

OBSERVATIONS: THE BUILDING BLOCKS OF THE WORLD¹

Vipul Arora and Laxmidhar Behera

ABSTRACT: Physics aims at building mathematical models of the underlying nature for explaining and predicting our observations. Based on the experimental data, mathematical quantities and concepts are formulated, and physical theories are constructed, from which we derive our ontological understanding of the underlying building blocks of nature. However, at times, certain phenomena, unnoticed before, fail to agree to the predictions made by those theories. This forces us to give up the old theories and construct new ones. In this paper, we argue that we can very effectively avoid this problem by constructing physical theories with observations as the basic building blocks, or the primary properties, and the mathematical constructs as the emergent properties. We provide an outline of the mathematical framework of our approach, and use it to analyze various concepts in physics, e.g., Newton's laws of motion, conservation of energy, wave-particle duality, etc., in terms of relationships between the observations made by different detectors. This approach not only provides a new robust way to do physics, but also leads to an ontological understanding of nature that goes beyond many of the present problems and paradoxes.

KEYWORDS: Observations; Primary and emergent properties; Classical and quantum physics; Measurement problem

¹ Editor's note: *Foundations of Mind*, the independent research group that has provided the papers for this special edition, has never taken either corporate or state money and is financed entirely by donations. Authors keep copyright without paying. The typical fee for this charged by open-access journals such as those published by PLOS, is around \$2k. If you value this project, and wish to see further such proceedings from this group, we ask you to consider donating to *Foundations of Mind* – as little as \$5 per download, through their website: <http://www.foundationsofmind.org/donate>. This will ensure there will be further published proceedings on the foundations of mind like this one for you and others to enjoy free.

1 INTRODUCTION

Physics aims at building mathematical models of the underlying nature for explaining and predicting our observations. From Newtonian to modern theories in physics, the general approach has been to build models that are mathematically coherent, conform to our intuitions as much as possible and successfully predict our observations. For instance, Newtonian mechanics conforms well with our intuitions, while special theory of relativity, although seems counterintuitive, is mathematically sound and predicts our observations well; both are valid physical theories.

An important fact to be noticed here is that observational data is collected and these theories are built to model the underlying reality, which ontologically causes the data that is observed. In certain cases, however, these theories lead to some predictions which are later observed experimentally. Einstein's theory of relativity is a well-known example illustrating this case. Similarly, the law of conservation of energy comes handy to make predictions while exploring many situations unobserved before.

Thus, assuming the nature of underlying reality in this way leads to great simplifications by providing convenient ways to understand nature, and at certain times even predicting the observations in unseen domains. But, on the other hand, these assumptions also limit us and become a great stumbling block in further enhancing our understanding. For instance, when phenomena, unnoticed before, bring observation data which does not abide by the earlier model, our understanding of the underlying reality is staggered, leading to fixing and even abandoning of the underlying physical models to build new ones. For instance, the observations of quantum behavior led to abandoning the classical understanding of nature. Nowadays, this limitation is being perceived starkly, in our quest to reconcile quantum with classical [9], unification of quantum mechanics with relativity [5, 1], and ultimately to understand biological processes [6] and consciousness [11]. In this paper, we argue that this awkward situation can be avoided if we work backwards, i.e., taking observations as the building blocks of our models. This involves modeling relationships amongst observations [2], without imposing any assumptions on the nature of underlying reality.

Our main proposal is to consider observations as the primary building blocks of objective reality. The correlations amongst the observations can be modeled using information principles. We start from visualizing Newtonian mechanics in terms of relationships between the detectors or the observations. What we have is a holistic experience, which we abstract out to form a physical concept. These experiences could be acquired through any of our five knowledge acquiring senses. For example, the

sense of touch or pressure can be abstracted out in the form of a quantity called ‘force’, F . An ordering is associated with it to give it a magnitude value. Similarly, the visual experience of movement of an object with respect to the background can be abstracted out to conceptualize ‘acceleration’ a . The mathematical relation $F = ma$ captures the linear dependency of these two experiential abstractions. Here, m acts as the proportionality constant for the object under observation.

We then propose how energy can be seen in terms of informational relations. Consider the Joule’s experiment of energy conversion. We have a visual experience of an object (called the weight) coming down, with respect to a fixed scale, on one hand, from which we abstract out h . On the other hand, we have a touch experience of water getting heated (experimentally, this is correlated with the visual experience of thermometer pointer rising), abstracted out as T . The law of conservation of energy correlates these experiences by formulating quantities called potential energy and heat energy. While the ontological reality is the sense observation, other quantities like F, a , energy, etc., serve as epistemic concepts serving to model the relationships between our sense experiences.

Further, we argue that quantum mechanics (QM) provides a suitable framework to work on this task, provided it is interpreted and expanded along these lines [3]. This is because, the basic quantity - a ket, $|\Psi\rangle$ - does not assume the ontological reality of object, but allows the operators to extract information about different experiential aspects of the object in the form of observables. The Schrodinger’s equation models the relationships between these experiential aspects through the Hamiltonian operator.

In addition to considering QM in terms of information, this paper discusses various aspects that need to be worked upon. For example, QM presumes many quantities, like time [10, 8], mass [7], etc., privileged as absolute. We need to revise their formulation so that they are also put on an equal footing with all other observables.

2 OBSERVATIONS AND CLASSICAL PHYSICS



Figure 1: An example visual experience

An observation takes place when a detector detects an object. An object is defined as that observation that can be identified distinctly. An observation made by our sense organ as the detector is called an experience. For instance, let \mathcal{V} represent the visual space, i.e., the space of visual experiences. This space comprises of visual objects. Our eyes are said to observe (or experience) two visual objects o_1 and o_2 if $o_1 \neq o_2$. For example, consider the visual experience illustrated in Figure 1. From this experience, we can abstract out various aspects. For example, we may abstract out the position of the two objects, which we see as two blobs. We may also abstract out the color of each blob as two distinct objects.

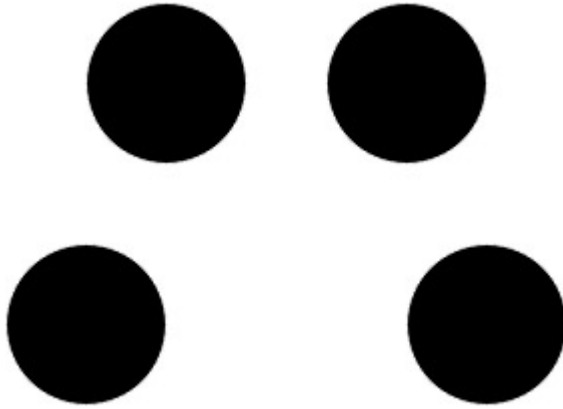


Figure 2: An example visual experience

Starting from the first principles, let o be an aspect that we abstract out from an experience. Now, if we can arrange different instances of o in a relative order, we can define a quantity $o \in \mathbb{R}$ that quantifies that aspect of our experience. Here, \mathbb{R} denotes a set of real numbers. Let us consider a visual experience as illustrated in Figure 2. An aspect of this experience, namely, the distance between two of the blobs, can be abstracted out as x . This distance can be arranged in a linear order to form a quantity $x \in \mathbb{R}$, which is the position of one object with respect to the other. In practice, the detector used to quantify x is a scale ruler (meter rod, Vernier calipers, etc.); i.e., $D_{\text{ruler}}(x) = x \tilde{\in} \mathcal{V}$, where, $\tilde{\in} \mathcal{V}$ denotes an aspect of an experience in \mathcal{V} . Further, a quantity can be standardized by comparing with respect to a fixed scale and thus defining units for it. In Figure 2, one can objectively experience that the distance between the lower balls is more than that between the upper two blobs.

Similarly, time is an important aspect of our experiences, that is experienced in the

form of changes in experiences (say in \mathcal{V}). We denote this aspect as t , and it can be ordered to form a quantity t , the detector for which can be a clock; i.e., $D_{\text{clock}}(t)$, or in general, $D(t)$, which gives us an experience in visual space \mathcal{V} .

Having the notion of x and t , we can quantify the change in x using the quantities $\dot{x} = dx/dt$ and $\ddot{x} = d^2x/dt^2$, known as speed and acceleration, respectively. Note here that we do not experience \dot{x} and \ddot{x} directly, but infer them from other experiences (say in \mathcal{V}). The relationships between different experiences and parts thereof can be modeled in terms of the equations of kinematics, like

$$\dot{x}(t) = \dot{x}(0) + \ddot{x}t \quad \dots (1)$$

(etc. Basically, these equations model the relations between detectors for aspects like x and t).

We call x, t or $D(x), D(t)$ as the primary properties of any object (or phenomena) under study, while the quantities like \dot{x}, t , etc., or \dot{x}, \ddot{x} , etc., as the emergent properties.

Definition. The primary properties are the objective aspects of our sense experiences. The emergent properties are the quantities that are either constructed to quantify the primary properties or are assumed as mathematical tools to model relationships amongst the different primary properties.

Now, we can introduce another kind of sense experience, namely, touch \mathcal{T} . An aspect of this is the pressure or force experienced. We denote the force as F from which a quantity $F \in \mathbb{R}$ can be formulated. The detector for F can be a weighing balance, i.e. $D_{\text{balance}}(F)$, or in general, $D(F)$. Note that we experience $D_{\text{balance}}(F)$ in the visual space \mathcal{V} and find it correlated with our touch experience F .

The second law of Newton models the relationship between the detectors $D(F)$, $D(x)$ and $D(t)$. But it does so by assuming the quantities F and \ddot{x} , which when observed, correspond to these detectors. The two quantities are linearly related as

$$F = m\ddot{x} \quad \dots (2)$$

where, m is the proportionality constant. Hence, this equation relates the aspects of our experiences – namely, F, x, t .

Consider another experiment on energy conversion, where an object (in visual or touch space) falling through a certain height raises the temperature of water. The height is experienced as x . Temperature T is an aspect of our touch experience, i.e., $T \in \mathcal{T}$, for which a quantity T is assumed. The relation between these quantities is formulated as $\Delta T \propto \Delta x$. Further certain quantities like the mass m of the object is assumed to be a fixed property of the object, derived from Eq. (2) and likewise, the quantity called mass M of water. The acceleration due to gravity g is formulated as a constant quantity derived from the observation that free falling objects show the same value of \ddot{x} . Finally, we arrive at an equation which contains quantities associated with

each object separately, and we call that expression as energy, E . Hence, E is an emergent property even farther removed from the primary properties. However, we find that for different kinds of objects, we can define such expressions which model the relationships between the primary properties of one object with those of others.

We see in the above examples that different equations model relationships between different detectors. If we have just $D(x)$ and $D(t)$, their relation is modeled via kinematic equations. If we add $D(F)$ to these detectors, their relationship is modeled using Newton's equations. Furthermore, the energy equation models relationships between different detectors, e.g. $D(x)$, $D(t)$ and $D(T)$.

3 PRIMARY AND EMERGENT PROPERTIES

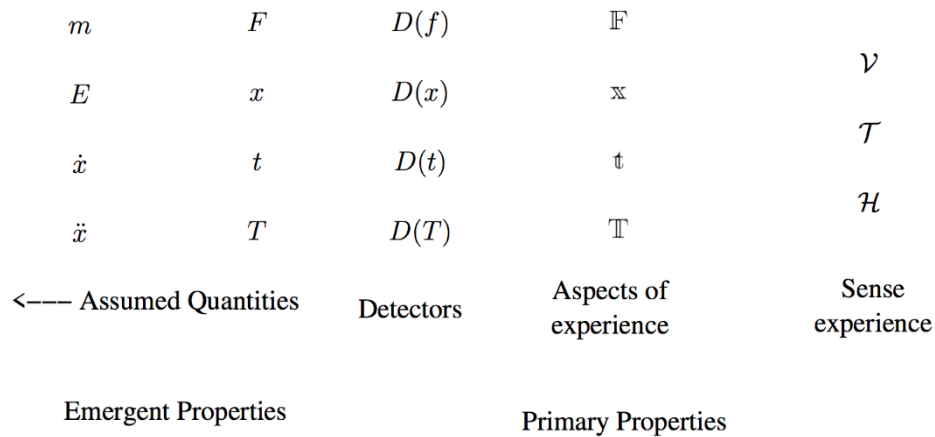


Figure 3: Sense experiences lead to the derivation of primary properties, which further lead to the derivation of emergent properties.

We pause here for a moment to reflect on the framework we have introduced in the previous section. We see that what we have primarily is the sense experience. The space of these experiences could be \mathcal{V} (visual space), \mathcal{T} (touch space), \mathcal{H} (hearing space), etc. We abstract out aspects like x, F, t , etc. from them, which are still directly observable. We call them as the primary properties. Then, we define detectors D to quantify these observables. Based on the observations made by the detectors, we define quantities like x, F, t , etc. We call them as emergent properties. Classical physics tries to

capture the relations between different observations $D(\cdot)$ by assuming the aforementioned quantities to be present as ontological properties of objects and formulating relations between these quantities. Furthermore, there are quantities like m, E , etc., which are not directly experienced but they help in modelling mathematical relationships. These are higher emergent properties. Figure 3 illustrates this chain of derivations pictorially.

Historically, philosophers like Galileo have defined the primary properties as those properties (like length, position, etc.) of an object that can be defined independent of any observer, while the subjective properties associated with sense perceptions are defined as secondary properties. In that notion, the primary properties provide objective factual information about the objects, and the secondary properties do not provide such information.

The above conception tries to separate the observer from objective reality. In contrast, we present a notion of primary properties where the observer plays an important role, while they still convey objective information about the object. The emergent properties, on the other hand, are formulated to help in formulating the relations to predict the primary properties. Mostly they are quantified by the detectors. Unfortunately, many a times we try to give an ontological status to the emergent properties. The present reductionist science is a consequence of this attempt.

In many cases, it is observed that addition of more detectors makes certain emergent properties to be no longer valid. At times, certain phenomena lead to finding detectors that no longer conform to the existing emergent properties. This leads to crumbling of our existing view of reality and we are forced to fix or even abandon the existing physical models. This is also true for our understanding of reality. For example, our intuitions based on classical emergent properties meet a hard time while understanding quantum phenomena. Hence, the over-dependence of the present science on such emergent properties need to be reduced by building models closer to the primary properties.

4 OBSERVATIONS AND QUANTUM PHYSICS

In the previous sections, we saw the difference between primary and emergent properties. Also, we saw how classical mechanics makes many assumptions while formulating relations between emergent properties. However, many of these assumptions on classical emergent properties were shaken in many experiments. This led to the formulation of quantum mechanics, which relinquishes these assumptions. One of the foremost amongst such assumptions was the one regarding ontological existence of these classical emergent properties. For instance, the famous double slit

experiment forced us to give up the assumption of ontological existence of quantities like position x and momentum p .

Another kind of experiments that laid the foundations of quantum mechanics are concerning how light interacts with different solutions. This area is known as absorption spectroscopy. Light is passed through a certain solution (or vapors) and its spectrum is obtained by passing through a prism (or more sophisticated spectrometers). The intensity I of light is obtained as a function of frequency ν . Here, spectrum corresponds to a visual experience. Frequency ν is an emergent property or quantity which corresponds to the position x or the color of the spectral line. Similarly, I is a quantity derived from the intensity aspect of the visual experience. It is observed that when white light is passed through a certain solution, certain frequency lines are missing in the spectrum, as compared to the spectrum of light not passed through that solution. This led the physicists to attribute this absorption of frequencies by a solution to the electronic structure of that solution. While different physicists were proposing different emergent properties, Heisenberg emphasized that “physical theories should concentrate on quantities closely related to the observations”. In other words, formulating emergent properties too far removed from the primary properties might lead one to trouble, and hence, one should prefer working as close to the primary properties as possible. Furthermore, assuming those emergent properties to be ontologically true is obviously disastrous.

For modeling the spectral lines observed in the absorption spectrum, Heisenberg considered the idea of Bohr orbits as unimportant because it was based on assuming quantities like position and period of revolution of electrons which are far removed from observation. On the contrary, he formulated matrix mechanics [4] in terms of quantities more closely related to observations.

Similarly, Schrödinger formulated wave mechanics, which is based on a quantity called wave function. In Dirac’s notation, the underlying object can be represented as $|\psi\rangle$, which imposes no assumptions on the ontological nature of the object. When this object is observed using a position detector, its expected value is given by $\langle\psi|\hat{X}|\psi\rangle$, where, \hat{X} is the position operator. The actual value observed by the detector can, however, be represented as $D_x(\psi)$. The relationships between different observations (i.e., outcomes of detectors) are defined with the help of operators $\hat{x}, \hat{p}, \hat{H}$, etc., and $|\psi\rangle$. Quantities like x, p, E , etc. are used in quantum mechanics to denote their observed values $D_x(\psi), D_p(\psi), D_E(\psi)$, etc. only and not any ontological quantities.

Here we see that the formulation of quantum mechanics allows one to work closer to the primary properties and imposes minimum assumptions on the emergent properties. However, in the present formulation, several quantities like mass m , time t ,

etc. appear to have a status similar to their classical analogues. These quantities appear as absolute properties, more or less independent of observation. Straightening such discrepancies will pave the way forward and will also help in mitigating the difficulties we are finding in reconciling quantum mechanics with relativity.

5 OBSERVATIONS AND THE WAY FORWARD

In this section, we present, with an example, the outline of how we plan to analyze the observed physical phenomena. We point out how present physical theories assume the ontological presence of certain objects to be causing the observations. We present an alternative way to model the phenomena in terms of sources, detectors, and the informational relationships amongst them.

Let us analyze what we call now an electron. When a high voltage is applied to metal plates, a beam of light is observed (earlier called as a cathode ray). This is observed to interact with a number of detectors in characteristic ways. From these observations, the nature of this phenomenon can be abstracted out. It is observed to interact with electric and magnetic fields, so a charge and magnetic moment, respectively, are assigned to it. This beam is observed to bend in the presence of electric and magnetic fields. From the relationship between force (exerted by electric or magnetic field) and acceleration (the deviation of the beam), it is assigned a mass (J. J. Thomson found the charge-to-mass ratio in his classic experiments). Generally, these kinds of properties are known to be shown by what we call particles, so this ray is assumed to be made of particles, named as electrons. However, we come across more kinds of detectors eventually, where these electrons show another kind of relationships, not known to be shown by other kinds of ‘particles’. When this ray is passed through two narrow slits, which are very close to each other, and projected on a far screen, an interference pattern is observed, i.e., a property known to be associated with waves. Further, when the intensity of the ray is reduced, one can observe instantaneous spots on the screen, which, when accumulated, form an interference pattern. These kinds of relationships cause our intuitions about particles and waves to merge awkwardly, leading to the long-standing confusion, famously known as the wave-particle duality or the measurement problem.

We propose to revisit the scenario from a different perspective, namely, in terms of source and detectors. The source is a metal plate at high voltage (a cathode) and we make a variety of observations with different kinds of detectors. Instead of assuming an absolute entity called electron and trying to formulate an absolute picture of it, we can talk in terms of a relational entity related to different detectors in characteristic ways. The next step for us is to formulate these relationships between a source and a detector

in a coherent way. This will not only deliver us from the perennial wave-particle duality, but will open up possibilities to understand the nature in a much broader way, without limiting ourselves to the pre-conceived notions. Such an approach, where we talk in terms of relationships of a source with detectors, also imparts a semantic meaning to the objects under study. We find the formulation of quantum mechanics to be a useful framework in this direction, where the object to be studied is represented as $|\psi\rangle$, which is a relational entity. It has different relations with different detectors, which are represented as operators. However, the present formulation has many limitations. While it considers many physical properties as relational, still some of them, e.g., time, mass, charge, etc., are given an absolute status. Secondly, it is applied only at microscopic scales, while, at the macroscopic level, the absolute nature of the objects and physical quantities is assumed. We are working towards a mathematical formulation, some of which is presented in the preceding sections, that will enable us to talk directly in terms of the observed relationships between sources and detectors. Such a framework will not only give a semantic meaning to the mathematical quantities and formulas, but will also be robust to newer discoveries. Instead of collapsing, it will allow the newer relationships to be incorporated seamlessly to the existing repertoire of knowledge.

6 CONCLUSION

In this paper, we presented the fallacy of the present physical theories which ascribe an absolute status to various physical quantities and objects. Such theories provide a limited (even if coherent) picture of the physical objects, and face multiple problems and paradoxes when seen from a bigger perspective. We point out that these quantities and objects are derived from experimental observations, and hence, are emergent. Hence, instead of ascribing an absolute, or primary, status to them, it is far better to talk in terms of observations as primary. We discussed in this paper, that what we actually have are the experiences. But assuming these emergent properties to exist independent of the underlying primary properties and the observations, leads us into troubles. The semantic meaning in these emergent properties lies in as much as they correlate with the primary properties. Emergent properties and the formulation of relations amongst them helps us in capturing the relationships amongst the primary properties. This undermines any attempts to establish the ontological nature of emergent properties. We can at best talk of the ontological nature of the primary properties. From there, we can formulate relationships between a source and various detectors.

We hope that doing science based on observations, detectors and their relationships provides not only a systematic paradigm to study nature but also provides a semantic

meaning to it. We presented an example analysis of an electron in terms of such relational properties.

Currently, we are working towards building a mathematical framework of relational properties which will give a more concrete form to the approach we presented in this paper. We hope that this will bring in a unified way to study a wide range of phenomena at a wide range of scales, including both macroscopic as well as microscopic.

Whilst this approach calls for a fundamental change in our understanding of the world, it has a great potential to help us in finding new insights that will break the glass ceiling in the form of multifarious problems our present physical theories are facing. This will lead to bringing about a more holistic science, and therefrom, more holistic technologies. This will also bring a new light to our understanding of consciousness, i.e., instead of trying to find what biochemical processes cause observation or sense perception, we can take observation as the fundamental ontological reality and find how biochemical processes are related with the changes in our sense perceptions.

Department of Electrical Engineering, IIT Kanpur, India
vipular.iitk@gmail.com
lbehera@iitk.ac.in

REFERENCES

- [1] Dijkgraaf, R. (2017). To Solve the Biggest Mystery in Physics, Join Two Kinds of Law, *Quanta Mag.*, retrieved from <https://www.quantamagazine.org/to-solve-the-biggest-mystery-in-physics-join-two-kinds-of-law-20170907/>.
- [2] Gomatam, R. (1999). Quantum Theory and Observation Problem, *Journal of Consciousness Studies*, 6(11-12), pp. 173-190.
- [3] Gomatam, R. (2009). Quantum Theory, the Chinese Room Argument and the Symbol Grounding Problem, in Bruza, P. et al. (Eds.), *Lecture Notes in Computer Science*, Volume 5494, pp. 174-183, Springer
- [4] Heisenberg, W. (1925). Quantum-theoretical re-interpretation of kinematic and mechanical relations, *Z. Phys.* 33, p. 879.
- [5] Marletto, C., and Vedral, V. (2017). Witness gravity's quantum side in the lab, *Nature*, 547(7662), 156-158.

-
- [6] Peterson, R. T. (2008). Chemical biology and the limits of reductionism, *Nature Chem. Biol.*, 4, 635-638.
- [7] Ramachandran, R. (2012). Quantum view of Mass, arXiv preprint arXiv:1208.5852.
- [8] Singh, T. P. (2015). *The problem of time and the problem of quantum measurement*, in *Rethinking Time at the Interface of Physics and Philosophy* (pp. 177-191). Springer.
- [9] Werbos, P.J. (2008). Bells theorem, many worlds and backwards-time physics: Not just a matter of interpretation, *Int. J. Theor. Phys.*, 47, 2862-2874.
- [10] Wolchover, N. (2017). Quantum Gravity's Time Problem, *Quanta Mag.*, retrieved from <https://www.quantamagazine.org/quantum-gravitys-time-problem-20161201/>.
- [11] Wolf, F. A. (2017). Ontology, epistemology, consciousness, and closed timelike curves, *Cosmos & History: J. Nat. Soc. Philos.*, 13, 6594.