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A Moving and Exhausting Cosmos: A Discussion on Entropy

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Thomas Nail (**TN**): *How do you define entropy?*

Joel White (**JW**): Firstly, I would like to thank you for agreeing to this discussion on the topic of entropy for *Technophany*'s special issue "Entropies," edited by myself and Gerald Moore. I would also like to take this moment to say that I very much enjoyed our conversation on the phone the other day/night, it was very inspiring for me to talk with someone that shares the same passion for questions regarding energy, entropy, process, flow, metastability, chaos, and everything in between the big bang and heat death (*Nepantla*—inbetweeness—as one might call it in Nahuatl).

Your first question, "how do you define entropy?" has remained with me since I received your email. It is comic or perhaps tragic to start our discussion with what seems like a simple question. As Dorion Sagan writes, ventriloquizing the Devil in "Entropy, Said the Devil," his article for our special issue: "I'm afraid most of you are quite lost. Entropy is both simpler and more complex than commonly thought." Entropy is a tragicomedy not just because its definition is so infamously obscure (thinking here about von Neumann recommending Claude Shannon the use of "entropy" in information theory precisely because it was so obscure) but also because, from a classical thermodynamic point of view, its mathematical definition (a condition which unambiguously qualifies what a mathematical term is and is not), as first formulated by Rudolf Clausius in 1865, is rather simple—outstandingly simple: the unit of entropy (S) is energy (J) over temperature (K), or S = J/K. *How* we define entropy, the method of definition, in classical thermodynamics is through calculus: we determine the change (Δ) of entropy ΔS by integrating the change in the difference between the internal energies (Q) and temperature of two systems: $\Delta S = \Delta Q / T$ (the incremental irreversible transfer of heat energy from the hotter system to the cooler system). Quantitatively, then, entropy can be defined as this change or transformation of energy content between systems (*Verwandlungsinhalt*), a transformation that renders the internal energy of the hotter system no longer capable of increasing its entropy, or in other words no longer capable of work. This is why in textbooks entropy is a "measure of a system's thermal energy per unit temperature that is unavailable for doing useful work." Indeed, when entropy (*Entropie*) was coined by Clausius this is precisely why the Greek *entropia* was chosen; it defined the quantity of energetic (*ergon*) transformation (*trope*)

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that occurs between systems (Shannon Mussett's book *Entropic Philosophy* is a brilliant resource for the Greek uses of *entropia* as a "turning towards.")

But entropy is not just the *quantity* of transformation. It describes a particular *type* of transformation, one that pertains to the configuration of energetic systems and their tendency (their turning towards, their movement, perhaps, between) one state rather than another. The question then of *how to define* this quantity opens the question of the qualitative nature of this quantitative unit of irreversible energetic transformation. Here, I, like many others including Sagan, believe it is best to avoid notions of order and disorder (*Unordnung*). While disorder makes the most sense in statistical mechanics, due to Boltzmann's terminology, it makes less sense if what we want to qualitatively define entropy as is the quantity of irreversibly transferred energy from a hotter to a colder system. Particles are always "disordered"—just look at Brownian motion. This has led physicists such as Frank L. Lambert to readopt Kelvin's terminology of energy dissipation, or dispersal. This is the best way of defining thermodynamic entropy—as energy dissipation—since dissipation means both that energy *tends* to become "spread" or "scattered" over time (and this holds down to the quantum level as energy excitations decay down to lower excitations) and that this spreading out equates to a type of "expenditure" of a system's capacity to perform work.

This brings me to how I define entropy. Amusingly, I actually have a specific "working definition" both of *entropy* and of that which is *entropic* ("working" since it has changed and will likely change):

> 1. Entropy is the *dissipative condition of possibility and impossibility* of any metastable energetic system.
> 2. A phenomenon or an energetic system can be predicated entropic insofar as it *exhausts its own dissipative condition of possibility*.

Both of these definitions were the result of a method, that I term, after Gilbert Simondon, "transduction," which itself can be defined as Cécile Malaspina defines it in *Epistemology of Noise* as how "one field of knowledge [...] transduces its guiding principles, concepts or problems, across academic divisions and institutional boundaries, into other fields of knowledge." In the same way that Kant, for example, *deduces* the categories of the understanding, which is to say, justifies them *as categories*, the trans-duction of concepts such as entropy could be seen as the operation through which a definition that is deduced in one domain (mathematically, say, for entropy) may guide the deduction of the definition of that concept in another domain, say philosophy. Philosophy, just like science, has lots of guiding principles, concepts, and problems as well as organizing structures and systems. For me, I believe that the Kantian transcendental architectonic system is the

most useful, or perhaps that which is most apt to being restructured (like a crystal from a saturated solution) by thermodynamics, and by entropy in particularly. I believe this to be so because the Kantian system seeks to locally determine what the conceptual conditions of the (objects) of experience are, as well as retaining general regulative unifying Ideas that guide notions of unity. For example, I see something like Heat Death and the Conservation of Energy as unifying Ideas; Ideas that cannot be experienced but, nonetheless, regulate the concepts of experience, concepts such as entropy.

JW: *The question I have for you is, how might entropic movement, this "tending toward dissipation," or this continual exhaustion of the dissipative conditions of possibility of metastable systems compliment or complicate kinetic materialism?*

TN: Thanks for these great reflections! I love how much you have really dug into the history of how people have defined entropy. It's not something that I have found many people doing outside of Sagan and Mussett. But it's so crucial. I fully agree with definition 1.

> "1. Entropy is the dissipative condition of possibility and impossibility of any metastable energetic system."

It's a great way to reframe the idea and avoid the unhelpful and metaphysically laden notions of entropy as "increasing disorder." Once we dig into the equations of entropy, we can see that everything hinges on the ontological status of Δ. J/K is just a description of the fact that energy spreads out proportionally as the temperature of something decreases. But this is hardly an explanation of why the cosmos would work this way and what the nature of Δ is such that it creates this ongoing effect. In other words, without Δ, S= J/K is just a statement of a static situation. All the magic happens with Δ, because Δ is the way or agent, if you will that produces the spreading effect with declining energy. And since all energy has momentum, and all momentum generates heat, Δ insures that this process does not stop and applies to all energy we know of so far. Δ is not just abstract "change" in general. Mathematically, you can reverse equations, no problem. But entropy is not reversible! The Belgian chemist Ilya Prigogine's book *Order out of Chaos* is unrelenting on this point against physical and quantum formalisms that suspend the irreversibility of Δ. Many quantum equations do not take seriously this irreversibility, so Prigogine creates his own!

Anyway, what is so cool about $\Delta S = \Delta Q / T$ is that it actually reveals something very specific and singular about the nature of change and motion in our cosmos that the mathematical formalism could never arrive at strictly formally. There is no mathematical or ontological "reason" why Δ must be necessarily irreversible. Let's be honest. No one

knows *why* this cosmos is *entropic*. No one knows why there is *turbulence* or can predict it with complete accuracy. No one knows why *fractal* patterns are so widely distributed across so many scales of nature or how to predict deterministically. And yet, we can easily observe, measure, and record them everywhere. It's fantastic and fundamental.

Before I answer your related question about "kinetic materialism," which is being answered mostly along the way in all this, I have a question about your second definition.

> 2. A phenomenon or an energetic system can be predicated entropic insofar as it *exhausts its own dissipative condition of possibility.*

What do you mean by "exhaust" here? Do you mean "heat death" as it has been classically understood, i.e. this universe will eventually be "fully" dissipated to "equilibrium"? Because, if so, I am not sure I am convinced on this point. And here is why. The idea of equilibrium in thermodynamics comes from the idea that there are "open" systems defined by energy coming into "a system" and "closed" systems where energy is "neither coming in nor going" out of a system. If the universe is a closed system, and entropy is universal, then equilibrium i.e. heat death follows. But I am not so sure I am willing to commit to two big metaphysical points here a) that the universe is a closed system and b) that entropy is universal.

It seems to me that the universe is not a closed system because it is rapidly and unevenly expanding. It is simply not a "system" or "substance" but a process whose changing or Δ is itself also changing. There is not just one Δ, but a Δ of Δ of Δ, and so on. In other vocabulary this is also a problem in the mathematical logic of category theory because one can never totalize all the potential features of a single "arrow" in category theory.

In other words, I am not prepared to lock Δ into one kind of process or change, even if this is all we have seen so far in scientific observations. If the universe, i.e. energy/space/time continues to expand unevenly, it's not clear to me that it will ever reach equilibrium, because it will not stop, ever. Δ may not exhaust Δ because there is no totality of energy in the universe. Yes, energy is not created or destroyed, but in quantum physics there is no such hard zero energy state. So-called "vacuum energy" does not have a determinate value. It is an indeterminate process. Thus, classical notions of thermodynamics begin to fall apart at the quantum level as the vacuum increases and decreases indeterminately. So, in this very technical quantum sense the world is not a system which is either open or closed by a classical definition.

As such, it seems to me that it must remain possible that energy, at least at quantum scales, could change its Δ to not be entropic if even for just a moment. But a moment

might be all that is needed in a very dissipated universe to generate enough gravity to bring things back together. It's speculative, I know. But the idea of a cosmic "big bounce," is based on known features of energy and argued for by physicists including Carlo Rovelli.

All this, I think, roughly answers your question about kinetic materialism. Your first definition complements KM, but the second one *may* conflict with it insofar as I have tried to keep KM consistent with the key experiments in quantum physics, which pose a challenge to nearly all the classical terms of thermodynamics including the nature of Δ, the nature of J (energy), and the belief in "closed" or "open" systems. But that is my question back to you. Does Δ S really exhaust itself and do you think closed and open systems exist ontologically, such that heat death is an inevitable consequence of entropy?

(**JW**)**:** There are two overlapping questions here; the first is regarding what I mean by "exhaust" and the second is whether the phenomenon of "exhaustion" is related in some way to the notion of heat death. I shall begin with heat death: whether "heat death is an inevitable consequence of entropy?"

It is worth saying that the two definitions of entropy outlined above partake of what I call the "transductive analytic of thermodynamics," they are, therefore, concerned with what is experienceable not what is speculatively possible for experience (or, perhaps, we should say speculatively *probable*); much like Kant's *Critique of Pure Reason*, the analytic follows what I call the "transductive aesthetic of thermodynamics", which is concerned with the relation that energy, entropy, and information have to space and time (the thermodynamic direction or order of time and space) and precedes the second to last "book" (to use Kant's term from the *Critique*), the "transductive dialectic of thermodynamics." This last section is concerned with transductive illusions, concepts without objects in experience but that are taken as objects of experience, *ens rationis*. These three "books" are a part of an overall critique of what I call *pure plasticity*, with *pure plasticity* analogically signifying something like Kant's notion of pure reason—*A Critique of Pure Plasticity*.

As you can see this division is architectonic in structure and highly influenced by Kant's first *Critique* as well as Helmholtz's claim from his 1854 "On the Interaction of the Forces" that: "everything was gained" (that it put science on a new advantageous footing) when Carnot inverted the dogmatic question "how can we use the known and unknown forces of the universal to create a perpetual motion machine" to the critical question "If a perpetual motion be impossible, what are the relations which must subsist between natural forces?" It is a critical question because it places a negative judgment concerning totality as its leading hypothesis. Pure plasticity for me, similar to pure reason, is related to paralogistic (false inferences based on substance) or subreptive propositions (fallacious judgment, where either concepts are taken for ideas or ideas for concepts) of infinite transformation:

perpetual motion machines of any kind and of any order. Digital immortality as proposed by transhumanists, affirmations of eternally cyclical negentropic universes, and perfect information engines capable of transforming information about a system into an infinite amount of work, perfect efficiency: these are all examples of transductive illusions that illegitimately presuppose the possibility of pure plasticity *in concreto*.

To say that "heat death is an inevitable consequence of entropy?" would be subreption (heat death qua Idea is introduced into the judgment concerning the understanding); pure entropy would be as dogmatic as pure plasticity. By its very nature, heat death would block any possibility of it ever being an object of experience. At heat death, because the conditions of possibility of experience cease to exist so too does the capacity to make a judgment about experience. Quite simply, at heat death, one cannot say, "this is heat death." This is not to say that it does not have a role to play in the architectonics of thermodynamics as an Idea in the Kantian sense of the term. To be clear, I am also not proposing a pure empiricism or a positivism, things can be real and affirmed as such without being experienced by each singular unity of apperception, and as you, I am not prepared to "lock" the universe into being just a simple analogy of a closed system nor am I prepared to abandon a more sceptical approach to science, there are just too many inconsistencies. Though perhaps different to you, or maybe I misunderstood what you meant by "There is not just one Δ, but a Δ of Δ of Δ, and so on" I do place a weak cosmological principle as a rather useful guiding regulative principle for philosophy and science; which is to say, working "as if" the universe is homogenous and isotropic is pretty useful if you want theory and experiment (not to mention what's already been observed) to mean anything at all.

Before I get to the Idea of heat death, how it functions as a regulative Idea in its own right and its relation to "exhaustion," it is probably worth saying that according to the current cosmology (see for example Katie Mack's *The End of Everything*), most of the other speculative Ideas regarding the "end" of the universe, which is not really an end, are looking *less likely* (and likelihood is the operative word!). Until recently, something like a Big Crunch (see "Bouncing cosmology from nonlinear dark energy with two cosmological constants" by Molly Burkmar, Marco Bruni on the slowing and expanding of dark energy) was pretty much ruled out, since the universe is observably expanding too fast (for whatever reason due to "dark energy"), Perlmutter, Reiss and Schmitt demonstrated this through the redshift in supernova light and won a Nobel prize for it in 2011; the problem with the "big bounce" you mention is that it too, like the Crunch, would have to produce a gravitational difference that might overcome this observable accelerated expansion; but like heat death itself, all of these fall prey to the very method they use: speculative probability. This recourse to probability has haunted science since Boltzmann. Lawrence Sklar, in his amazing book *Physics and Chance,* argues that the problem with speculations

that deal with small probabilities is that if a fluctuation did occur—which is, of course, always probable because that's what it means to be probable (our very universe could be proof of it!)—it is also *more probable* that it doesn't. Furthermore, given the very precise configuration needed for a bounce to happen (the models that Burkmar and Bruni are working on), it is also unclear whether our universe would get another chance at another bounce, so to speak.

Regardless of what might occur towards this so-called end of the universe, whether it is a big crunch, a bounce, a big chill or a rip, almost all physicists, Rovelli very much included, especially in his more recent work on entropy, memory, and time, do not deny that the *movement of energy*, its *tendency, direction* or *order* is towards maximum entropy. As he writes in *The Order of Time* "it is entropy that drives the world, not energy." It is true that if quantum vacuum fluctuations were experimentally proven, then the law of the conservation of energy could be violated. But given the amount of observable evidence for conservation, perhaps the first law of thermodynamics would succumb to the same fate as entropy did at the end of the 19th century, that is to say, it would become highly probable instead of *necessary*. Where I am going with this is that that all experimentation and almost all theory thus far has not violated the second law whether probabilistic or not. There is nothing we can point to and say that is not subject to entropy. And while entropy is probabilistic from a statistical mechanical point of view (counterfactual theory proposed by Chiara Marletto is trying to turn this into the question of *what is* and *what is not* possible, which I think is a bit fraught with epistemic problems), to say that nothing has violated the second laws also means that we cannot get back to a low entropy state, the state that drives the world, without increasing more entropy! Again, as Rovelli writes (despite the recourse to the order/disorder paradigm), "The entire coming into being of the cosmos is a gradual process of disordering." That entropy envelops *all* changes and processes means that the concept of entropy (that which allows us to make the judgment: "that is entropic") connects, immanently, to an unconditioned Idea, which is the Idea of heat death. For me then, it is not a matter of affirming what will or will not happen "at the end," (how could we do this without slipping into metaphysics), but it is a matter of connecting experienceable entropic phenomena to an Idea that hypothetically unifies these phenomena as a guiding principle. Heat death is the *focus imaginarius* of thermodynamic architectonics.

Why then do I use the verb "exhaust" in English? Exhaust is a good equivalent, albeit using a different Latin root, of the French verb *épuiser* and the German verb, *erschöpfen*. These verbs (exhaust, *épsuier*, and *erschöpfen*) describe a form of de-construction, destructive creativity or negative sublation. Something is drawn out of something (*puiser*), created or invented (*schöpfen*), through the negation of its own continued possibility to be drawn out or created again. If all phenomena, fleeting or sustained, have their cause in the

dissipative transformation of low entropy into higher entropy, then that very tendency, as per the first definition I gave, is the condition of possibility *and* impossibility of it. As you say, "entropy is not reversible!" We can't get that causal situation back again! (unless of course we wait for a bounce to happen). This then seems to demand the statement that something is entropic when exhaustion happens, exhaustion being understood not as destruction but as an irreversible unidirectional causation. As Rovelli writes "Causation is therefore a macroscopic thermodynamic phenomenon where the total entropy is raised by an intervention, and the effect is the trace left on the system by the intervention." This trace is not reversible. Indeed, this is precisely how Marletto turns the second law into a counterfactual, but unlike Marletto, perhaps, I do not therefore want to "lock Δ into one kind of process or change," and consistent with KM there is nothing we can point to and say, "that's not moving," but likewise I don't think there is anything that we can say, "that's not entropic," "that's not exhausting low entropy."

JW: *To change tack a bit, I know you have been doing work on non-Western conceptions of chaos, if I remember correctly? I know that in many Aztec cosmologies (which differ from other Mesoamerican cultures, for example, the Mayan) we are still in the period of the fifth sun, after which there are no more suns—they have a type of entropic logic where the sun is sustained by sacrifice. I think part of my interest in entropy is that it's a fairly novel idea in Western thought. We discuss some of the political and ethical notions related to entropy when we spoke especially in relation to how it might be possible to overcome the "negative" or "reactionary" accounts of entropy. Why do you think people have historically and still think of entropy as such a "negative" concept?*

(**TN**)**:** Thanks, Joel. That was great and provoked so many thoughts for me and questions. It is now clear to me that we both reject the *metaphysical* idea of heat death which says, "the cosmos will necessarily eventually stop and achieve perfect equilibrium," which is how that word is most often used in the history of thermodynamics. I am going to have to think more about the use of the regulative idea of isotropy because I think there may be a third option between acting as if everything is changing and everything is not stable. Do you think it's possible to act as if everything were metastable? For example, and to answer your question a bit, this is something like what we find in animistic traditions in ancient Sumer and Shinto Japan. In the most ancient texts in these traditions, a particular tree would not be treated as isotropic or pure flux but as a person-spirit with stability, like us, but also with its own unique agency that may also surprise us. I suppose I worry that a regulative idea of isotropism and its "practical" utility and instrumentality may blind us to the deep indeterminacy of the world and its capacity for novel agency. But maybe you are not thinking of this regulative idea as strictly as I am. I just worry that it comes with a deep danger with a long history and Western-centric bias that has caused a lot of harm. Again, not saying you are fully endorsing the version I worry about.

But quickly, I wanted to add that quantum fluctuations have been experimentally proven many times since the 1950s. But their *interpretation* typically falls into the same camps as the *interpretations* of QM, which I will not re-hash here and are heavily burdened by unprovable metaphysical speculations about randomness and determinism. Rovelli does a great job of debunking them in his book *Helgoland: Making Sense of the Quantum Revolution.* Thus, most physicists think quantum fluctuations do not violate the law of conservation only because they believe that Schrödinger's wave equation is a *real* description of a deterministic universe containing superpositions that balance out any *apparent* non-conservation. But Karen Barad and Rovelli both do well to show that the experiments to not have to assume this particular interpretation. Thus, not everyone agrees about the violation of conservation. But we can save debates about the first law for another time! Let's get back to the second law.

I think we are in agreement on this one and I love the way you put it: that if entropy is ever violated it will happen *through* entropy. Thus, one effect of entropy might be to produce non-entropy. And the converse is true, if our current universe was the result of a previous Big Crunch, then entropy would have been the result of non-entropy. And then we have what Empedocles imagined as the cosmological dialectic of Love and Strife.

In any case, I now understand what you mean by "exhaustion," and I agree with your definition as "the fact that we cannot point to anything in the cosmos so far that it is static or is not proceeding from low to higher entropy." It helps me to think of this word more of a gerund than a past participle. The cosmos is not exhausted but *exhausting*. And here is where the philosophy of movement connects up well to this idea of exhaustion. That said, I can't bring myself to use the word "heat death," though, although I understand your definition well, it just has such historical and metaphysical baggage I can't shake and don't want to confuse people with. But "exhausting" or perhaps "exhaustion," I am ok with.

I think one difference between us on this is that it sounds like you are taking a more post-Kantian approach thinking of entropy as a new transcendental. It's a cool idea and I like it a lot more than the typical metaphysical scientific approach or the typical phenomenological approach. Indeed, the line between it and the ontology of movement is pretty fine, I think. I think we both have a pretty *historical ontology* such that we accept that the cosmos may become different than it is and that we may learn something that changes what we knew. If we find something that violates entropy, it seems like your transcendental thermodynamics becomes weaker, but maybe you would still want to use it because most things still follow entropy. So it's just practical even though it's not ontologically true. I think for me, much more would be on the line if we found something that didn't move. Perhaps the difference between us is that I have a performative historical ontology and

you have a more historical transcendental? Or my historical transcendental is slightly larger and has a performative dimension? If you think that is a fair characterization? The ontology of motion can handle entropy and non-entropy just fine as long as it's all happening *through movement*.

However, if we found something static or some region of the cosmos became static, then everything falls apart for my view because it would mean that our performance here on earth would no longer be an iterative performance of the cosmic drama itself, as Bataille says. Some part of the cosmos would be ontologically different than the rest and we would get a dualism. It would be almost theological. Indeterminacy would be the cause of emergent stasis, but in stasis, kinetic indeterminacy would be abolished as would any ontology committed to it. I wonder what you think of the strengths and limits of our positions if you agree with my characterization.

But to your question, which I would in turn pose to you, why has Western metaphysics understood entropy as "negative" and even "bad?" In my most recent work on ancient cosmogonic texts, I think a big part of the historical antipathy toward entropy has to do with a single cosmogonic difference. The conclusion of my book *The Birth of Chaos* is that all twelve of the oldest surviving native-language cosmogonic texts in the world began with a primordial condition of formless, flowing, indeterminate, moving, creative darkness or "chaos." In the book, I show that in these texts, primordial chaos had nothing to do with disorder at all. Order always emerged from chaos and returned to it. I can't go into all the textual evidence supporting these conclusions, but they mean that these cosmogonies are consistent with the cosmic entropy you and I are describing.

However, I also tracked the precise times and places where all these chaosmogonic texts were transformed by later largely conquering peoples who removed primordial chaos from the narrative. This happened around 1500 BCE in Egypt and Sumer and then around the 6th century BCE in Greece, India, and China. After this the history of Eurasian civilizations was exclusively dominated by cosmogonies where a principle of order came first, and chaos increasingly was redefined as the "lack of order." All Eastern and Western philosophies, religions, and sciences have followed this turn away from chaos and eventually fuelled colonial powers who travelled around the world murdering and burning nearly every trace left of indigenous world chaosmogonies. Again, big claim, but I think I have good textual evidence for it.

The bigger point here is the following hypothesis: to the degree the story I am telling above is accurate we should expect to find an antipathy to entropy in every culture whose cosmogony begins with a principle of order and not in cultures whose cosmogony begins with chaos. In chaosmogonies, entropy (they do not use this word of course) is

the creative expression of a beautiful cosmos of which we are fully performative and iterative aspects of. Everything is born and thus everything dies. To die is to do what the cosmos is doing and thus be iteratively united with it. There is no god, principle, or law which was not born by something else. On the contrary, cosmogonies that place any kind of order first are fundamentally at odds with the process of exhaustion because it threatens to exhaust them and destroy their orders. It may also contribute to certain culturally specific fears of death. And so, I would hypothesize that nearly every religion, science, and philosophy which does not begin with chaos would necessarily be threatened by cosmic entropy. It would also explain why worldviews that begin with order also call entropy "disorder," just as they have been calling chaos "disorder" for the last 2,500 years. This is an important connection between our respective research programs. I know you have spent a lot more time looking at entropy in the modern European context, but our stories are in some way tell a continuous story. Movement and entropy are strongly related (although not strictly identical) and are major world historical conceptual lynchpins or pivots that distinguish many ancient and indigenous worldviews from modern ones. Their explanatory power runs deep.

JW: Thank you for this Thomas; correct, we are not here to debate quantum fluctuations or the first principle but the second! Though in a way the second is contingent on the first in so far as if energy could be created from nothing then the effects of entropy would be less weighty, there might be something like actually existing negentropy; but that is for another day. And as you also rightly say, there *is* experimental evidence for fluctuation or at least there is experimental evidence for the effects of fluctuation (electrons popping up in different orbitals) when and where they shouldn't and there are different interpretations of this; whether physics, especially of a quantum variety, should bother with "should" is a different story, though this story is perhaps one connected to our shared historical approach to philosophy and science.

Other than strictly neo-Kantian (though Helmholtz, Lange, and Vaihinger are a great influence on me) I would say that my "method" is something I call *critical epistemology*, or perhaps this is the "domain" of philosophy that I see myself developing. It is epistemological since it is it concerned with the historical development of certain *epistemes* (the conditions of knowledge and the formation of ontologies and discourses that arise from out of these systems—I concentrate on classical mechanics, thermodynamics, and information theory). It is critical, in the Kantian or neo-Kantian sense of the term, in so far as it seeks to do two things: 1) determine the conditions of possibility of these *epistemes* (both materially and theoretically) and 2) to construct, through transduction (as I defined it above), an architectonic system that enables us to see with some more clarity the very *episteme* in which we think and act. This architectonic system is one that places a strong emphasis on the *"as if,"* as influenced by Vaihinger's *The Philosophy of the "As if."* Moreover, it is

with good reason that Yuk Hui argues that we are still in a "thermodynamic ideology." I believe thermodynamic architectonics will serve to understand what a thermodynamic ideology is and why entropy has not been properly integrated into it. A thermodynamic ideology is an ideology of energy not entropy, or at least is views entropy as dangerous to its own basic premise: energy extraction, accelerative production, and perpetual growth. To the question: "why has Western metaphysics understood entropy as 'negative' and even 'bad?'" I might answer quite simply that it undermines the metaphysics and any accompanying political economy based on infinite growth.

Thermodynamic architectonics is, then, practical insofar as it seeks to better survey this ideology, but it is not a closed system. One must be open to the inevitable re-structuring of the scientific structure and its models (as Serres might put it). The construction of my thermodynamic architectonics is thus practical but results from an experimental spirit, it asks the question: "What might a transcendental philosophy look like, if, instead of Newtonian mechanics, which inspired Hume, Kant, and Hegel, it took thermodynamics and/or information theory as its point of departure." (This is not a discussion about information, but I believe that the information paradigm is but a further reduction of the same basic thermodynamic ideology, information is viewed as that which can ultimately increase production via an increase in the capacity for energy to produce work [the more I know of a system, the more I can extract from it]—our thermodynamic ideology is at once a thermoinformatic one).

I am currently finishing a book called *On Logomachy* that might also help to link our positions and will give further clarity to your question about my approach to science and philosophy. I believe strongly that we should not have to choose between either absolute stability on one side and absolute instability on the other—metaphysical claims *par excellence*. We have the third option you mentioned: metastability. The book is called *On Logomachy* because this term—*logomachia*—is used by Socrates in the *Cratylus* to shut down the debate that Cratylus and he are having about the meaning of *episteme* (the dialogue is about the correctness of names): one where either the *movement* or the *stasis* of things in their relation to the soul etymologically defines *episteme*. In this dialogue, knowledge must be either only moving or only stable; to reopen the debate would consist of a conflict (*machia*) in and of the logos, a *logomachia*, something that Socrates argues must be avoided since Cratylus and he are supposed to be friends, and no one wants a civil war between friends! As Simondon writes, the Ancients (perhaps Heraclitus aside, whose *logos* qua fire is metastable and middle voiced) didn't really have a notion of metastability. What would happen to our notion of *episteme*, indeed to knowledge itself, if its definition was instead: "the metastable relation of the soul (itself being metastable) to metastable things in a metastable world"? *Of Logomachy*, seeks to answer this question.

Beyond the regulative nature of metastability—meaning that the "as if" is metastable—I have been experimenting with a fourth notion recently to replace what I was calling meta-metastability (which is clunky): patastability. One can hear in this notion resonances of Alfred Jarry's "pataphsyics," which is often defined as being "the science of imaginary solutions," or "the science that is beyond metaphysics." In *On Logomachy*, I argue for a conception of knowledge that is meta-metastable, that is, knowledge is a metastable relation between metastable systems, systems that include conceptual networks relating through *différance* (I think Derrida was spot on here), objects that are in different stages of metastability and instability and so on (I include the metastability of perception and the perceiver, emotional states or internal working memory models etc). Logomachy is perhaps my thermodynamic transcendental logic, to talk in Kantian terms.

Regulative ideas, then, to answer your question, are ideas that immanently unify knowledge and function at a patastable level: the regulative use of isotropy would be patastable, it would be that type of metastability that holds together the metastable relations of other metastable systems. Just as in Simondon's theory of individuation, such a patastable system, or *episteme*, would necessarily have to re-structure its relations if and when new evidence arises.

Concerning your suggestion of using the gerund "exhausting," I couldn't agree more. This is much better than the past participle or even just the noun "exhaustion." Though taking this a step further, one might want to think of this not as being in the gerund but as being in the old middle-voice tense called the passival. The cosmos is exhausting. Where the subject and the object of the verb are mediopassive: "that a person or thing both performs and is affected by the action represented." It is the cosmos that exhausts *itself through itself as both object and subject*.

This also brings me to your statement about cultures that are antipathic to entropy, how their cosmogonies begin with a principle of order and not chaos. Here one might want to think of that philosophical principle *par excellence*, the sun. If the sun is placed as the ultimate principle, that metaphysical being beyond being, as it is for Plato, which is to say Formness as such, then anything that does not participate of that perfect life-giving sphere is damned. As you write, to die is to do what the cosmos is doing, dying is returning to the universe. Here Artaud, more than Bataille, is the great Nietzschean philosopher-poet I turn to. We are not just of the sun, but we are the dying sun, we are its shit. As Artaud writes in his first ever poem: "*Le soleil se meurt*" (the sun is dying). Here the sun is dying in the passival, it dies *through itself as both object and subject*, and it is through its dying (here in the gerund) that life is at all possible. This is why I write that any metaphysics and any political economy that grounds itself on such a metaphysics of the sun qua absolute life-giving order cannot think life itself. Life exhausts (destroys and creates) itself through

itself, the *élan vital* is always once at the same time an *élan mortal*. We need a politics that actually takes into account not only the moving but also the exhausting cosmos.