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Scientific Method, Testability Criterion and Application for Multiverse

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Abstract

Scientific methodology upon which empirical sciences, including physics, are based, essentially encompass the framework within which physicists perceive the world and work toward modeling it. Criteria for having acceptable physics models have changed over time since 1900's, however, compatibility with observations/experiment is still largely regarded as the decisive criterion. On the other hand, recent progress in theoretical physics, especially in high energy physics and the notion of multiverse, has revived again the question of the relation between physics models and experiment. In this talk I state that, in my opinion, internal consistency, computability, predictive power, testability and compatibility with experiment/observation are the main five criteria for rejection or acceptance of ideas or models by physics community. I will then specifically discuss these criteria in connection with the notion of having a multiverse which appears in some different areas of modern theoretical physics.

`This is a work in collaboration with M. Golshani, S. Masoumi.`

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1 Introduction

As physics progresses and as in our formulations, theories and models we become engaged in questions which are far from our everyday experiences, and in this sense they become more abstract, one may always cast doubts on various entities, concepts and etc. introduced in physics formulations. Moreover, for similar reasons it is harder to gather and analyze observational data and we need to rely more on our deduction power, intuition or generalization of lessons from the history of science to gain ideas for constructing new physical formulations. On the other hand, again as history of science shows, no human-being and hence no scientist, perceives the world and thinks and analyzes it empty-mindedly; there are always assumptions or specific viewpoints at conscious or unconscious level which influence one way or other physical formulations made by physicists. It is hence more crucial than ever before to rethink/debate various elements, the stands, viewpoints or perhaps underlying beliefs which enter into our physics model building.

In this seminar, I will try to engage in such debate. Of course such debates and thinking have a long history and rich literature and is the subject of a well established academic discipline, the philosophy or history of physics (science). It would hence be impossible to delve into this in any meaningful depth due to my ignorance of the topics and also lack of time. Instead, I will try to present my own viewpoint and try to compare it with some mainstream schools of thought in the philosophy of science. This will be the subject up to section 6.

In the second part of my talk, section 6, I will adopt my "philosophy of physics theory" and view some contemporary problems appearing in HEP-TH or early Universe Cosmology areas, and in particular the question of multiverse, in some new lights provided by this philosophy of physics.

2 Basic Questions in Philosophy of Science (Physics)

In my understanding, philosophy of physics emerges in the attempt to answer the following fundamental questions:

1. What are physicists (or empirical scientists in general) up to?
2. How do we *demarcate* what is scientific (in the sense of empirical science) or not?
3. How do physicists work toward achieving their stated goal? Is there a unique stated way or unique scientific methodology?
4. How do they measure whether we have reached, approached or come closer to the stated goal?

As one can see the nature of these questions is of the kind that the answer to last three questions, does not come out through a logical deduction from the answer to the first. The answers to these questions lie out of the physics formulations themselves; these are questions in the realm of philosophy of physics.

There have been different answers proposed to the above questions based on different philosophical standpoints. Here, I will state mine and try to answer these four questions.

Disclaimer/Note: *My standpoints may be shared in part by some of the existing philosophies or may be a common denominator of those, while in cases may crucially differ from the existing ones. In such cases I will try to make a comparison.*

3 My take on philosophy of physics

Let me start with the most fundamental of the stated questions, the first one:

Physics is a collection of human knowledge based on common sensory.

Physics is about **modeling Nature.**
This modeling is done through and for **uncovering laws of Nature**.

One should note that all the statements above are philosophical stands and are not coming out of physics formulations themselves. The above statements needs some explanation.

- "Model" is a *representation* and any representation has three pillars, what is represented, which here is taken to be the "Nature"; the representor, which here is the notions, concepts and quantities appearing in physical model and in particular its "observables"; and finally the "relation" between representor and represented, the correspondence rules. Correspondence rules are statements which can take True or False values.
- A representation may ideally be a *complete isomorphism* or be a *partial* and/or *approximate* isomorphism.
- Implicit in the above is that Nature has laws, and that we human-beings are entitled to uncovering them, as similarly, we are entitled to using logic and deduction.
- Through historical examples and experiences we believe that the best language for presenting the physical models is mathematical theories and (mathematical) logic. This statement, again, is a (philosophical) assumption, which has shown its usefulness through the history of science.

  That is, a physical model is a set of mathematical equations/formulations through which we represent laws of Nature, relations among "quantities" associated with concepts or notions associated with Natural phenomena.
- We are about to model "the Nature". Therefore, we should take Nature to exist and to be "factual".

  As is implicit from the above, the "value" of the physical models is determined when compared against the Nature. This latter of course needs explanations and clarifications to which we will come next. Note that by "value" here I mean both its conventional commonsense meaning and its philosophical meaning, being (approximately) True or False. This latter is possible because I have already given, factual reference frame, the Nature.
- I take the *realistic* viewpoint, that Nature is real, it exists and that the notions, concepts and quantities appearing in physics models do correspond to objects in reality. For more discussion on this see section 3.3.

  One could have chosen the "instrumentalist" viewpoint where physics models are just instruments for making predictions about observables and for organizing our observations, as neo-empiricists like van Fraassen advocate. But that is not what I choose.

3.1 Structure of Physical Models

Before moving on further to the other questions, I would like to pause and state the terminology more common to physicists, but unfortunately not among philosophers (of science).

I would like to distinguish between physical **theories** and physical **models**. As mentioned physicists have found it extremely useful to use **mathematical language and logic** in their formulations.

Physical theories are *mathematical frameworks* in which the quantities and variables are chosen for an eventual of goal of being used in modeling Nature. One may perhaps divide physical theories into more fundamental ones, the **meta-theories**, over which many other theories can be built, and less fundamental ones. These *meta-theories* are very close to the notion of *paradigm* that Thomas Kuhn and constructivists following him are using.

This division may be a bit subjective, but I will explain it by giving various examples: Newtonian mechanics is a meta-theory, while e.g. classical theory of elasticity is not a hyper-theory it has its shoulders on Newtonian mechanics. Statistical physics is a hyper-theory, but theory of complete gases or thermodynamics are not. Quantum Mechanics is a hyper-theory, but perturbation or scattering theory are theories within QM. Special relativity is a hyper-theory, but e.g. relativistic theory of sound waves is a theory within this hyper-theory. Quantum Field Theory, is a hyper-theory, while e.g. chiral gauge theory or QED are theories within it. String Theory, is perhaps a hyper-theory, while supersymmetric gravity (SUGRA) or D-brane dynamics are theories within string theory. In general, a hyper-theory contains many sub-theories all of them have been constructed within the same framework and mindset.

For example, the whole branch of condensed matter physics is under the hyper-theory of (Quantum) Statistical physics. While, e.g. particle physics is now dominated by the paradigm/hyper-theory of (Relativistic) Quantum Field Theory (QFT). Atomic physics and quantum computations is dominated by QM hyper-theory and so on.

Physical models are models based on physical theories. It is in the models that mathematical *symbols* of the theories are loaded by their physical meanings. At the model level mathematical symbols of theories are dressed by their physical notions and concepts. In physics models the theories are tailored and adjusted to explain/describe certain physical systems or processes. Here the focus is on modeling specific Natural phenomena rather than providing a framework.

Examples of physical models, is Newtonian gravity (as a model for gravity); Bohr atomic model, Quantum ChrmoDynamics (QCD) as a model for strong interactions; Standard Model of particle physics, canon ball model for supernovae; various star evolution models and so on. In condensed matter physics, the distinction between theory and models are not usually as pronounced as in high energy physics or cosmology.

Measurement theory provides the framework how elements or symbols of a hyper-theory are related to possible observables in a given physical model. Any hyper-theory comes with its own measurement theory. And therefore, this measurement theory extends over all theories (and consequently models) built within this hyper-theory. For example, in QM measurement theory says that (only) norm of the total wave-function of a system is a measurable quantity. In Special Relativity, measurement theory states that any observer independent quantity is an observable. In QFT the measurement theory states that correlators of operators are physical observables.

Although the measurement theory of a hyper-theory extends over all its descendent theories, each sub-theory may have its own additions to this “meta measurement theory”. For example, in quantum gauge field theories, this is the gauge invariant correlators which are observables.

Physicists tend to construct the measurement theory at the level of the theory rather than the specific models. This is based on the understanding or intuition that the measurement and the correspondence of theoretical symbols and the natural phenomena should be model independent; this intuition or belief is stemming from the “realistic viewpoint” stated earlier that the mathematical symbols are in correspondence with realities and Natural phenomena.

A physical model generically contains some *parameters* specific to the phenomena it is modeling and some “dynamical” variables governing the *degrees of freedom*. The value of these parameters are not determined by the model or theory, they are inputs. Moreover, the mathematical equations of the model are generically of the form of (partial) differential equations of degrees of freedom, the solutions of which are specified only after giving the initial and/or boundary conditions. These latter too, are not specified by the model, they are inputs.

One may analyze the model and extract **observable-statements** from the model. These are combinations of degrees of freedom and parameters which are specified as observables of the model by its measurement theory. The observable-statements of the model are also called its **predictions**. The observable-statements of a model are *fallible*, i.e. they can take (approximately or partially) True or False values. While (mathematical statements) theories themselves, being derived from mathematical logic (and as long as the computations are correct) do not assume True or False values. However, once such theoretical statements are presented through specific models then one can search for their True or False value (more discussion on this will come later, in section 5).

3.2 Observations and Observation-Reports

As mentioned we deal with factual world/Nature. An observation is gathering data about specific phenomena. These data should be analyzed (oftentimes with statistical methods and with choice of model dependent *priors*) to extract **observation-reports**. As mentioned all our observations are done within a specific mindset and is not empty minded. Therefore, the observation-reports are influenced by the way the observations and data analysis are carried out; that is, the observation-reports are **hyper-theory-influenced** and **theory or model laden**. The observation reports are *fallible* and can be (partially or approximately) True or False.

3.3 Testability and Value of Models

Having extracted observable-statements from a model and prepared observation-reports of an experiment/observation, one can compare the two. Although, as mentioned each of these two are fallible and despite the fact that the observation-reports are hyper-theory-influenced and theory-laden, matching between the two provides a test for the model.

A model is hence called ***`testable`*** *if one can in principle prepare observation-reports which can be matched against* ***all*** *of its possible observable-statements.*

The observation-reports inevitably come with various kinds or *errors and approximations* and of course they carry information about specific phenomena. Therefore, the observable-statements of a model can in principle have a partial/approximate matching with the data. Depending how good is the matching, we have a partially/approximately true model; *the best scientific models are those with highest precision or least approximation.*

We should stress that as pointed out above, test of a model comes through `testing the observable-statements of physical models`; *theories and meta-theories are not directly put to test.* Nonetheless, scientists may declare a theory or hyper-theory false, as will be discussed in section 5.

Since we are adopting scientific realism (Leplin 1984), we perceive that

- Observable-statements are genuine, existential claims.
- *The approximate truth of a physical model is the only possible explanation of its predictive power.*
- Approximate truth of a physical model is sufficient explanation for its predictive power.
- The basic entities and concepts and quantities of the approximately true physical models are genuinely referential. Nonetheless, the converse is not true: a physical model may be approximately true even if it is not referentially successful.
- Physical models, theories and meta-theories are *progressing* when we improve them to describe/explain observation-reports (and hence Nature) better.

4 What is scientific (physical) and what is not?

With the above explanation about physical models and their testability we are now ready to answer the question posed above. Before stating our demarcation criteria and **testability** as its core, I will start with a brief review of logical empiricists' **verifiability** criterion, Popper's **falsification** criterion and Thomas Kuhn's **constructivism** which helped shaping neo-empiricists view of **experimental adequacy**.

4.1 A short review of present standpoints

One may ask if the question of *science demarcation problem*, that what is scientific or not, is a timeless question or differs in time. This question has been at the core of philosophy (of science) from the very early ages. Accepting that the answer is Yes, there have been many attempts to define its boundaries, especially in the last century or so.

The *logical positivists (logical empiricists)* tried to answer this question by defining what is **meaningful**. For them anything which its **truth** could be established was meaningful. They had only two sources of knowledge: *analytic* statements whose truth is based on logic and is *a priori*; and *synthetic* statements whose truth is **verified** by experiment/observation. The truth of synthetic statements are *a posteriori*. Anything which is not **verifiable** (**proved to be right or wrong**) were deemed meaningless and hence definitely outside realm of human knowledge and science.

Historically logical empiricists were challenged in many different ways, but perhaps most importantly by the facts that

- the very thesis of logical empiricists itself cannot be verified by any observation/experiment,
- from $P \Rightarrow Q$ True, Q True, one cannot *deduce* truth of P. That is, logical deduction based on *modus ponens* cannot be used to verify things.

This latter prompted Popper to propose his **falsifiability** criterion, motivated by the fact that from $P \Rightarrow Q$ False, Q False, then we can *deduce* P is true. According to Popper *demarcation* in science should be based on **falsification**:

Theories are scientific which could be falsified by observation-reports.

To Popper, logical deduction is not the only source to science production; scientists may be led by their intuition, beliefs and ... for construction of their theories but what is the defining rule to call them science is being falsifiable. Note that, the falsification rule should be viewed as a matter of principle, that theories should *in principle* be falsifiable and scientists should be working toward falsifying their own theories.

The above last statement seems to be self-contradictory: to try hard to construct a theory and then try harder to prove it false. Moreover, as admitted by Popper himself, observation-reports are oftentimes (if not always) pretty much theory-laden and truth of $P \Rightarrow Q$ statement mentioned above is not independent of the value of P. Furthermore, as stressed by Thomas Kuhn, history of science shows that the reason for abandoning a theory is usually not its falsification. Added to this, the observation-reports are not usually “overwhelming enough” to indicate false or truth of a theory. As put by Dohem and Quine, there is usually an *underdetermination* for proving some theory false. In practice we cannot usually conclusively falsify a theory. Scientists may still not abandon a theory which is falsified or conversely, abandon a theory which is not falsified yet.

Another critique to Popper is the fact that it rejects any kind of route, or methodology, to science and just focuses on the outcome. However, one can find several examples where falsifiability alone cannot appropriately demarcate what is thought to be scientific or not, e.g. religious belief and religion itself do have (in principle) falsifiable observable-statements while are not accepted to be scientific even by Popper himself. There are also examples of what is perceived to be scientific but not falsifiable.

This prompted logical empiricists, led by van Fraassen in 1980's, to reload, revise and loosen their *verifiability* criterion to **observational adequacy**:[1] To render a theory meaningful it is enough if it in principle can have sufficient supports from experiments. If a theory has observational adequacy it is deemed to be true. This thesis, however, is still within the main logical empiricists **anti-realism**, more precisely **instrumentalist** view and still stresses on logical deduction as the only way for theories leading to observable-statements.

Finally, for completeness I should mention that there are a group of philosophers who argue science demarcation problem has no timeless answer. They use Kuhn's historical/social viewpoint and conclude that *science is basically what scientists do.* One of the direct consequences of this stands is that people in this group should inevitably be anti-realists. Being an advocate of realistic viewpoint, we do not discuss this thesis here.

4.2 Testability as the demarcation criterion

Given the above discussions, we take the standpoint that

A model is called physical if it leads to observable-statements/predictions which can (in principle) be tested by observation-reports.

As we will discussed, giving a demarcation measure without specifying the scientific methodology will always suffer from underdetermination and the above testability criterion is no exception. So, a scientific model/theory should have some other additional (less important) criteria, which we call them **features**. These features, among other things, carry the main points of scientific methodology to make the demarcation unambiguous. These features should be used along with the testability to render it scientific. To this end, we use the lessons drawn from Kuhn's historical analysis. These **features** are:

- **Internal Consistency**: the model should be based on theories and meta-theories which have logical/mathematical internal consistency.
- **Computability**: A model/theory setup is physical which allows for extracting observable-statements via mathematical computation within it.

Once we declare a model within the realm of physics (by the above criteria and features), we need to establish its *grade* and where it stands among other competing models (or theories). The decisive *grading measure* of a model (see section 3.3) is its **observational compatibility**:

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[1] One of the reasons van Fraassen's thesis of constructive empiricism is viewed as significant is that it carries on the tradition of the logical positivists without being saddled with the problematic aspects of the positivists' positions. The constructive empiricist follows the logical positivists in rejecting metaphysical commitments in science, but she parts with them regarding their endorsement of the verificationist criterion of meaning, as well as their endorsement of the suggestion that theory-laden discourse can and should be removed from science. Before van Fraassen's "*The Scientific Image*", some philosophers had viewed scientific anti-realism as dead, because logical positivism was dead. Van Fraassen showed that there were other ways to be an empiricist with respect to science, without following in the footsteps of the logical positivists.

The best scientific models are those the observable-statements of which have the highest compatibility with existing observation-reports with highest precision or least approximation.

The above two features, besides assisting with the testability demarcation criterion, can also be used as a grading measure. In this capacity, we add the other **model grading feature,** the **predictivity**: a model is better if it has more predictive power; it can explain larger set of observation-reports with less inputs. This larger set of observation-reports are not necessarily related to observations of similar phenomena.

Grading of models would then naturally extend to the competing theory setup and the hyper-theory umbrella encompassing the model. For example, a theory which allows a simpler analysis and deduction of observable-statement (due to e.g. simpler mathematical structure) is a "better" model. Or a theory which allows for extracting observable-statement for a wider range of phenomena has a "better predictive power"; or a model which allows for making similar predictions with less (observational) inputs is a more predictive model, and hence better. Likewise, if the internal consistency of a theory is proved by smaller number of postulates or working assumption, it is a better theory.

I also share Kuhn's view that demarcation criteria and features, and grabbing the attention of the scientific community are not necessarily the same; it may happen that even in the presence of a "better" theory (e.g. by the above measures) another theory/model wins the consensus of the scientific community for a while. Moreover, the *grading features* mentioned above are not exclusive and some people may use features like elegance, beauty, simplicity and ... However, I would argue that these other criteria/feautres are already embedded (implicitly or explicitly) in the above mentioned features.

5 Our "Model" for Scientific Evolution: Theory Revision, Change of Meta-Theory

As discussed a model is called (approximately) true, and hence acceptable, if its observable-statements are in agreement with the observation-reports within their accuracy and precision range. However, it may happen that (some of) observable-statements of a model are not in desired agreement with observation-reports, i.e. there is a mismatch or *anomaly.* In this case, physicists try (their best) in constructing several different models within a given theory and hyper-theory setup. If with these new models and within the expected approximations and precisions of the observation-reports the *anomaly* still persists, then physicists are *led to the conclusion* that perhaps the theory setup does not provide the suitable framework for their modeling. In a loose sense one would say they conclude that theories are incorrect and false. In such a case they try to *modify, revise or improve* the theories, but still within the same hyper-theory, to resolve the anomaly. To this end, they reengage in model building within the new improved theories and repeat the model testing.

If after *trying their best* with modification in theory setup, the anomaly still persists, physicists are *led to the conclusion* that perhaps the meta-theories may need a revision.

Once we reach to this stage, the existing hyper-theory is in *crisis*. The crisis is usually resolved by a change in the hyper-theory.

The above cycle for modification and improvement in models, and if needed the theories, is the *normal phase* of scientific development, and if the anomalies are stubborn and survive such revisions and improvement, we enter into the crisis phase, which is resolved by a change of hyper-theory. Once the new hyper-theory is established we reenter the new normal phase again. This is essentially the cycle Thomas Kuhn depicted.

The "scientific evolution cycle" described above, despite similarities with Kuhn's *theory of scientific revolutions*, has important differences with it. For example, I used scientists "are led to conclude" that a theory revision or a change in hyper-theory is needed. Although, this conclusion is not a logical deduction (from the mismatch of observable-statements and observation-reports), it is definitely based on it; it may not be the only logical possibility, but is certainly among them. The kind of possible modifications and improvements are certainly *experiment/observation guided*, although admittedly they are also guided/influenced by the theory setup and by the hyper-theory (usually through the *intuition* based on the latter two). Although, admittedly there are extra-scientific factors are also playing role *establishment* of a new theories or meta-theories, their role is not as large as Kuhn points out.

Scientists usually try their best to resolve the issue with improving their models first. The next stage, usually reluctantly accepted, is theory revision. The revision in meta-theories is usually the last resort and is usually not advocated with the "older generation" who have lived their scientific lives in the challenged hyper-theory. The change in hyper-theory, if happens, will be *adopted and adapted* by the next thriving generation.[2]

6 Multiverse and Testability criterion

After setting the stage with my new philosophy of science, I would now like to apply it to one of the existing problems in HEP-TH or cosmology, the multiverse. To this end, I need to first give a brief account of what a multiverse is, and how and where it appears in physical models/theories.

6.1 Multiverse, a brief account of recent history

In the last century and within the realm of physics, multiverse was first mentioned in Everett's account of wavefunctions in quantum mechanics. Everett proposed in 1950's that all possible values that a wavefunction can take, or any state in the Hilbert space, is indeed realized (before making any measurement) in infinitely many "parallel worlds". Once

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[2] It is also notable that Kuhn's constructivism is based on an anti-realistic view, while ours is adapted within realism. Moreover, Kuhn tends to reject rationality behind scientific revolutions, putting more weight on social and historical backgrounds. In my viewpoint, the changes are rationally oriented toward achieving better theories and they are "guided" in the sense described above, furthermore, while social and historical stances play a role, the outcome of hyper-theory change is primarily an academic endeavor.

a wavefunction collapses due to a measurement one finds oneself in only one of them. These parallel worlds are all governed by the same physical laws. The parallel worlds idea was abandoned very soon, as it suffers from many basic problems.

More recent appearances of multiverse are all somehow related to the Quantum Gravity (QGr) problem. To see this note that due to Einstein theory of General Relativity gravity is a (classical) field theory with metric as its physical degree of freedom, and that metric of a spacetime is indeed (one of) the geometric quantities defining it, it is not unexpected that any attempt in quantizing gravity should one way or other deal with the possibility of having various metrics or spacetimes, the multiverse.

In QGr setups, the three places where multiverse is discuss (in historical order) are:

- in the Wheeler-De Wit quantum cosmology,
- in eternal inflation model (e.g. in chaotic inflation models),
- in string theory and its landscape.

In formulation of quantum gravity/cosmology through Wheeler-De Wit equation our observed Universe is the realization of reduction of a wavefunction defined on "superspace" or multiverse. The wavefunction of the Universe (as it is called) is governed by the Wheeler-De Wit equation. This approach to "quantum cosmology" was used by Hartle and Hawking to resolve the Big Bang singularity problem.

In the eternal inflation models, multiverse or pocket Universes as it is called in this context, are produced as a result of quantum fluctuations of inflaton field. In this setting, quantum fluctuations of inflaton are so large that they can compensate or dominate over the classical rolling of inflton field down its potential. Since these quantum fluctuations are random (not happen for all over the space uniformly), there are parts of the space which remain in inflationary phase forever and parts in which inflation has ended. We could be living in one of those regions, in one of the pocket Universes.

In string theory case, the story is different. The notion of multiverse, is a classical (not quantum) one. It appears because string theory is primarily formulated in ten or eleven spacetime dimensions. To relate it to our four dimensional spacetime we usually use compactification (on Calabi-Yau manifolds). In this picture all the properties of four dimensional theories or models are related to geometric properties of the compactification manifold. Although there are some (strong) consistency conditions on the compactification manifold for potential matching with our observed Universe, we still remain with a very large number of such possibilities for Calabi-Yau's, each associated with a Universe. This large number of possible Universes is called *string theory landscape (of vacua)*.

The landscape is not completely mapped and charted yet, however, it is believed that there should be around 10^{500} or more of such Universes. This poses a great danger to string theory itself, because regardless of the specific model built on each of these Universes, we need to have a mechanism or criterion to decide which Universe we are going to end up in. Unfortunately, string theory does not seem to provide such a mechanism or criterion.

This renders string theory, even as a hyper-theory, useless and unphysical because we need information from outside the hyper-theory for making this choice. This information can only becoming from a hyper-theory which exceeds string theory (need a paradigm shift) or may mean that string theory is not the right path.

There is, of course, another way out of the landscape problem: we may change our science demarcation criterion and live with theories which are not verifiable, falsifiable, or even testable. This last path is what has been advocated in the last 10-15 years among some string theorists. They suggest that the only important criterion for a scientific model is having some sort of **predictive power**, once helped with some "outside information". (A prime example of this was the S-matrix theory, which was finally abandoned in favor of Quantum Field Theory.) This outside information in this case is not provided by the theory nor by a direct observation-report; it said to be the **anthropic principle**.

While as stated, I have based my science philosophy and demarcation as testability, in view of the string theory opponents and advocates of anthropic principle, I would like to defend the testability. The core of my argument is that

> *If we open the door for anthropic principle, there is no argument, rational, or theory, to restrict its usage to only landing to a specific point in the landscape of string theory vacua, and not other places in science or physics. This will basically undermine all our current notion of science altogether.*

The above argument needs explanation and clarifications which comes in upcoming publications.

One of the questions which may arise is whether in addressing the issue/problem of multiverse, resorting to anthropic principle is inevitable for any kind of multiverse, or is limited to string theory landscape. And if it usage is inevitable for the string theory landscape and whether this forces us to revisit usefulness of string theory in the first place. Let me start with the latter question, as it is simpler to discuss: To our knowledge today (of string theory), string theory does not provide any way to land in a desired location in the landscape, leaving alone the fact that we have not yet found a completely desirable region/point on the places of the landscape mapped sofar. I stress that, this does not mean that such a criterion within string theory may not be found in principle. These issues and much more will be discussed elsewhere.

References

[1] In preparing this note I have crucially used the online **Stanford Encyclopedia of Philosophy**, `http://plato.stanford.edu`.