Sāṅkhya and the Foundations of Physics

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1. Introduction

One of the crowning achievements of modern physics is the Standard Model of particle physics. This is a collection of fundamental particles that are described in terms of quantum field theory (QFT), one of the most powerful tools in the arsenal of techniques used by physicists. However, the Standard Model is incomplete. For one thing, the masses, charges, and spins are parameters that cannot be derived from any other principle in the theory. It is well known that the Standard Model does not include gravity; however, the incompleteness of the Standard Model extends beyond that. A major issue with the Standard Model, as well as physics in general, is that there is no mechanism to explain the interaction of consciousness with the material world. The Vedic system of philosophy, however, *does* deal with consciousness, the material world, and their interaction. According to the Sāṅkhya system, the physical world is composed of *mahābhūtas*, which can be thought of as fundamental properties, and *tan-mātras*, which give information in the form of sense experience. Included also in the Sāṅkhya system is an analysis of the mind, intelligence, identity, and ultimately the consciousness, called the *atma*. This project is an attempt to develop a mathematical model for (possibly) the simplest part of the Sāṅkhya system, the *mahābhūtas*, and to discuss some potential applications to physics.

As stated above, the *mahābhūtas* are included in the Sāṅkhya system as the fundamental building blocks of the material world. They are five in number: *ākāśa, vāyu, teja, ambha, prithvi*, which are sometimes known in English as ether, air, fire, water, and earth. These five elements have their properties delineated in traditional Vedic texts (*Śrīmad-Bhāgavatam*, chapter 3, verses 34, 37, 40, 43, and 46 respectively)[1]:

1 A.C. Bhaktivedanta Swami Prabhupada. *Śrīmad-Bhāgavatam*, Fourth edition, vol. 4 (Bhaktivedanta Book Trust, 2013).

1. The activities and characteristics of the ethereal element can be observed as the accommodation of room for the external and internal existences of all living entities, namely the field of activities of the vital air, the senses and the mind.
2. The action of the air is exhibited in movements, mixing, allowing approach to the objects of sound and other sense perceptions, and providing for the proper functioning of all other senses.
3. Fire is appreciated by its light and by its ability to cook, to digest, to destroy cold, to evaporate, and to give rise to hunger, thirst, eating and drinking.
4. The characteristics of water are exhibited by its moistening other substances, coagulating various mixtures, causing satisfaction, maintaining life, softening things, driving away heat, incessantly supplying itself to reservoirs of water, and refreshing by slaking thirst.
5. The characteristics of the functions of earth can be perceived by modeling forms of the Supreme Brahman, by constructing places of residence, by preparing pots to contain water, etc. In other words, the earth is the place of sustenance for all elements.

In Vedic metaphysics, these five elements are concerned with everything including medicine[2], cosmogenesis[3], cosmography[4], and many other topics. But how are we to understand these elements? We already have a view of matter based on atomic theory that is able to give us detailed accurate predictions of the behavior of matter. How are we to understand the *mahābhūtas*? I propose that the *mahābhūtas* are fundamental properties that underlie our current physical theories. We will model these using the formalism of Wolfram Models.

2. Wolfram Models

Wolfram models are a class of finite automata introduced by Stephen Wolfram in 2020 in order to try to develop a fundamental theory of physics[5]. For a

2 Vasant D. Lad, *The Complete Book of Ayurvedic Home Remedies*, Third edition (New York: Three Rivers Press, 1998).

3 A.C. Bhaktivedanta Swami Prabhupada. *Śrīmad-Bhāgavatam*, Fourth edition, vol. 4 (Bhaktivedanta Book Trust, 2013).

4 Sanātana Gosvāmī, *Śrī Bṛhad-bhāgavatāmṛta*, vol. 2, First edition, translated by Gopīparāṇadhana Dāsa (Bhaktivedanta Book Trust, 2019).

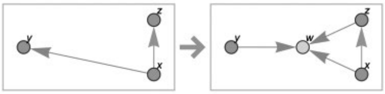
5 All figures in this section are taken from the introductions found on the following website: https://www.wolframphysics.org.

complete introduction to Wolfram models, go to the Wolfram Physics Project website[6]. Here we will only provide a basic introduction to the model.

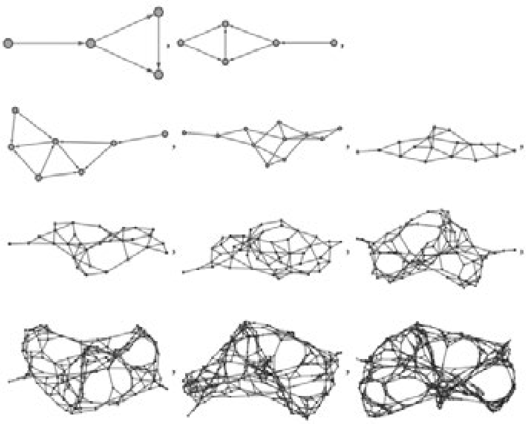
Wolfram models are in essence directed (hyper)graphs that update their topology according to predefined rules, which take the form of relations between sets. This is perhaps easiest to see using an example. Suppose we have the update rule:

$$\{\{x, y\}, \{x, z\}\} \longrightarrow \{\{x, z\}, \{x, w\}, \{y, w\}, \{z, w\}\} \qquad (1)$$

and the initial set graph $\{\{x, y\}, \{x, z\}\}$. Then we update the graph such that wherever we see the pattern on the left, we replace it with the pattern on the right, as shown in the following figure:



These rules can lead to very complicated graphs:



Although the above examples were just directed graphs, Wolfram models can also have self loops (edges starting and ending with the same node), multi-edges (multiple edges connecting the same two points) and hyperedges (connections between three or more points).

Associated with each graph is a second graph known as the casual graph. This is an analogue to a lightcone and encodes which node "caused" another

6 "Finally We May Have a Path to the Fundamental Theory of Physics. . . and It's Beautiful." https://writings.stephenwolfram.com/2020/04/finally-we

node: point A is connected to point B if the input to B involves the output from A. Just like a lightcone, two edges are causally connected if they can be connected through the causal graph.

It can be proved that in all Wolfram models, there are properties that correspond to accepted laws of physics. For example, one can derive properties related to Lorentz transformations, Einstein field equations, quantum mechanics, and ideas from most other branches of physics[7]. However, there is a problem with these as they were originally proposed: there is no *a priori* method for saying what rules should be used to reproduce our universe. This is what we hope to elucidate with this project: we wish to use the properties encoded by the *mahābhūtas* in order to determine what sort of update rules our graphs should have.

3. Using Wolfram Models to Model the *Mahābhūtas*

How exactly should we express the properties represented by the *mahābhūtas* in terms of our Wolfram models? We can get some indication by thinking about the fundamental particles as found in the Standard Model. Each particle is defined by some collection of values: mass, charge (of various kinds), and spin. Additionally, in quantum mechanics there are energy levels and interactions. In the Standard Model, these collections of values are parameters which cannot be derived from more fundamental theories, and the interactions are contained by the Lagrangians, which obey some symmetry laws. How do these values and interactions arise from Wolfram models? We shall discuss some general principles which will hopefully lead to actual specific rules.

We shall start with the *ākāśa*. This *mahābhūta* is slightly different from the rest. The *ākāśa* is the background on which the other structures are defined. If we look at the characteristics of the *ākāśa* given above, then it very closely corresponds to the idea of space. This gives a headway into a perspective on quantum gravity. One of the largest unsolved problems in physics is how to develop a theory that unites quantum mechanics and general relativity. This theory using Wolfram models is a candidate for such a framework, since both gravity and quantum mechanics are consequences of structures that are defined on this network. There are also cosmological questions that this helps to answer. For example, there are temperature correlations in the Cosmic Microwave Background[8]. In this framework, these angular correlations could

7 Proofs of these can be found on the Wolfram Physics Project website

8 Kin-Wang Ng and Guo-Chin Liu, "Correlation Functions of CMB Anisotropy and Polarization," I*nternational Journal of Modern Physics D* (1999), 08(01): 61–83.

be explained by the early universe being a smaller or more highly connected graph that grows later on.

The element of *vāyu* has to do with movement and allowing the approach of the information contained in the *ākāśa*. In terms of physical quantities, this could be thought of in terms of currents. Most generally, we can consider the ”*vāyu* principle” to be conserved currents. In physics there is a foundational result known as Noether’s theorem, which states that conserved currents come from symmetries of the underlying physics. So this element could also be considered as the symmetries from which these currents are generated. These symmetries are encoded in the form of mathematical structures called groups[9]. Physically, a group of major importance is the Poincaré group.[10] All of the fundamental particles are irreducible representations of the Poincaré group. Additionally, different particles obey rules that are preserved under different symmetry groups such as $U(1)$, $SU(2)$, or $SU(3)$. These symmetries are enforced in their respective Lagrangians.

In our model, how do we express particles? If we think about it, what we expect are a few properties:

1. *Persistence*: The particle is stable for some non-trivial length of time.
2. *Irreducible*: The particle is not a bound state of more fundamental particles.
3. *Distinguishable*: There are no two fundamental particles that have the exact same properties.
4. *Compositionality*: They are able to form bound states with other particles.

So we can think of particles in our model as structures in the graph that obey such rules. As an analogue in another cellular automata system, consider the ”glider” in Conway’s game of life (see Figure 1). This represents a more or less stable structure that can move across space and get emitted or absorbed by larger structures. We would expect that in our system, we would have similar particles.

Of course, the particles would have to obey the symmetry relations (whatever form they take) that form the basis of the *vāyu* rules. So in a certain sense,

9 Groups are structures with some operation (such as addition or multiplication) that has an identity (an element that does nothing) and inverses. An example are the integers with addition. Of vital importance is a group representation, which takes the group to an equivalent structure of operators. In standard particle physics, these groups take the form of Lie Groups, which also include a continuous structure.

10 Which is the set of all transformations of 4-dimensional spacetime that leave the 4- dimensional lengths preserved, with composition as an operation

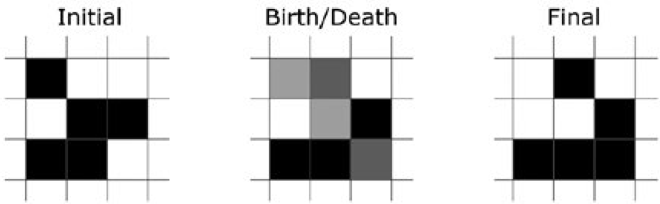


Figure 1. Glider from Conway's game of life

we can say that *vāyu* does not represent rules, in the sense of how to update the graph, so much as "meta-rules" that any rules that we wish to have due to later elements would have to satisfy. These rules, along with those from the following elements, could also give rise to ways to measure parameters that correspond to the Standard Model. An example of this could be measuring the correlation between two points: in certain quantum field theories this gives rise to terms like $\langle \phi(x)\phi(y) \rangle \approx e^{-|x-y|m}$, where ϕ is a quantum field that can then be used in our system to predict the mass of a particle. This approach could also help inform the search for new particles, since we can start with a symmetry group and then see what sort of particles are generated.

The next element, *teja*, corresponds to energy levels. This causes emission of light, heat, and other such changes. Note that in the current physical understanding, parameters such as mass, charge, and spin are constant for particles, while the energy level can change. This can be realized by having a core structure of a fixed mass, charge, and spin that is "decorated" by a structure that, absent any other external interference, will trend overtime (that is, over successive application of the rules) to go to the group state, or the "core" structure.

This approach could also give some insight into why energy levels are quantized. If we have a graph, which is a discrete structure, then it follows that there will be "gaps" between the energies that it is allowed to take. Note also that as we move from the first *mahābhūtas* to later ones, we get progressively less "fundamental": from the point of view of physics, if we change the mass, charge, or spin we get a different particle; but not so with the energy levels. We will see this trend continue.

The qualities of *ambha*, as given in the *Śrīmad-Bhāgavatam*, are a bit harder to understand in terms of physical quantities. However, if one looks closely, he can note that all of them that do not have to do with the subjective experience of a conscious person involve two or more types of things. This seems to indicate that the *ambha* principle is that of interactions. In the Standard Model, the allowed interactions are given by a function known as the Lagrangian. An example Lagrangian, taken from quantum electrodynamics, is:

$$L = \bar{\psi}(i\gamma^{\mu}D_{\mu} - m)\psi - \frac{1}{4}F_{\mu\nu}F^{\mu\nu} \quad (2)$$

where ψ is the electron-positron field, $D_{\mu} = \partial_{\mu} - ieA_{\mu}$ is the covariant derivative, $F_{\mu\nu} = \partial_{\mu}A_{\nu} - \partial_{\nu}A_{\mu}$ is the electromagnetic field strength tensor, and A_{μ} is the photon field.

The Lagrangian can be split into "kinetic terms" that feature squared functions (so in this case the terms $m\psi\psi$ and the term with the field strength tensor.) The other terms included would indicate what type of interactions are allowed to occur. For example, for this Lagrangian, we would have a term such as $-ie\psi A_{\mu}\psi$, which tells us that we are allowed interactions (or vertices in Feynman diagrams) that involve two fermions (electrons or positrons) and a photon, which can be seen in the example Feynman diagram in Figure 2.

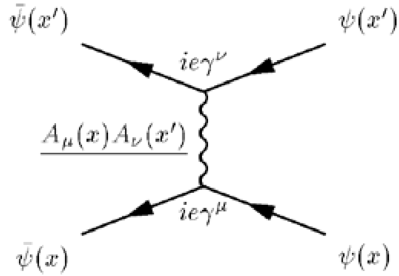


Figure 2. Electron Electron Scattering

This also can help tell us why every particle does not participate in every reaction (i.e. why there are chargeless particles.) In the Standard Model, these are simply based on experimental results: there is no theoretical reason why certain particles do not participate in certain interactions. But in our model, we should be able to see if there are any reasons that interactions between two particles, that is between two irreducible graph structures, are forbidden, which would give indication for the form of our Lagrangians.

This idea of interaction also leads to a discussion of the scale of these elements. If we look at condensed matter systems, such as a solid, then we can have quantities known as *quasiparticles*[11]. These quasiparticles can have an effective mass, charge, and spin as well as interactions. As an example, there is a quasiparticle known as a phonon: it is the particle description of waves in the lattice of a solid. However, one can treat these phonons as if they were interacting with electrons through the same machinery of the Lagrangian. This gives an indication that it is possible for our model to be applicable at

11 These are also sometimes termed "collective excitations."

multiple scales: we can use the same ideas to discuss particle physics, condensed matter, and possibly other systems such as cosmology as well.

The last element, *prithvi*, encodes order. Physicists tend to think of order in terms of its opposite: entropy. Entropy is a measure of the disorder of the system: it increases the more ways there are to rearrange things to get an equivalent system. However, *prithvi* is not entropy or order in itself, but is the principle (or set of rules) which encompasses both.

This provides the connection between classical and quantum mechanics. In quantum mechanics, all laws are reversible. For example, if we take the evolution of a quantum states

$$\psi(x, t) = e^{ihHt^{-}} \psi(x, 0) \quad (3)$$

where H is the Hamiltonian, the energy operator of the system. Then this equation is reversible in time: there is nothing stopping us from having time (t) run backward as well as forward.

However, in classical mechanics it is a different story. One of the strongest laws in physics is the second law of thermodynamics, which states that if S is the entropy, then

$$\Delta S > 0 \quad (4)$$

for all systems. This induces an "arrow of time," or to put another way, a non-reversibility in the laws. The *prithvi* principle encodes this non-reversibility. It is also possible that this has connections with information theory, with the rules determined by *prithvi* being a limit on the information that is available from previous elements.

This leads to several larger questions as well: given certain rules for our graph model, are the laws of thermodynamics derivable? The laws of thermodynamics are axiomatic, but are some of the strongest laws in physics. If we are able to give an indication for how these arise, it will speak to the strength of our model.

There is also another mystery in physics on which could shed some light. In statistical physics, the system is quantified in terms of its partition function Z; if one has this they know everything about the system. It is given by:

$$Z = \sum_{i=0}^{N} e^{-\frac{E_i}{k_b T}} \quad (5)$$

where N is the number of states, E_i is the energy of each state, T is the temperature and k_b is the Boltzmann constant. One will note the very close resemblance between $eihHt$ ¯ and $e^{-E}\underline{i}k_bT$. In fact this correspondence is used to great effect in lattice formulations of quantum field theory, where we can take the quantum mechanical operator and transform it into the statistical quantity, so that we can use the techniques of statistical physics on it. However, there is no known reason for why this correspondence occurs. One possibility in our model is that the rules of *ākāśa* through *ambha* that lead the quantum mechanical version get "filtered" through the rules of *prithvi* to get the statistical version.

4. Future Work

There are several avenues for future work connected to this model, broadly grouped into theoretical efforts, experimental efforts, and concepts connected with this model but not in the main theoretical program.

The first and foremost among the theoretical efforts would be codifying the exact rules that are needed to have a working model. This is a tall order, since it must recreate what is known about the Standard Model. Some of the work is already done for us: principles of relativity and quantum mechanics already exist in the model by their formulation. What is needed is to be able to model specific particles, rather than just particles in the abstract.

Related to this is that to ensure that our model is correct, it needs to be able to recreate known physics. We should be able to calculate the quantities that we already have by the "standard" physics methods in order to crosscheck our model. A related question to this is: on what level are we going to make our predictions? It should work for fundamental particles, but as mentioned above, it is possible for this to work at multiple scales; then we can find ways to fit other branches of physics as well.

After we get predictions that conform to known physics, we can also see if there are any new predictions (such as new particles or phenomena) that are given by this model. In both the known and new physics, we will also need experimental confirmation. Another theoretical aspect would be to explore whether this graphical theory can be transformed into a field theory, which might have better properties for phenomenological and theoretical investigation, whereas a discrete approach is better for computation.

There are also several concepts connected with the *mahābhūtas* that are worth investigating. The first is the idea of karma. According to relativity theory, any two events outside the lightcone of a third (i.e. not causally connected physically) are able to be ordered in spacetime however one wants by changing the frame of reference. This is an artifact of the finite speed of light.

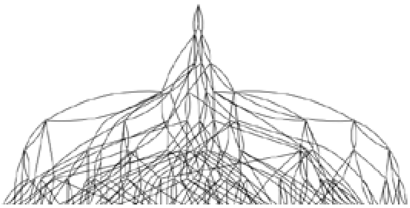


Figure 3. A Causal Graph

However, in traditional understandings of karma, there is no finite speed. But the idea of the causal graph (mentioned in section 2 below) is able to give us an idea of causality that is independent of the frame of reference, being an abstract relationship between points on a graph. This allows us to make a system of karma that is consistent with relativity.

Another area of connection concerns the ideas of the *tan-mātras*, information fields of the different sense experiences. How does this fit into the model? Moreover, in the Sāṅkhya system, certain *mahābhūtas* are associated with certain *tan-mātras* and not with others. How are we to understand this, since these *mahābhūtas* are thought to exist at the lowest physical level?

There seem to be two alternatives to how to approach this. Alternative one is that our senses go down to the fundamental level of reality, even past the level of the Standard Model. There are a couple of ways one could make this argument. The first is that they do so in the obvious way, and the reason we can't experience individual particles is that all of our sense experience gets averaged out by the aggregate. One could also argue that the machines that we use to view this level of reality, such as particle accelerators, are the way in which we access these *tan-mātras* at the fundamental level, since the machine is, after all, a product of our consciousness. The second alternative is one that I have mentioned in several places: that these *mahābhūtas* actually exist at several scales and therefore so do the *tan-mātras*.

Hopefully this model will be useful to model the physical universe, as well as shed light on philosophical questions relevant to physics. This is a very flexible model that also has a lot of potential for expansion, so hopefully it will be useful to scientists in the future.