentionally injected or created – might have a constructive and/or heuristic role in bringing forward the underlying features or principle(s) of order in the systems under study. In biology, as well as physics, noise not only is able to enhance (or initiate) existing processes, but it can itself produce ordered states, for example the emergence of patterns in natural systems (eg thermal fluctuations), similar to, say, crystal growth, honeycomb manufacture and floret evolution.[12]

If we are allowed a short digression, this role of noise can be further spelled out by looking at it from a methodological point of view – moving then from 'real' noise' in physical or biological systems to 'functional' noise, using some philosophy of science for guidance. When we think of a scientific theory, or of a scientific law, we usually think of a type of device or construct which provides a picture of some state of nature, or of a correlation, or mechanism, in nature. Such a picture seems necessarily to exclude a whole series of factors which – were to be included – would impede the good functioning of the relations stated by the picture itself. There is a good deal of idealisation

[11] J. H. Van Vleck and D. A. Middleton (1946), "Theoretical comparison of the visual, aural, and meter reception of pulsed signals in the presence of noise", *J. Appl. Phys*., vol. 17. Also, Middleton, D. (1996), *An Introduction to Statistical Communication Theory*, Piscataway NJ.: IEEE Press; North, D. O. (1943), "An analysis of the factors which determine signal/noise discrimination in pulsed carrier systems," *RCA Labs*., Princeton, NJ, Rep. PTR-6C.

[12] Shinbrot, T. and Muzzio, F.J. (2001), 'Noise to order', *Nature* 410, p.251, also for further interesting examples of patterns generated from noise, eg. in the fast growing areas of granular physics and phase separation. In the context of a discussion of order out of noise, Shinbrot and Muzzio also raise as an open, final question, what to make of the causal relations which result in orderly patterns, a question which they describe as having a possible religious significance. In their own words: 'are the patterns that constitute life itself possible through only random influences, or was a deterministic, intelligent intervention involved?' Ibidem, p. 257.

going on in theories and scientific laws, which obtains by adopting a strategy of *ceteris paribus* conditions, or more generally of assumptions to the effect that no factors can affect the event as described by that sentence other than those specified in a certain theoretical or lawlike sentence. For example, at a purely theoretical level nothing excludes the possibility that two bar magnets suspended by fine threads close to each other at the same level will not arrange themselves in a straight line. Indeed, in case a strong magnetic field of suitable direction should suddenly appear, then the bars would orient themselves so as to be parallel to each other. This means, on one side, that the theory of magnetism does not by itself guarantee the absence of disturbing factors; on the other side, that such an absence is somehow always presupposed by the theory.[13]

So, the conditions which are intended to preserve the features of idealization in theories or laws (which in their turn guarantee the good functioning of a theory or a law) function like 'screens', fencing off everything which might come to interfere with the accomplishment of a stated correlation, or an inference. What the screens fence off is, in our terminology, 'noise'. However, if we were to stop here, we would simply be acknowledging a negative side of noise (noise is the sum of the disturbing factors of a theory, and as such we must ensure to keep it at bay). Nonetheless, by acknowledging a necessary methodological function to the likes of *ceteris paribus* conditions, we make a further claim about the 'noise' of a theory, or of a law: namely that nothing can be meaningfully affirmed by a theory or a law if we do not take into due account all the conditions and restrictions entailed by the claims made by a theory or a law. This is another way of saying that the 'noise' surrounding a theory or a law is in some ways part and parcel with how the theory itself fulfils its role and function (eg. how it achieves its explanatory/predictive results) – in a way perhaps analogous to how in a physical system a noisy environment is functional to the appearance of the system itself.

[13] The literature on *ceteris paribus* laws is vast. An early contribution in this domain can be found in Hempel, G.C. (1988), 'Provisos: A problem Concerning the Inferential function of Scientific Theories', *Erkenntnis*, 28 (although Hempel denies that provisos are just like *ceteris paribus* conditions).

In more general terms, a principle of order, or the recognition of a pattern or of a structure can indeed only make sense on the basis of a background of exclusion of interfering factors; but also, and conversely, what is excluded as potential 'noise' becomes a necessary condition for the achievement of a sought after order.

Is noise necessarily bad (no) news?

There is a second positive issue to consider regarding noise, namely that with noise we are not simply or necessarily dealing with an undifferentiated 'rumour' – the opposite of well-ordered information. To use a mundane example, a conversation is not by itself noise. It becomes so whenever it interferes with another activity with which it clashes. What is 'noise' for us is a conversation for the person conversing.[14] So noise has *a contextual meaning.* It is relative to particular circumstances, subject to specific conditions of evaluation.

In fact it is interesting to see how in the English language of five centuries ago 'noise' meant 'news', as in 'I heard a noise', which is stronger than the contemporary expression 'I heard a rumour'. 'Rumour' stands for a not yet verified type of information, which at the very end might turn out to be untrue, and therefore not a piece of information at all. In the late middle ages, 'noise' was instead associated with a specifically informative content: this is how the word was used in common discourse.

By being contextual, noise is not recognised as such by everybody indiscriminately. This is true not only in ordinary discourse, but also in more specific fields of communication. As it has been noticed, 'Uncovering mysteries of natural phenomena that were formerly someone else's "noise" is a recurring theme in science.'[15] In other words, what one scientist might take to be irrelevant information might well become a source of knowledge for somebody else, or upon entering a different research project. This, philosophically, prompts at least two thoughts.

[14] A strong magnetic field is 'noise' only by reference to two bar magnets suspended by fine threads close to each other at the same level by preventing them to arrange themselves in a straight line.

[15] Bedard, A. jr., Georges, T. (2000), 'Atmospheric Infrasound', *Physics Today*, v.52, n.3 March.

On one side, it pushes us towards acknowledging that there is an interpretative aspect in any empirical observation. Seeing a system, a principle of order, or some meaning within and beyond what we observe depends largely on our capacity, partly psychological and partly epistemological, of discovering, of assembling, or attributing some cohesive form to what occupies our perceptual fields. This is known as 'pattern recognition'. On the other side, it prompts us to acknowledge the changeable dimension of so called observational data. Facts as observed often change their evidential role or their empirical relevance depending on what/how we observe, and what for we observe them; and what we observe changes depending on the circumstances – practical, theoretical, descriptive, or historical – of the type of research we are conducting. Both meanings enter and mingle in what came to be once famously called the thesis of 'theory-ladeness': seeing something is *seeing that* something is the case; and seeing that something is the case crucially depends on our views, theories, evaluations, niches of evidence, etc. [16]

To apply this type of reasoning to our topic, seeing noise instead of order (or vice versa) follows a similar strategy of pattern recognition: seeing order (or seeing that something is an orderly pattern) entails being able to extract it from a background, selecting features and separating out aspects which we interpret as being functional and relevant to the structure we aim to recognize, single out, or bring forward. There is an element of construction (or reconstruction) in any factual discovery.[17] In the reminder of this paper I want to substantiate the view that there is more to noise than bad news and distorting effects. I will shift in between examples of physical noise and what these examples might suggest an idea of noise stands for (its meaning, connotations, or use as an explanatory/descriptive tool). By treading a line from one sense to the other I will try to show how and in what ways noise, after all, might be the not so dark face of order.

The curious story of Wilson's 'cloud chamber'

[16] Holding such a view does not necessarily involve a radical step into relativism, but this is not a story to unravel here.

[17] This, again, does not imply that any scientific discovery is 'just' a construction (in the derogatory sense of being fictional).

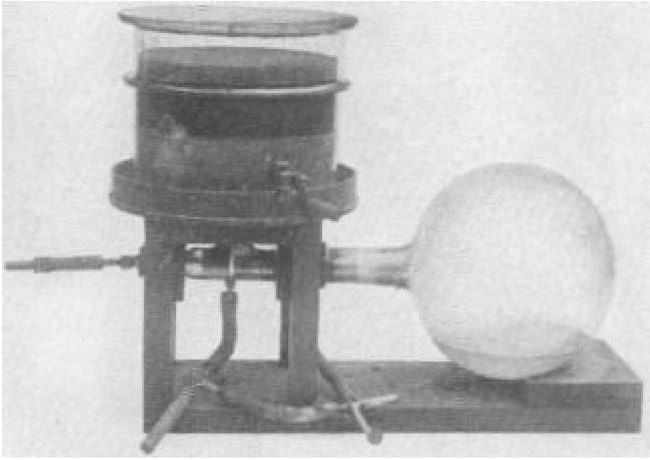
Here is how this story is recounted by Peter Galison.[18]

If one asks any physicist in the 20th century “what is a ‘cloud chamber’?”, they would describe it as the first particle detector, that instrument which for the first time made it possible to ‘see’ the interaction of elementary particles. The chamber creates a phenomenon of condensation in the form of traces of fog, and these traces condensate precisely along the trajectories of the ionised atoms of the particles responsible for condensation. By doing this, the chamber revealed positrons and meons to Carl Anderson, and was used by John Cockcroft and Ernest Walton to demonstrate the existence of nuclear transmutation. The machine was also used as a prototype for other particle detectors, such as the nuclear emulsion stack or the bubble chamber.

Scientists realized almost immediately the importance of the cloud chamber for modern physics. Lord Rutherford took it to be the most original and wonderful instrument in scientific history.

Curiously enough, though, its inventor C. T. R. Wilson was not at all a particle physicist. Looking at his early studies in 1895, to which he returned towards the end of his career, Wilson was attracted by meteorological phenomena. The cloud chamber was invented by him not as an instrument of discovery in the field of transcendental physics (as in those days analytic research into the basic structure of matter was sometimes called). It was invented to study more mundane, yet not less complex, phenomena such as clouds, fog and rain. Wilson was interested in understanding the principle of condensation which lies behind these phenomena, and the best way to do this was to try to recreate artificially, in a lab-type situation, the effects of condensation.

[18] What follows is a very simplified version of the complex story of Wilson’s cloud chamber as recounted in Galison, P. (1997), *Image and Logic, A Material Culture of Microphysics*, University of Chicago Press; ch. 2 ‘Cloud Chambers: The Peculiar Genius of British Physics’. Its significance and relevance in terms of a history of noise is not Galison’s.



Wilson's 1911 Cloud Chamber. (http://www.lateralscience.co.uk/cloud/)

This fascination for natural phenomena of the type that caught Wilson's imagination was not unusual in Wilson's times. The Victorian period was besotted by nature's most dramatic performances. It was the period of the great explorers, who ventured themselves into the most remote corners of the world and witnessed the most extraordinary natural phenomena. It was also the period in which poets and painters celebrated the power of nature (tempests, storms).

As a matter of fact, there was a double attitude towards nature, displayed by scientists and artists alike: a 'rationalizing' attitude, which emphasized order; and a more 'spiritual' attitude, which would explore the mysterious and unpredictable forces possessed by nature. Within the sciences themselves, this double attitude was mirrored in a split between the more abstract, nomological and mechanistic sciences such as physics, and the more naturalistic, historical approach displayed by disciplines such as meteorology, hydrology, oceanography and physical geography. Pushed by the desire to understand how real natural phenomena occurred, scientists who were engaged in the latter disciplines increasingly resorted to experiments in order to reproduce miniature natural occurrences of phenomena such as glaciers or tornadoes.[19] This also accounts for the Victorian passion for photography as a means to capture and reproduce the

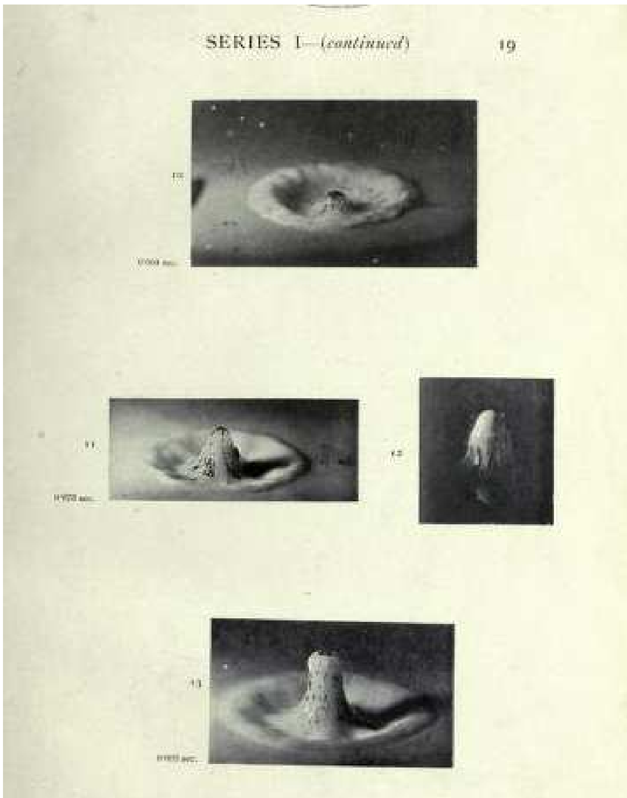
[19] This is the so-called tradition of 'mimetic experimentation', that is 'the attempt to reproduce natural physical phenomena, with all their complexity, in the laboratory.' Galison, ibidem, pp.74-75.

dramatic forces of nature – weather being one of the most powerful vehicles for such an expression.[20]

Wilson belonged to the latter tradition. His early interest was in thermodynamic instability (the fundamental feature of cloud condensation). This, joined with his fascination for Scotland and Scottish mountains, where it was easy to witness dramatic nature at its best, led him to spend time at the observatory at the top of Ben Nevis and consolidated his desire to mimic some of the phenomena that he saw (and photographed) from that vantage point. Indeed he set his mind to performing experiments which could reproduce clouds and fog in view of calculating the measure of expansion for the phenomenon of condensation. It was this interest that eventually made him focus on the data to collect, and on the way he constructed and used his instrument.[21]

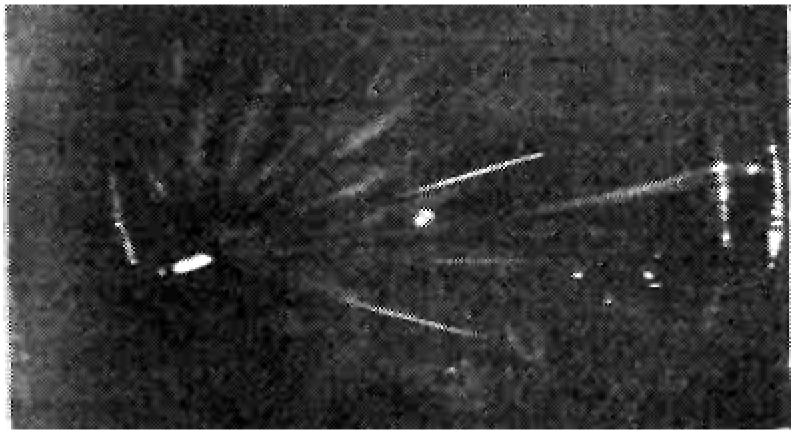
However, soon enough it became clear that condensation alone was not sufficient to produce real rain. So Wilson's interest shifted onto the process supposedly responsible for the formation of rain drops, and his efforts were directed to trying to see how drops took shape. It was during these attempts that he came across some extraordinary high velocity pictures, taken by Warthington and Cole, of drops falling on liquid surfaces.[22] It was this photographic technique that provided him with an essential clue as to how to reveal the basic processes involved in condensation. By taking pictures of the artificial clouds produced by his machine Wilson discovered that they hid a whole range of traces: these, he soon realized, were due to the passage of ionized particles.

[20] Millard, 'Images' (1977), pp. 23-24, as quoted in Galison, ibidem, p.85.
[21] For the differences between Wilson's chamber and the analogous instrument of a contemporary of his, John Aitken, see Galison, ibidem, pp.91 ff.
[22] Worthington, A.M., *A Study of Splashes*, London, New York, Bombay, Calcutta: Longmans, Green, and Co., 1908.



Worthington's photographs of water splashing into milk from 'A Study of Splashes'
http://www.archive.org/details/studyofsplashes00wortrich

By March 1911 Wilson was able to single out individual rays, chiefly radiating but also running in all other directions. His first paper on the topic shortly after appeared: 'On a Method of Making Visible the Paths of Ionizing Particles through a Gas'. Here he exhibited his photographs of alpha rays and the 'clouds' where they appeared.



C. T. R. Wilson, "Cloud Formed on Ions Due to Alpha-Rays," from "On a Method of Making Visible the Paths of Ionising Particles Through a Gas*," Proceedings of the Royal Society of London*, 85 (Nov. 1911, fig.1.

Galison effectively sums up:

'… within his special science of condensation physics Wilson oscillated between thunderstorms and atoms. (…) his technical success with the photography of rain formation led him from meteorology into ion physics.'[23]

It was then thanks to Wilson's physicist friends working at the famous Cavendish Laboratory in Cambridge, excited by the newly revealed applications, that the machine came be used as a full time particle detector. The cloud chamber moves from condensation physics to ionic physics, to the study of subatomic matter, and then eventually to nuclear physics. It shifted from one research programme gradually to others. What had motivated the invention of the machine in the firsts place (reproduction of clouds and study of condensation) is now marginalized to an out-of-focus background (it becomes 'noise' in our terminology). Asking in what way drops of water materialize leaves way to questions concerning the energy of gamma rays involved in the production of electrons, or about the distribution of alpha particles, or about the mass and interaction of the particles detected by the machine.[24]

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[23] Galison, ibidem, p.109.

[24] This does not mean that Wilson himself turned into being a particle physicist. For him, the interest in ions was always subservient to his main scientific concern with the natural phenomenon of condensation. Yet, Wilson's interest not only in imitating nature (which was at the heart of the tradition he belonged to) but also in 'dissecting' nature in view of explaining its functionings is what makes his machine such a controversial and fascinating tool of discovery

This episode well illustrates how what is observed/can be observed changes depending on what scientists come to be interested in discovering about it, and what interest the scientists have depends itself on the research projects they find themselves involved in. Clouds, which were Wilson's original and main focus of scientific interest, become then a background of noise from which to 'extract' the discovery of the tracks left by the passage of ionized particles (the new focus of scientific interest).

The object of a scientific inquiry changes and shifts depending on how questions and new discoveries (led by further questions) also change and shift, leaving behind as irrelevant 'noise' what was first considered to be the main focus of scientific concern. This does not mean that clouds (the real objects) become, as by a stroke of magic, some kind of unrecognized phenomenon, or of undifferentiated noise. Clouds as such do not change, they stay where they are. It is scientific inquiry which labels them as 'noise' once the concern of research moves elsewhere.[25]

There is, however, also a more literal story to recount about noise in this episode in the history of science. The photographs of the particle tracks were indeed full of literal 'noise' – stuff which interfered with the clear vision of the tracks.

As it was put by P. M. S. Blackett (a famous British cloud-chamber physicist who won the Nobel prize for his discoveries in the field of nuclear physics and cosmic radiation):

'An important step in any investigation using [the visual techniques] is the interpretation of a photograph, often of a complex photograph, and this involves the ability to recognize quickly many different types of sub-atomic events. To acquire skill in interpretation, a preliminary study must be made of many examples of photographs of the different kinds of known events. Only when all known types of event can be recognized will the hitherto unknown be detected.'[26]

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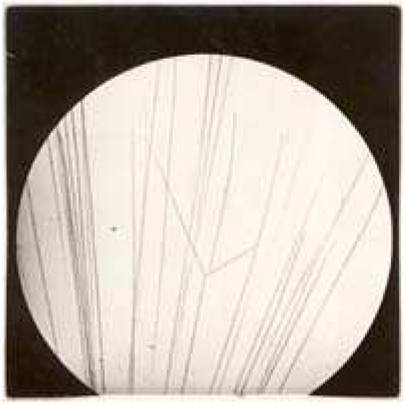
in the history of science, and places it at a cross road between different traditions and styles of practicing science. See Galison, ibidem, pp.136-37.

[25] On the topic of what constitutes a scientific object of inquiry see Daston's Introduction to Daston, L. ed by (2000), *Biographies of Scientific Objects*, the University of Chicago Press, Chicago IL.; and also my *The Objects of Social Science*, Continuum Press, London/New York, 2003.

[26] P. M. S. Blackett, Foreword to G. D. Rochester and J. G. Wilson, *Cloud Chamber Photographs of the Cosmic Radiation*, New York: Academic Press, Inc. and London: Pergamon Press Ltd., 1952, p. vii.



One of Blackett's photographs of particle tracks using the cloud chamber method. The forks show the collision of the particles with the nucleus of an atom.
http://royalsociety.org/New-Theories-of-the-Atom

The physicist leads his eye, by training and skill, to separate the relevant from the irrelevant, the essential from the distorted, the pattern from the disturbances. Yet, and somehow paradoxically, the 'noise' of the photographic medium, where tracks become visible, was part and parcel with the very detection of the particles. The expert observer, guided by his set priorities, is able eventually to build up an accurate description of the primary object of his vision. The noise of the physical medium becomes the enabling condition for the appearance of the particles' tracks.

This can be clearly shown by following up a second, and to some extent complementary, example.

Photographing particles

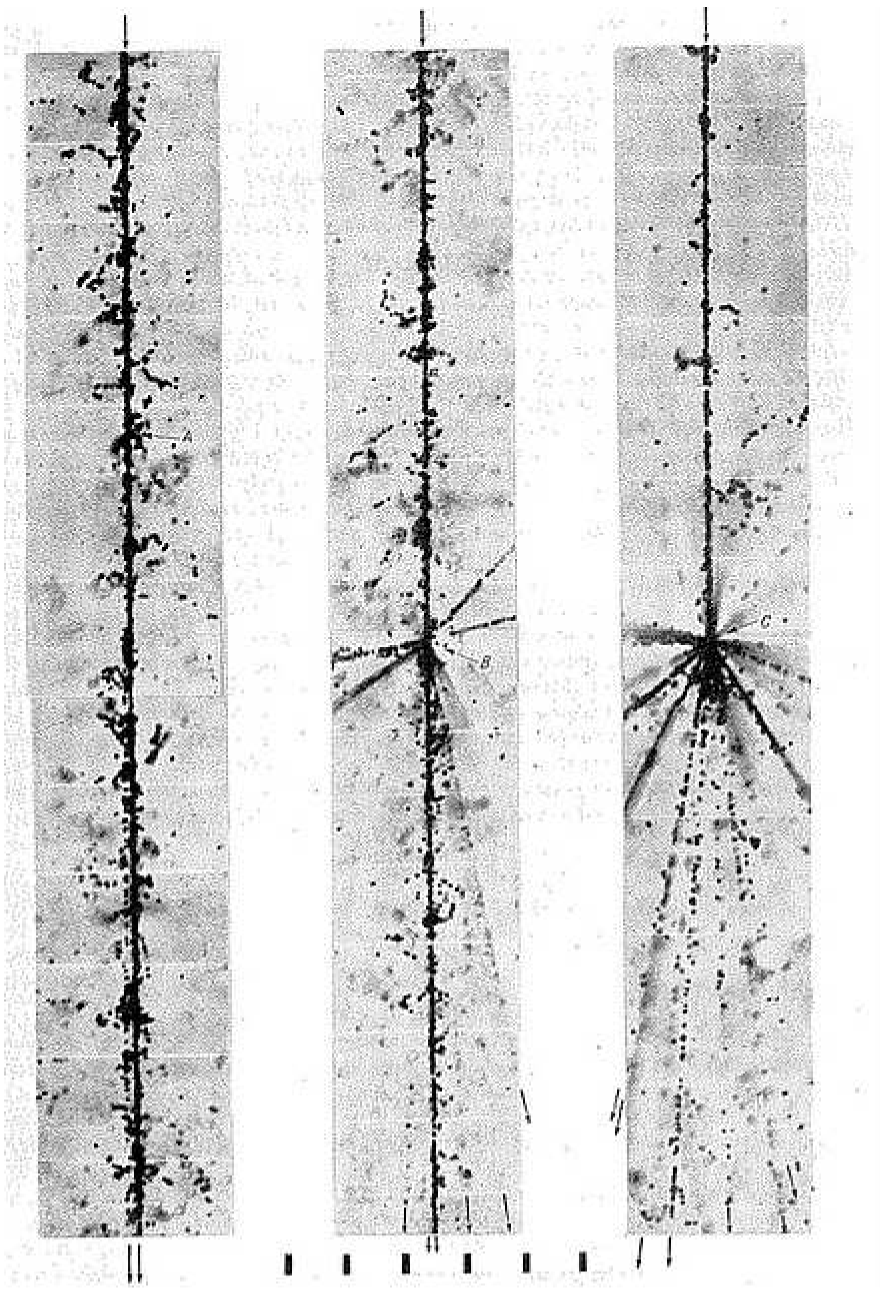
Ever since the 1930s it was known that certain types of emulsions used in photography could be used to track down various types of micro particles. Marietta Blau, a marginalized and yet influential figure in the raising field of emulsion physics, had pioneered a method for tracking cosmic rays using nuclear emulsion. Cecil Powell, a student of Wilson's, was pushing the cloud chamber technique more and more in the direction of tracking particles' trajectories while developing, at the same time, newer emulsion techniques.[27]

[27] On Marietta Blau and Cecil Powell see Galison , ibidem, ch. 3 'Nuclear Emulsions: the Anxiety of the Experimenter'.

It was soon clear that the production of suitable emulsion was beyond the capacity of individual scientists or the resources of university labs. So, after the World War II, Powell – as a member of the 'Photographic Emulsion Panel', established by the Cabinet Advisory Committee on Atomic Energy to encourage the production of more sensitive films for the detection of particles – started putting pressure on Illford to get them to develop new emulsions.[28] The turning point occurred in 1948 when Kodak and Illford together announced that they had manufactured an emulsion so sensitive that it would be able to register the tracks of *any* possible charged particles. So what was effectively made available to the scientific community was ultimately a very powerful nuclear physics detecting instrument, able to compete with the particle accelerators already in use in America. Needless to say, the European physicists jumped on the opportunity and signed a contract – though well aware that collaboration with industrial production or commercial chemistry was not an easy marriage (clauses of secrecy attached to the sale of the emulsions, patenting, etc.).[29]

A period of exciting discoveries followed this controversial, yet decisive collaboration. Pions, kaons, the anti-lambda-zero, the sigma plus, a myriad of new decay patterns, all came to the fore and drew the borderlines of what were to become the new field of elementary particle physics. Cecil Powell himself (who eventually won the Nobel Prize in 1950 for his photographic identification of the 'meson pi') poignantly claimed that it was like breaking into a walled orchard full of all types of exotic fruits.

[28] Galison, ibidem, p.187.
[29] Galison, ibidem, pp.189-92.



Tracks endings recorded on Ilford and Kodak plates and emulsions (from Powel, C. F., Fowler, P.H., Perkins, D.H., *The Photographic Method*, Pergamon London, 1959, pl.1-13 on 31; reproduced from Galison, ibidem, p.190

However, excitement also bore a great deal of anxiety. Indeed, one of the interesting aspects of this way of discovery for the story we are trying to single out in this paper is that the detection of this extraordinary micro world of particles did not happen on a neutral nor stable background. The emulsion of photographic pellicles changed from one to the next, producing an effect of instability and interference on the photographic images. During development

and drying, emulsion and paper backings would bend and distort tracks, or they would make one track difficult to separate from another. So, the photographic apparatus, which was a necessary means and condition for the detection of the particles, was at the same time a source of disturbance, of distortion: a background of ‘noise’. The photographic method was, as a consequence, perceived as ‘fragile’.[30]

As Galison acutely points out, however, this anxiety, partly induced by the fragility of the method and the instability of the apparatus, was no doubt productive:

‘For with each move to stabilize the method, nuclear emulsions became more capable of sustaining claims for the existence and properties of new particles. At each moment, the film appeared to be unstable: at one moment the photographic plate appeared to be selective in what particles it would reveal; at another it was obscured with fog, distorted by development, or uneven in drying. Reliability was threatened by the chemical and physical inhomogeneity of a plate or a batch of plates, and by other difficulties in scanning or interpreting the photomicrographs. Without cease, the struggle to stabilize the emulsion method was a response to the anxiety of instability. Anxiety and the material, theoretical and social responses to it were eventually constitutive of the method itself.’[31]

In other words, particles would not be recognized if not from within a context which made them visible and identifiable in a struggle that was both material and theoretical. It is tempting to say that particles exist, but there is a sense in which it is this disorderly, unstable, fragile context, with all its interferences and imperfections, that makes these particles real for us, discoverable for what they appear to be. As already pointed out, ‘noise’ becomes an enabling condition for the detection of these particles. Noise acts as a ‘limit’ to discovery, but not simply in the sense of being an impediment or obstacle, but in that of being a sort of Kantian condition of possibility. The limits of knowledge, the limits of what we can know, for Kant are what allow us to establish what we can indeed know for certain. They are the positive assumptions on which we build our intuitions, theories, etc. Noise could then be viewed as a limit in this ‘enabling’ sense.

[30] Galison, ibidem, pp.230-31.
[31] Galison, ibidem, pp.237-38.

Back to where we started

To put it in Bart Kosko's words, noise has a head and a heart. The head is the scientific part: noise is a signal (anything which conveys information). The heart is the value-laden part: noise is (often) a signal we don't like.[32]

This points at two conclusive thoughts, in tune with what we have been arguing. Firstly, noise is not just a blurring residue. By being a *signal*, it has a form and an identified structure. It is not then simply the equivalent of a disorderly state. Secondly, being a *signal we do not like* is not a matter of fact but a matter of judgement. What brings us to form such a judgement, and most importantly in what circumstances such a judgement might not apply, are not processes which can be lightly set aside.

Let us then return to our initial questions: is noise only a negative, interfering residue to be eliminated any time it appears? Is the elimination of noise a most relevant way to achieve or preserve order, and to keep potential sources of disorder at bay? I hope I have given some evidence and argument to at least acknowledge that, before answering such questions, careful consideration of both the nature of real noise and the meaning of its idea and function is required.

By no means have I suggested here that noise is always good, or so are variability, randomness or fluctuation. Noise can indeed be a form of pollution. But this is only part of a far more complex story – and a story which doubtless needs its balance readdressed.

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[32] Kosko, B. (2006), *Noise*, Viking/Penguin, pp.3-5.