Geometrical Universe Hypothesis

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Max Tegmark, exploring implications of the External Reality Hypothesis (ERH) that there exists an external physical reality completely independent of us humans, claims that physics is so successfully described by mathematics because the physical world is completely mathematical, isomorphic to a mathematical structure, and that we are simply uncovering this bit by bit. In this interpretation, the various approximations that constitute our current physics theories are successful because simple mathematical structures can provide good approximations of certain aspects of more complex mathematical structures. In other words, our successful theories are not mathematics approximating physics, but mathematics approximating mathematics.[1]

In this essay we will give a sketch of the theory of mathematical physics compatible with ERH. We call it Geometrical Universe Hypothesis (GUH).

A theory of mathematical physics shall consist of:

- a **correspondence rule** which links a mathematical structure with an empirical domain (e.g. in General Relativity, gravitational force that can be measured is only a manifestation of spacetime geometry that can be calculated)

- an **empirical domain** (following the example above, we possess a lot of observational and experimental tests of GR)

- a **mathematical structure** (consistently following the same example, we hold 3+1 dimensional, pseudo-Riemannian manifold)

Correspondence rule

We have started from the correspondence rule as it has a potential to look at the vast existing empirical domain from a different angle and lead us to the correct mathematical structures. We do not need new data nor new mathematical structures. We need this different angle - a **paradigm shift**.

The best example of a real paradigm shift is General Relativity that we have taken as an example of a theory of mathematical physics. So let us start with GR which describes the relation between the geometry of 3+1 dimensional, pseudo-Riemannian manifold representing spacetime, and an energy–momentum contained in that spacetime. To understand and continue that revolution we do not need Einstein's equations and even pseudo-Riemannian manifold. What we need, at the moment, is the paradigm that the **force** is simply a **manifestation of spacetime geometry**. This is the **bond between physics and mathematics** (geometry). This is also the bond between the reality (geometry, mathematical structure) and our perception of reality (physics, experiments and measurements). We perceive and measure a force (physics), we know and calculate a deformation of spacetime (geometry).

By definition, a **force** is any **interaction** transferring **energy.** A **force field** is a vector field that describes a **non-contact force.** A non-contact force, in turn, is the force applied to an object by another object that does not stay in direct contact with it. Nowadays, the concept of direct contact forces is valid only in a colloquial language. Possibly, we could imagine a scientific meaning of that notion, in the case where an interaction/superposition of waves we called a contact (e.g. solitons can interact with other solitons and

emerge from the “collision” unchanged, except for a phase shift). Regardless of the fact that the general term of force is commonly used and convenient, what we have presented above implies that any force (as being non-contact) is a manifestation of spacetime geometry.

It is also the only explanation of another attribute of forces. They are **transmitted instantaneously**. A **propagation delay** in gravity would lead to unstable planetary and stellar orbits, what does not happen. In Quantum Mechanics, in turn, a force between two particles is described as an action of force *field* generated by one particle on the other, or as an exchange of *virtual* force carrier particles between them. In this case there is also no significant propagation delay in the force transmission. Albeit that is easy to prove only for the electromagnetic force/field that acts at much greater distances that nuclear forces. The concept of force carriers, however convenient for calculus, seems to be not indispensable here.

Summing up the correspondence rule: all **fundamental forces are non-contact** (action-at-a-distance)**, transmitted instantaneously, manifestations of spacetime geometries.**

So far we are aware of **no other compelling explanation** for the phenomenon of force/field. Therefore the concept deserves at least serious consideration.

Empirical domain

Today we recognize **four fundamental interactions** (forces/fields): gravitational, electromagnetic, strong and weak nuclear.

There are substantial differences between these interactions: a **scale/distance** they act over, an **attractive** or **repulsive** character, their **strength** and others like spin. All these attributes we can measure.

Gravitation and electromagnetism act over potentially infinite **distance**. The other two, act over subatomic distances. If we assumed, following previous considerations, the geometric character of them (an elastic spacetime distortion or curvature), we would understand that in reality the distances are also infinite. This is the attribute of any elastic medium. Why do we find their limits? The strength of every known field has been found to diminish with distance to the point of being undetectable. For example the Earth's gravitational force quickly becomes undetectable on cosmic scales. In the case of strong and weak nuclear interactions, the distance to the point of being undetectable is subatomic.

Gravity is the force of **attraction** that exists among all bodies having mass.
Electromagnetism is the force of **attraction** or **repulsion** that causes the interaction between electrically charged particles.
Strong nuclear force is an **attractive** or **repulsive** force and takes place between fundamental particles within a nucleus.
Weak nuclear force is an **attractive** or **repulsive** force that takes place between fermions (an alternative explanation is the emission or absorption of W and Z bosons).

Matter does not have an universal definition. It is not even a fundamental concept in physics.
So called “ordinary matter” is composed of quarks and leptons. It is adopted to consider only the first-generation particles: the up and down quarks, the electron and its neutrino.
Matter should not be confused with mass, as these notions are not the same in modern physics.

With this notion we have completed our empirical domain and we are about to look for the proper mathematical structures.

Candidates for mathematical structures corresponding to our universe

On the observational and experimental basis (empirical domain) and our previous considerations (Correspondence rule chapter) we can assume that spacetime is a **differentiable** (smooth) **manifold,** can be given a differential structure locally by using the **homeomorphisms** in its atlas, is **continuous**, has **elastic** property that is **isotropic**.

The mathematical structure we look for is an 3+1 dimensional spacetime.

The simplest mathematical structures corresponding to the spacetime of modern physics (including relativity) involves a set of **Thurston geometries** (the geometrization conjecture, proved by Perelman). We can treat them as a space-like, totally geodesic submanifold of a 3+1 dimensional spacetime.

In three dimensions, it is not always possible to assign a single geometry to a whole space. Instead, the geometrization conjecture states that every closed 3-manifold can be **decomposed** into pieces that each have one of eight types of geometric structure, resulting in an emergence of some attributes that we can observe. Thurston geometries include: the three-sphere S^3 the geometry of constant positive scalar curvature (parallel lines converge), three-dimensional Euclidean space E^3 the flat geometry, three-dimensional hyperbolic space H^3 the geometry of constant negative scalar curvature (parallel lines diverge) that all three are homogeneous and isotropic, and five more exotic Riemannian manifolds, which are homogeneous but not isotropic. These five exotic ones we will address shortly in the conclusion.

In the tables below we assign an interaction and matter to the proper Thurston geometries.

Interaction	**Gravitation** notice1	**Electromagnetic**	**Weak**	**Strong**
Maximum **scale** *(to become undetectable)*	infinite	infinite	subatomic	subatomic
Local geometry notice2,3 *(Bosons - "particles mediating")*	$\mathbf{S^3}$ *(Gravitons?)* notice1	$\mathbf{E^3}$ (Photons)	$\mathbf{S^3}$ (W^+) $\mathbf{H^3}$ (W^-) $\mathbf{E^3}$ (Z^0)	$\mathbf{E^3}$ (Gluons) ---------- $\mathbf{S^3}$ $\mathbf{H^3}$ $\mathbf{E^3}$ (Mesons)
Acts on	All	Electrically charged	Quarks, Leptons	Quarks, Gluons, Hadrons
Strength *(in the scale of quarks)*	10^{-41}	1	10^{-4}	60 *(not applicable to mesons)*
Spin *(geometric structure on a Riemannian manifold ?*[16][D])	*not applicable*	1	1	0, 1

Matter	**Leptons**	**Quarks**
Local geometry notice2,3 *(Fermions)*	**E^3** (Neutrinos) **H^3** (Electron) **H^3** (Muon) **H^3** (Tau)	**S^3** (u, c, t) **H^3** (d, s, b)
Spin *(geometric structure on a Riemannian manifold ?*[16][D])	1/2	1/2

Notice 1: gravity possibly can be an emerging interaction - a superposition of other geometries with S^3 being the outcome? Then it could be decomposed into the other geometries
Notice 2: *There is a metric associated with each geometry [6]*
Notice 3: *The geometries / metrics evolve by a wave equation. The constant curvature geometries arise as steady states of the **Ricci flow**, the other five homogeneous geometries arise naturally where the dynamics of the Ricci flow is more complicated and where topological changes (neck pinching or surgery: physicists might call these "wormholes") happen. This picture is not yet completely clear [14][C][15]*

The structures presented in the tables are **static,** space-like submanifolds (see Notice 3). The time is not included yet.
Let us recall our previous considerations that a *force is any interaction transferring energy***.**
The classical descriptions of **energy transfer** methods are:

- thermal radiation that is electromagnetic radiation - this is the **wave transfer** of energy
- thermal conduction is the transfer of internal energy by microscopic “collisions” of particles. As the matter exhibits wave-like behavior and forces are non-contact, this is also the **wave transfer** of energy
- mass transfer - the matter[A] exhibits wave-like behavior so this is also the **wave transfer** of energy.

As we can infer, **wave is the only method of energy transfer** (action of force, interaction). The wave is a periodic deformation of elastic medium (we assume - of space or spacetime). The elasticity and energy are the preconditions for periodic motion.

Unfortunately (or fortunately?) since this point we have started to compose a wave theory… Taboo.

The **weakness of wave theories** was that waves would need an elastic **medium** for transmission. The existence of the hypothetical substance luminiferous (light-bearing) aether was cast into doubt by the Michelson–Morley experiment. These gentlemen attempted to detect the relative motion of Earth through the stationary luminiferous aether . They could not take into account that matter (the Earth) also could be a wave packet made of the same, elastic medium like the light. The wave is a disturbance (or deformation), that travels through that medium, transferring an energy or matter. The wave motion transfers energy from one place to another, with **no permanent displacement of the points of the medium**. Conclusion: there is **no motion of Earth through the aether**. There is nothing to measure.

The nail in the coffin of the aether was the fact that Einstein's 1905 Special Relativity could generate the same mathematics without referring to the aether. This led most physicists to the conclusion that the notion of a luminiferous aether was not a useful concept. Below we present, more or less chronologically, some famous physicists’ opinions on the aether.

"Physical knowledge has advanced much since 1905, notably by the arrival of quantum mechanics, and the situation [about the scientific plausibility of aether] has again changed. If one examines the question in the light of present-day knowledge, one finds that the aether is no longer ruled out by relativity, and good reasons can now be advanced for postulating an aether. We have now the velocity at all points of spacetime, playing a fundamental part in electrodynamics. It is natural to regard it as the velocity of some real physical thing. Thus with the new theory of electrodynamics [vacuum filled with virtual particles] *we are rather forced to have an aether*". *Dirac P. [9]*

An aether theory might help resolve the EPR paradox by allowing a reference frame in which signals go faster than light. He suggests Lorentz contraction is perfectly coherent, not inconsistent with relativity, and could produce an aether theory perfectly consistent with the Michelson-Morley experiment. Bell suggests *the aether was wrongly rejected* on purely philosophical grounds: "what is unobservable does not exist".
Davies P., Brown J. R. [10]

The word “aether” has extremely negative connotations in theoretical physics because of its past association with opposition to relativity. This is unfortunate because, stripped of these connotations, it rather nicely captures the way most physicists actually think about the vacuum. . . . Relativity actually says nothing about the existence or nonexistence of matter pervading the universe, only that any such matter must have relativistic symmetry. [..] It turns out that such matter exists. About the time relativity was becoming accepted, studies of radioactivity began showing that the empty vacuum of space had spectroscopic structure similar to that of ordinary quantum solids and fluids. Subsequent studies with large particle accelerators have now led us to understand that space is more like a piece of window glass than ideal Newtonian emptiness. It is filled with 'stuff' that is normally transparent but can be made visible by hitting it sufficiently hard to knock out a part. The modern concept of the vacuum of space, confirmed every day by experiment, is a relativistic aether . But we do not call it this because it is *taboo*.
Laughlin R. B., Nobel Laureate in Physics [11]

Personally we do not like the word “aether” because of that negative connotations that could discourage the reader. This is the reason that we use the notion of elastic spacetime or space instead.

Summing up: the *wave* is a disturbance (or deformation), that *travels through the elastic medium* of spacetime, *transferring an energy and matter*. The **wave** motion **transfers energy and matter** from one place to another, with **no permanent displacement of the points of spacetime**.

Customary terminology in physics textbooks:

– a wave **carries on** an energy and information.

GUH states that:

– a wave (travelling spacetime disturbance) **is** an energy and information.

We write “**is”** rather than “**corresponds to**” here, because if two structures are isomorphic, then there is no meaningful sense in which they are not one and the same.[12]

[…] physics has come to focus on the way the external reality works (described by regularities known as laws of physics) rather than on the way it is (the subject of initial conditions). However, could it ever be possible to give a description of the external reality involving no baggage? [E] If so, our description of entities in the external reality and relations between them would have to be completely abstract, forcing any words or other symbols used to denote them to be mere labels with no preconceived meanings whatsoever. A mathematical structure is precisely this: abstract entities with relations between them. [1]

The description of geometrical structures, presented in this short essay, is obviously only very general sketch. It delivers the **initial conditions**, the abstract entities, and is focused on the way the reality is and not

on the way it works. We could not calculate anything on that basis. To specify the proposed structures we have to provide a lot of details of structures / metrics and properties of the medium. Just for example, for the elastic medium we would propose to use the generalized Hooke's law for the case of large deformations like Mooney-Rivlin model, the neo-Hookean solid, the Ogden model or others [13]. Tensors used in these models are also geometric objects that describe linear relations between vectors, scalars, and other tensors. But this and many other problems have not yet been solved...

Conclusion

Finally we are able to have our GUH broken down into:

- the **correspondence rule** that **all interactions and matter are manifestations of** spacetime **geometry**
- the **empirical domain -** gravitational, electromagnetic, strong nuclear and weak nuclear **measurements** and cosmological **observations**
- the **geometric structure** being a set of **Thurston geometries with metrics** and the **wave transfer**

GUH can be valid for any universe, however putting a harness of Thurston geometries on it, we are constrained to the universe we observe (our empirical domain). The correspondence rule itself remains universal and shall be valid for all other physical universes.
…universal structural realism can be taken as the two-fold claim that (i) our physical universe is an instance of a mathematical structure, and (ii), other physical universes, if they exist, are either different instances of the same mathematical structure, or instances of different mathematical structures.[2]

GUH makes the **testable prediction** that five more Thurston geometrical structures remain to be uncovered in nature. These are five exotic Riemannian manifolds, which are homogeneous but not isotropic: the geometry of $S2 \times R$, $H2 \times R$, the universal cover of $SL(2, R)$, Nil geometry and Solv geometry.

At the end we come back to Tegmark's claim that the physical world is completely mathematical. Only some things that exist mathematically exist physically, others do not.[3]

Let us try to find out why is that? We propose the **evolution of information** concept. To explain it very shortly, we have to apply the theory of Darwinism beyond its original sphere of organic evolution on Earth. The organic evolution refers to some pieces of DNA (a kind of information) and not to species (what is the most common misconception). Going further beyond information carried by pieces of DNA (that are sets of molecules), we observe only the waves (information) possessing long-term existence and stability. The comprehensive description of the information evolution is too extensive and deserves a separate essay.

The evolution of information refers also to our language (its syntax and semantics). The geometrical description of reality that we have used today is created by humans for humans. Albeit we are able to create another forms of geometrical description, especially visual languages, that would be more universal and baggage-free description [E]. But this problem has not been yet solved.

References

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Endnotes

[A] The elementary particles are certainly not eternal and indestructible units of matter, they can actually be transformed into each other. As a matter of fact, if two such particles, moving through space with a very high kinetic energy, collide, then many new elementary particles may be created from the available energy and the old particles may have disappeared in the collision. Such events have been frequently observed and offer the best proof that all particles are made of the same substance: energy.[7]
Eddington remarked, when observing the ocean we perceive the moving waves as objects because they display a certain permanence, even though the water itself is only bobbing up and down.[8]

[C] We have to normalize the Ricci flow to obtain a flow which preserves volume

[D] 3-manifolds can have more than one type of geometric structure

[E] …theories have two components: mathematical equations and “baggage”, words that explain how they are connected to what we humans observe and intuitively understand. Quantum mechanics as usually presented in textbooks has both components: some equations as well as three fundamental postulates written out in plain English. [1]