Gravity beyond Einstein? Part I: Physics and the Trouble with Experiments

Abstract: This article provides a review of the latest experimental results in quantum physics and astrophysics, discussing their repercussions on the advanced physical theories that go beyond both the SMs (standard models) of particle physics and cosmology. It will be shown that many of the essential concepts of the advanced theoretical models developed over the past 40 years are no longer tenable because they are contradicting the novel data. Most recent results (December 2016) from the Large Hadron Collider revealed no new matter particles up to particle masses of 1.6 TeV/c^2, which is in accordance with recent ACME experimental data (2014) that saw no electric dipole moment for the electron as predicted by these theories. Moreover, the LUX experiment (since 2013) did not see any dark matter particles either, thus independently supporting LHC and ACME measurements. Furthermore, experimental particle physics seems to be telling us that dark matter particles (LHC results) do not exist, suggesting that dark matter particles either are more exotic or are more difficult to detect than had been predicted in the past decades (less likely with recent LHC results). Astrophysical observations since 1933, starting with Caltech astronomer Zwicky, however, have provided irrefutable evidence for the existence of dark matter, for instance, based on the phenomenon of gravitational lensing as well as observed rotational velocities of stars orbiting the galactic center that are deviating from Newton’s law. Surprisingly, recent astronomical observations by Bidin, ESO (2010, 2012, 2014), seem to indicate the absence of dark matter within galaxies. In addition, cosmology at present has no explanation for about 68% of the energy in the Universe that comes in the form of dark energy. Recently, measured data from three entirely different types of experiments both on earth and in space (2006–2011) are hinting at completely novel features of gravity that, if confirmed, must be outside Einstein’s general relativity. Extreme gravitomagnetic and gravity-like fields may have been observed at cryogenic temperatures generated by a rotating ring or disk. However, these experimental results are not conclusive so far. The strength of these extreme fields has been calculated and, according to the respective equations, should be sufficient to serve as a basis for a gravitational technology that, for example, could establish long sought field propulsion (i.e. propulsion without fuel), actively researched by physicists and rocket engineers in the 1960s and 1990s. This article concludes with an outlook on the novel technology of gravitational engineering that might follow from gravity-like fields and discusses the novel physical concepts resulting from the existence of these extreme gravitomagnetic fields.

Keywords: Extension of Einsteinian Gravity by Extreme Gravitomagnetic Fields; Extra Dimensions Challenged by Experiments; Extra Systems of Numbers; Missing Particles and Recent Experiments; Recent Contradictory Experiments.

1 Introduction: Current Physics, Recent Experiments, and Astrophysical Observations

Gravitational technology has so far not been realised in the field of science. This means that gravitational fields, in contrast to electrodynamic fields, cannot be generated in the laboratory. Though the linearised Einstein equations, termed Einstein-Maxwell equations, are similar to the Maxwell equations of electrodynamics, the gravitational fields $E_g$ (acceleration field from static masses) and the so-called gravitomagnetic field $B_g$ (moving masses) produced in the laboratory are so extremely small as to be completely insignificant for technological applications. In
particular, the gravitomagnetic $B_\perp$ field, named in analogy to the magnetic induction field $B$, which is generated by a moving (rotating) mass (i.e. gravitational Lorentz force because mass can be considered as gravitational charge), is a purely relativistic effect (not present in Newtonian gravity) and thus very difficult to measure. This was clearly demonstrated by the Gravity Probe-B experiment [1] launched in 2004 that used the mass of the Earth (some $10^{24}$ kg) as a rotating test body to measure the so-called frame dragging effect over a period of about 10 months. Nevertheless, the tiny observed effect, in accordance with GR (general relativity), is far too weak to be of technological use. Einstein’s GR therefore cannot be employed in providing the building blocks for any type of gravitational technology.

However, as will be discussed in this article, there are numerous recent experiments that appear to be in conflict with the advanced (super) physical theories developed over the past 40 or 50 years.

The first class of these experiments is questioning the fundamental concept of these theories, namely the existence of extra spatial dimensions. This means that both the SM (standard model) of particle physics and cosmology may require major extensions but not as foreseen by supersymmetric theories, and limitations derived from present physical concepts may not be final. This article (subtitle: Physics and the Trouble with Experiments) presents and discusses those experimental results that are in conflict with current leading physical theories and demonstrates that the numerous ideas on which these theories are based are at least questionable or even no longer tenable. In addition, in Chapter 8 [2] and in the companion paper [3] entitled Generation of Gravity-Like Fields, ideas are presented that suggest an interaction between electromagnetism and gravity due to symmetry breaking and also require major extensions of both the SM of particle physics and cosmology. The postulated extreme gravity-like fields would be strong enough to serve as a basis for a gravitational technology, similar to the generation of magnetic fields in electrodynamics.

Furthermore, there exists a second class of experiments whose results appear to contradict each other. The most contradictory data concern the measuring of the value of Newton’s gravitational constant $G$, the radius of the proton, and the lifetime of the neutron. Recent careful analysis of these experiments showed no systematic errors, that is, the apparent contradictions in the measured results are not resolved in the framework of current physics (next section). The data of these experiments provide unmistakable hints that the present formulation of general relativity and/or particle physics may be incomplete.

Moreover, there is a third class of experiments that hint at the existence of additional gravitational fields. In particular, there are experiments, to be discussed in the following section, which might have seen extreme gravitomagnetic fields generated in the laboratory. There is also the possibility that these fields were generated (inadvertently) in the Gravity Probe-B experiment itself. The novel physics behind these fields may result from an interaction between electrodynamics and gravitation along with an interaction of the surrounding spacetime field. Einstein himself had surmised the existence of such an interaction – following an idea that goes back to Faraday who carried out substantial experimental work. If the experimental results of the observation of the so-called extreme gravity-like fields can be confirmed, drastic extensions of both the SM of cosmology (including general relativity, GR), and particle physics would be required. In addition, unification attempts of all physical interactions, in particular from string theory, would have to be reformulated.

Most recent experimental data from particle physics, in particular by the Large Hadron Collider (LHC) in Geneva, have revealed that the missing matter in the Universe, as predicted to exist in baryonic form by the most advanced physical theories, has not been found, severely questioning the physical concepts on which these theories are based. In operation since 2008, the LHC was hailed as the ultimate tool by numerous high-energy physicists in detecting the many new particles predicted by these theories, developed over the past four decades. Eventually, in December 2016, it became apparent that the LHC had not found any of these particles, including the long sought particle of dark matter. Lack of discovery of the particles predicted by string theory requires that the theory either undergo significant modification or accept that existence of those particles must be questioned. It is currently believed that four interactions exist: gravitational, electrodynamic, weak, and strong force, but if the experimental hints for the existence of extreme gravitomagnetic fields turn out to be correct, then gravity is more than Newtonian (Einsteinian) gravitation. Such shifts in theory have major consequences for accepting the validity of unified theories (extra dimensions, superstrings, multiverse, etc.). Long sought dark matter has revealed its existence only through its strong gravitational effects, holding galaxies together, but no dark matter particle was ever detected.

In addition, the most recent observations (September and October 2016) by McGaugh et al. [4, 5] (Section
2.3) are a further challenge for the (exotic) baryonic dark matter concept. Moreover, the idea that dark matter might be made of intermediate-mass primordial black holes in the 10 $M_\odot$ to 200 $M_\odot$ range was ruled out in 2016 by Mediavilla et al. [6]. Furthermore P. van Dokkum, Yale University, and Abraham, University of Toronto et al. in 2016 proved the existence of a so-called dark matter galaxy located in the Coma cluster about 329 million ly from Earth. This galaxy has an extension of about 100,000 ly and is almost as large as the Milky Way galaxy, but only comprises a few billion visible stars, that is, about 99 % of the matter must be dark. This unforeseen result was detected using an ingenious novel low-cost type of telescope, called the Dragonfly [7, 8]. The third option, namely that dark matter does not exist at all is deemed unlikely because gravitational lensing clearly is an established observed phenomenon. The experimental situation appears to be contradictory as both the measurements from the LHC and the astrophysical observations are beyond doubt. In Part II of this article, an attempt will be made to explain these otherwise irreconcilable facts.

If there were only one experiment contradicting the currently prevailing advanced physical ideas, one might argue that this experiment should be reconsidered or simply ignored for the time being. However, this view cannot be justified given the accumulated evidence inflicted by the numerous experiments as well as astrophysical observations that will be discussed below. The data from these experiments/observations demonstrate that the principal underlying physical concepts of the advanced physical models beyond the two SMs seem to be incorrect at the most fundamental level. The resolution of these contradictions most likely cannot be achieved by shifting theoretically predicted particle masses to a realm far beyond the LHC and requiring the construction of the next-generation supercollider, operational in 2050 – if it is feasible at all. Instead, it appears that the search for completely novel physical ideas has to be resumed in order to match physical theory and physical reality in a way suggested by the latest experimental findings.

After this brief warm up, where the status of current physics, recent experiments, and astrophysical observations were narrated, the second chapter introduces the recent LHC results and reveals their impact on the concept of extra spatial dimensions as well as high-energy particle physics. This is followed by discussions of the interplay of dark matter and particle physics, dark matter and astrophysical observations, and the presence or absence of dark matter inside galaxies, eventually leading us to the conclusion that major unresolved discrepancies of terrestrial experiments and astrophysical observations obviously exist. In the following chapter, two more sets of experiments are described concerning the proton size and neutron lifetime, which, although they were repeated several times, lead to mutually exclusive results. In each case, we describe the necessary details of the experiments and show how the apparent contradictions arise. Given that the collected experimental data is correct, it is suggesting a fundamental lack of understanding in our theoretical models. Next, Einstein’s GR is revisited, questioning the completeness of the theory, and, citing computational results from CDT (causal dynamic triangulation), possible further constraints on GR and spacetime topology are discussed. We then briefly present several measurements of Newton’s gravitational constant that are in conflict with each other, showing a discrepancy already in the third decimal place, a fact, however, that is incompatible with stated experimental bounds. Finally, two speculative topics are addressed, namely a possible interaction of electrodynamics and gravity (searched for since the time of Faraday) and, based on this interaction, the existence of extreme gravitomagnetic fields outside GR is pondered and their use as a means for propellantless propulsion (actively searched for since the 1960s) is outlined. This article concludes with a discussion of the present status of physical reality of extra dimensions and a possible extension of the four fundamental forces of physics in order to resolve the seemingly irreconcilable experimental facts presented.

All is not well with contemporary physics, or, the trouble with experiments.

The authors

2 Troubling Experiments and Observations I: Missing Particles and Higher Dimensions

In this article, a collection of recent experimental data from particle physics as well as astrophysical observations is discussed that appear to be in deep conflict with some of the aspects of the SM of cosmology as well as the so-called advanced physical theories beyond the SM of particle physics.

It is argued that fundamentally novel ideas are needed to be in accordance with all of these experimental
findings. In our companion paper [3], a physical model, termed EHT (extended Heim theory) [2] is presented that employs three completely novel and alternative concepts, namely, Heim space $H^8$, an internal eight-dimensional gauge space, providing a classification scheme for all existing particles and fields in conjunction with an extension of the system of numbers (replacing the concept of extra dimensions) from real ($\mathbb{R}$) to complex ($\mathbb{C}$), quaternionic ($\mathbb{H}$), octonionic ($\mathbb{O}$), and sedenionic ($\mathbb{S}$) (coupling constants) numbers [2] in order to set up a (much larger) class of physical symmetries, in an attempt to describe all of the existing particles and fields. These two concepts are then combined with the third approach, the extension of four-dimensional (Minkowski) spacetime by a so-called dual space (imaginary time coordinate), aiming at explaining the location and nature of both dark matter and dark energy.

In the following, those experiments are discussed whose outcome seems to be in contradiction with several of the key ideas of current advanced physical theories.

2.1 Large Hadron Collider Results

2.1.1 LHC Found No New Matter Particles up to Mass 1.6 TeV/c²

As recent results from the LHC [10] revealed, upon covering the entire range of particle masses up to 1.6 TeV/c², no new elementary fermions were detected. This is a most important fact because it calls into question some of the most basic predictions of all supersymmetry models. Apart from the Higgs boson observed in July 2012 (predicted by Higgs, Englert et al. in 1964) (the claim of a boson with a mass around 750 GeV/c² turned out to be wrong) as well as a possible anomaly in the decay of the $B$ meson, the search for matter particles remained futile. Of course, this does not mean the fall of the SM of particle physics. The SM has been confirmed experimentally in all of its aspects, but it is that the SM is incomplete because there is no dark matter particle in the SM, nor is there an explanation for dark energy, while gravity does not exist at all in the SM. This has been known for decades and so-called super… theories were developed since the late 1960s to provide the major extension of the SM.

Supersymmetry (SUSY), a major part of the super… theories, was invented in the late 1970s and is a symmetry of spacetime that changes the spin of a particle by a half-integer value, e.g. spin $\frac{1}{2} \rightarrow 1, \frac{1}{2} \rightarrow 3/2$ etc., converting fermions (matter) into bosons (mediators of physical force, interactions) and a boson into a fermion. The aim of the supersymmetry concept is to unify the two different concepts of matter and force. So far, it was assumed that Nature only knows particles of half-integer spin (fermions) and integer spin (bosons). Indeed, in three dimensions, all elementary particles can be classified as either fermions or bosons according to the Fermi-Dirac and the Bose-Einstein statistics. However, more recently, the concept of anyons was presented by Wilczek [12] and Laughlin [13], which are exotic quasiparticles that can take on fractional spin values, ranging continuously between the Fermi-Dirac and Bose-Einstein statistics. Their existence so far has not been proved, but very recently (August 2016), experiments with ultracold atoms reported the realisation of anyonic statistics for these exotic quasiparticles. Thus, the original goal of supersymmetry may be in jeopardy, i.e. anyons would be excluded from the supersymmetric description. In the SM of particle physics, there are 26 free parameters (including neutrino masses), in the supersymmetric model the number of free parameters exceeds 100 – not a really elegant or fundamental theory. Moreover, if R-parity (see below) is not conserved, extra

1 In 1977, the late B. Heim published his novel ideas for a unified description of elementary particles in Z. f. Naturforschung [9] by introducing an internal six-dimensional space in order to provide a classification scheme for all types of energy and matter. Heim did not suggest extra real dimensions. This was a step in the right direction but, as it turned out, was not sufficient to explain the existence of dark matter and dark energy particles, nor was the Higgs particle accounted for. However, Heim predicted an interaction between electromagnetism and gravity, but the principle of symmetry breaking was not utilized. There were other shortcomings in his theoretical work, e.g. the modified gravitational law he proposed turned out to be incorrect, etc.

2 The energy of the two particle beams of protons each is 7 TeV. However, it is the energy of the valence quarks within the proton that is to be used to generate novel particles. In the high momentum LHC particle beams, the $u$ and $d$ valence quarks of the proton only carry a certain percentage $\alpha \ll 1$ of the proton momentum, whereas the remaining momentum is distributed among the gluons and the sea quarks, that is, the virtual quark – anti-quark pairs created and annihilated by the strong interaction.

3 A completely different definition of supersymmetry is employed by P. Rowlands, Chapter 6 of [11]. Here fermions and bosons are their own supersymmetric partners through the creation of vacuum states, i.e. supersymmetry is an intrinsic property like the spin of the electron, so that the concept of real supersymmetric partners in order to solve the hierarchy problem is no longer needed. For instance, fermions generate their own vacuum boson super partners with the same energy $E$, momentum $p$, and mass $m$, i.e. in this case, the total energy coming from boson (positive) and fermion (negative) loops should add up to zero.
free parameters appear. In the absence of R-parity, there are no stable superpartners, i.e. there is no neutralino, which is the proposed SUSY dark matter particle, and the proton loses it stability.

If supersymmetry were an exact symmetry in Nature, every fermion of a given mass must have a superpartner boson of the same mass and vice versa. For example, for the electron, there should be a scalar electron (selectron), for the neutrino there would be a scalar neutrino (sneutrino), quarks would have scalar quarks (squarks), and the graviton of spin 2 should have the gravitino with spin 3/2 as superpartners. Obviously, Nature did not realise this concept. Thus, supersymmetry cannot be exact, that is, it must be a symmetry that is inexact or broken. The physical hypothesis of supersymmetry is that shortly after the hot Big Bang this symmetry actually existed (owing to the extreme temperature), but in the course of the cooling of the Universe, supersymmetry was broken – if it ever existed. The question remains at which energy scale this happened. At a supersymmetry breaking scale of 1 TeV, the gravitino mass should be about $10^{-5} m_e$ (electron mass), which is impossible because of recent LHC results. Moving the scale up to 10 TeV its mass should be around $10^{-8} m_e$ [14], much higher than the neutrino masses, but nothing has been observed. In addition, the predicted magnetic monopoles never appeared. The existence of supersymmetric particles is resting on the hot Big Bang hypothesis, which itself has not been fully verified so far (see the following discussion).

That is, it may be that there are no supersymmetric particles in Nature. Any hope for their future experimental discovery and validation in accelerators now rests on a super LHC of about 100 km diameter (see discussion below) – but this will take decades, provided such a machine can be built and operated.

The latest LHC data show no new fermions but also no new bosons (superpartners), that is, no new quarks ($u, d, c, s, t, b$) or leptons ($e^+, \mu^+, \tau^+, \nu_e, \nu_\mu, \nu_\tau$) or any other predicted superpartners were found as well as no gravitino. Supersymmetry as predicted by string theory therefore is in contradiction with the LHC results, and the numerous supersymmetric models are being phased out step by step as shown in Figure 4 (page 36) in [2] by the increasing accuracy of experiments. For example, relentless efforts at Harvard university during the past 3 years have lowered the experimental limit of the electric dipole moment of the electron down to $8.7 \times 10^{-31} e m$ (e is the electron charge), substantially lower than predicted by most of the SUSY models. The lower bound for the mass of a new fermion particle is now at 1.6 TeV/$c^2$ owing to the upgrade of the LHC in 2015. Due to these results, the inventory of matter with its 48 particles ($6 \times 3 \times 2$) flavored quarks and anti-quarks as well as ($6 \times 2$) leptons and antileptons has remained unchanged, i.e. it is as predicted by the SM of particle physics (gravity is not part of the SM).

Of course, it can be argued that there exist so-called extensions of the next-to-maximal supersymmetric models (NMSSM) and the many other variants that are not yet not ruled out. This argument is unphysical, and it reveals a major misconception of how physics is working. The requirement that all supersymmetric theories have to be ruled out by experiment in a step-by-step fashion is an unscientific demand. It is not the task of experimental physics to disprove scores of theoretical models. Instead, theory has to deliver a model that can explain the experimental data and provide guidelines for doable novel experiments to confirm (or falsify) its predictions (at least according to Feynman and Popper who require that any physical theory must be falsifiable – if not, it is not a physical theory). There are also R-parity violating SUSY models (this simply describes that $R=1$ for normal particles of the SM, and $R=\pm 1$ for their superpartners) that still have not been ruled out (and never will) because the energy scale these models are now predicting is beyond (present) experimental reach. $R$ is a multiplicative number and, if conserved, pair production should be expected, that is, the supersymmetric particle and the normal particle should be measured in the same event. However, the CERN (now retracted) data only showed a single 750 GeV boson but did not mention the partner particle. In addition, R-parity conservation (including a slight violation) requires the existence of a stable lightest supersymmetric particle (LSP) (because it cannot decay any further), which was never observed. These particles should be abundant from decays since the beginning of our Universe but have not been found, in spite of decade-long experimental efforts.

Every time experimenters succeeded to weed out a variant of the SUSY theory, new ones requiring higher particle energies appeared. Thus, these models, by construction, cannot be falsified, because the experimental effort to reach the next level of energy finally becomes insurmountable – it increases exponentially. For the past 40 years, every time a new accelerator has been commissioned, supersymmetry breaking has been shifted to higher energetic grounds in order to escape experimental evidence. This process started in the early 1980s (for instance, see the excellent article by Raby: Supersymmetry breaking at 100 GeV [14]). Fact is that the (few) specific predictions made so far, eventually turned out to be in contradiction to experiment. Theorists have been constructing revised theories at a much faster rate than experimenters are able to test them – suggesting
that there may be more basic considerations of theory to ponder. It is therefore correct that nobody can claim with certainty that the lack of SUSY at TeV scales does mean that SUSY predicted by string theory is experimentally excluded. At present, there is a complete absence of any hint for supersymmetry both from the LHC and from the ACME experiments. Because theory cannot make predictions on the energy scale of supersymmetry breaking, it remains completely unknown, except that experimenters over the past 40 years have shifted its lower bound from a few 10 GeVs to about 1.6 TeV (2016). In mathematics, the Landau symbol $O$ is used to classify the magnitude of an entity, and according to theorists, the LHC can be treated as a mathematical entity of type $O(1)$ TeV, i.e. it has the potential to generate new particles with a mass of order $1\text{ TeV}/c^2$.

In order to perform further research on SUSY – for the LHC delivered only a lower bound of $O(1)$ TeV – a new $O(10)$ TeV machine most likely will be needed. However, as the scale of supersymmetry breaking is not known, it may be advisable to directly proceed to the Earth accelerator, devised by Fermi in 1949 and termed the Globatron, which was meant to be operated in low earth orbit, and would roughly classify as an $O(100)$ TeV machine – alas an unfeasible construction.

Recently, there were theoretical arguments trying to relate the scale of supersymmetry breaking to the size of additional external compact dimensions based on the quantisation of the magnetic flux. In this context, it is to be noted that a different string theory based on heterotic strings (closed) is being considered to classify the existence of such a particle – which shows how flexible current advanced physical theories have become, and, at the same time, how far removed from physical reality [15]. Bosons are the carriers of physical interactions (forces). Since this boson would have been a particle of spin 0, it could most likely have been identified as a further Higgs boson. The Higgsinos proposed by string theory are of spin 1/2, and gauge bosons have spin 1. In Figure 18 (p. 146) of [2] the inventory of bosons and fermions together with a total of 12 charges is pictured, based on three groups of type $O(8, q)$, where $q \in \mathbb{H}$ denotes the set of quaternions.

The associated physical model is a collection of ideas categorised under the name EHT (extended Heim theory). EHT is basically different from what is known as string theory which is based on the existence of extra spatial dimensions, but instead is based on the extension of the field of numbers, i.e. going from real (complex) numbers to the field of quaternions that give rise to entirely novel physics (e.g. novel types of matter or extreme gravity-like fields outside GR), including the so-called 12 Higgs fields [2]. In EHT, extra spatial dimensions do not exist.

4 The effort of constructing and operating an $O(1)$ TeV machine, also known as LHC, cannot be overestimated. The LHC almost was a superhuman effort in technology, informatics, and applied physics requiring a circumference of 27 km, took more than a decade to build and test as well as tens of thousands of dedicated people at an overall cost of about 17 billion Euro. Hence, even experts may be hard pressed to predict the effort, cost, and time for an $O(10)$ TeV machine. Because Newtonian gravity has been shown to be valid on the microlength scale, it seems to be reasonable to consider the gravitational field as a superposition of the elementary fields of the individual atoms and molecules that are of size $10^{-10}$ m (or, from the protons and neutrons bound in the nuclei). Thus, it seems to be logical to assume gravity to be valid down to this scale, rendering the whole concept of extra spatial dimensions questionable.

2.1.2 LHC Found No Boson of Mass 750 GeV/c²

At this year’s conference on High Energy Physics (ICHEP) in Chicago, Illinois, on 5 August, CERN scientists from both the ATLAS and CMS experiments reported that new data did not provide any experimental evidence for a novel 750 GeV boson, which might have been seen in December 2015. Since December, already more than 500 theoretical papers were published in order to explain the existence of such a particle – which shows how flexible current advanced physical theories have become, and, at the same time, how far removed from physical reality [15]. Bosons are the carriers of physical interactions (forces). Since this boson would have been a particle of spin 0, it could most likely have been identified as a further Higgs boson. The Higgsinos proposed by string theory are of spin 1/2, and gauge bosons have spin 1. In Figure 18 (p. 146) of [2] the inventory of bosons and fermions together with a total of 12 charges is pictured, based on three groups of type $O(8, q)$, where $q \in \mathbb{H}$ denotes the set of quaternions.

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A new boson could mean that the novel physics accompanied with it may provide a possibility for a novel type of symmetry, that is, a new interaction. For instance, the assumed interaction between electromagnetism and gravitation, surmised by Faraday in the 19th century and long sought by Einstein, would require additional symmetries and mediator bosons [2]. It will be discussed below that the original Kaluza-Klein theory (1921, 1926) cannot lead to a unification of electromagnetism and gravity, because only neutral particles would exist. However, these gravitational bosons should not be produced in the LHC, but they may have been seen in the experiments of the gravity-like fields. There may also be processes in superconductors that give rise to novel heavy bosons.

The LHC in conjunction with the numerous other experimental results presented (from very diverse areas) have been sending an unmistakable but somewhat unexpected message:

– The SM [17] of particle physics has been fully confirmed.
– If neutrinos are to have mass, as required by experiment, this has to be enforced by additional seven parameters, resulting in 26 free parameters for the SM.
– The symmetries predicted by the super theories have not been found by the LHC. Every time a new accelerator went online and failed to detect these symmetries, they were shifted to a presently unavailable higher energy scale – mission impossible for the experimenters to falsify such a running theory. Weighing the experimental evidence accumulated over the past 40 years, it seems now to be more likely to consider supersymmetry breaking nonexistent. This means that, concerning the real physical model of particle physics, we are most likely back to the early 1970s.
– The absence of supersymmetric particles requires a symmetry different from supersymmetry, and thus, the quest for a totally different alternative theory has begun – no further scanning of the SUSY parameter space. This problem is not resolved by a new accelerator [O(10) TeV collider] but by the search of genuinely novel physical concepts.
– At present, particle physics has no place for a dark matter particle – in our Universe. If such a particle existed in a light version, i.e. less than 100 GeV/c², it would have been found long ago by Fermilab, Desy, or the LEP. It cannot be in the range of 100 GeV/c² up to 1.6 TeV/c²; otherwise, it would have been detected by the LHC.
– The nature of the dark energy is outside the SM and remains unknown, but there is compelling evidence that our Universe contains dark energy, currently modeled by Einstein’s positive cosmological constant \( \Lambda \) [18]. The anthropic argument of Weinberg has caused string theory of creating a vast number of vacuum configurations. Estimates predict that there must be at least \( 10^{500} \) distinct solutions. In simple words, the human species did win in the cosmic lottery against the odds of \( 10^{500} \) – suggesting no real physics.
– Gravity is outside the SM and thus no interaction with the other forces is possible, for example, as surmised by Einstein, the interaction between electrodynamics and gravity.

### 2.2 Higher Dimensions Challenged

The existence of extra spatial dimensions has been discussed for hundreds of years. Extra dimensions are supposed to provide the means of escaping the physical constraints imposed by the three spatial dimensions of our perceptible four-dimensional spacetime. As there is no direct evidence for additional dimensions of space, they might exist in the form of higher dimensional compact objects, e.g. as tiny loops or spheres. Most important, if the leading theories of particle physics – string theory, supersymmetry, supergravity, and the other variants beyond the SM of particle physics – are to be correct (see above), our Universe must be higher-dimensional, that is, there must exist more than three real spatial dimensions, as, for instance, postulated by Kaluza in a letter to Einstein already in 1919 [23].

\[^{7} \text{It is to be noted that our arguments are based on the most recent experimental results to provide credibility, because ultimately physics is an experimental science. However, as H. H. Bauer demonstrated in his recent article [19] and already in [20], science is not always evidence based. One of the most striking examples is the current climate debate. The findings of the comprehensive Sky experiments by H. Svensmark, Denmark and the Cloud experiment by Kirkby et al. CERN, on the formation of low altitude cloud cover as well as the long-term statistical analysis of temperature measurements by Scafetta and West [21, 22] are largely ignored together with the satellite temperature measurements since 1980. In May 2016, finally CERN scientists confirmed (6 years after the experiment by Kirkby) the earlier theory of Svensmark, Shaviv, Veizer et al. etc. This theory implies that the magnitude of the Sun’s magnetic field is controlling the cosmic ray flux density into the Earth’s atmosphere and thus is the major driver for cloud formation in the lower atmosphere. About two-thirds of the observed temperature increase (some 0.8 K ± 0.1 K since 1900) are to be attributed to this phenomenon. Instead, in 2012, NASA recalculated selected land-based measured temperatures and removed the original measured data, eventually producing a much steeper temperature gradient. Everyone remembers Climategate and the infamous hockey stick curve.}\]
Since then, numerous experiments have been performed to demonstrate the existence of these dimensions – but so far not the slightest hint of their existence has been established. Spacetime appears as four-dimensional, therefore higher dimensions need to form a compact space of small volume, otherwise, if of noticeable finite dimension, they should be visible. However, the original idea of Kaluza (published in 1921) has become untenable because the fifth dimension in order to unify electromagnetism and gravity would have a size of $6.7 \times 10^{-34}$ m and would lead to particle masses starting at about $10^{17}$ GeV/c$^2$, which is completely unphysical. Furthermore, in the meantime, the electromagnetic and the weak interactions have been unified, and thus, the original goal of Kaluza who only knew about gravity and electromagnetism has become obsolete. In order to produce observable masses in the TeV range, the coupling constant would have to be $10^{-15}$ weaker than the fine structure constant $\alpha$, but such an interaction was never observed.

As a five-dimensional world is no longer possible, the question arises if higher dimensional spaces are physically feasible? For the existence of a sixth dimension, this question can now be answered utilising the recent experimental results by Sushkov (see below) that proved the validity of Newton’s law down to the microscale, that is, to be valid at a distance of about 1 μm. Thus, the original idea of Kaluza and Klein (1924) also has become untenable.

The foundations of string theory – as a physical theory to unify the four fundamental forces – are becoming increasingly challenged by recent experiments and astrophysical observations that undermine string theory’s preeminence.

### 2.2.1 Size of Higher Dimensions

If higher dimensional spaces would have no measurable impact on our four-dimensional spacetime the 100 year-long search for their existence should have been discontinued for a long time. However, extra dimensions are deemed not only to be at the foundation of string theory and the unification of forces but are expected as a solution for the gauge hierarchy and dark matter problem. As physics ultimately is an experimental science, unequivocal experimental proof of their presence needs to be demonstrated.

For instance, how does such a higher dimensional space affect the value of the Planck length $\ell_{Pl}^{(D)}$ in $D$ dimensions? Which physical effects determine the size of extra spatial dimensions? What are the experimental constraints and how do theoretical predictions hold up against the most recent data?

If these dimensions existed, gravity needs to be defined in this $D=4+d$-dimensional world, where $d$ is the number of extra spatial dimensions, in conjunction with a different value of the higher dimensional Planck length $\ell_{Pl}^{(D)}$, where $d+3$ denotes the number of real spatial dimensions. There is exactly one real time coordinate. The Poisson equation of gravity in $D$ dimensions takes the form

$$\nabla^2 V^{(D)} = G^{(D)} \rho_m,$$

where $G^{(D)}$ is the modified gravitational constant that for $D=4$ is equal to Newton’s constant, i.e. $G^{(4)} = G_N$. The mass density $\rho_m$ is to be calculated with respect to the $d+3$-dimensional spatial volume.

Let us start with the simplest assumption, the existence of one extra spatial dimension, as Kaluza did in 1919. Suppose our Universe possessed one extra (hidden) spatial dimension that is curled up (compactified) into a circle of compactification radius $R_c^{(5)}$. The ratio between the five-dimensional constant $G^{(5)}$ and Newton’s constant is given by

$$\frac{G^{(5)}}{G_N} = 2\pi R_c^{(5)} = \frac{L_c^{(5)}}{\ell_{Pl}^{(5)}},$$

where $L_c^{(5)}$ denotes the size (length) of the (circular) compact higher dimension. This equation can be generalised to $D \geq 5$ dimensions [23]

$$\frac{G^{(D)}}{G_N} = 2\pi R_c^{(D)} = (\ell_{Pl}^{(D)})^{D-4},$$

where $R_c^{(D)}$ is the compactification radius and $\ell_{Pl}^{(D)}$ denotes the size of the compactified dimensions in the $D$-dimensional spacetime. Using dimensional arguments, the Planck length in $D$-dimensional spacetime, $\ell_{Pl}^{(D)} = 10^{-26}$ m (as chosen by Zwiebach to solve the hierarchy problem, see the following discussion), can be related to the Planck length in four-dimensional spacetime by the equation

$$(\ell_{Pl}^{(D)})^{D-2} = \ell_{Pl}^{(4)} \left(\frac{G^{(D)}}{G_N} \right) = \frac{\hbar G^{(D)}}{c^3} = \ell_{Pl}^{(4)} (R_c^{(D)})^{D-4},$$

where the speed of light $c$ was also used for the extra dimensions, in spite of the fact that only gravity can propagate into these higher dimensions (through the curvature of space). That is, photons are confined to our four-dimensional spacetime. It is also generally assumed that
mass $m$ and length $\lambda$ in higher dimensions are related by the usual formula from four dimensions $\lambda = \frac{h}{mc}$, despite the absence of electromagnetic phenomena in the extra dimensions.

For our spacetime $D = 4$, the abovementioned formula gives the well-known result $\ell_{Pl}^{(d)} = \ell_{Pl}$, that is, the compactified Planck length $\ell_{Pl}^{(d)}$ is equal to the Planck length $\ell_{Pl}$.

Replacing the ratio $G^{(d)}/G_n$ by $(\ell_{Pl}^{(d)})^{-A}$ in the abovementioned equation, the size of the compactified dimension $L_{C}^{(d)}$ can be expressed by the two Planck lengths $\ell_{Pl} = 10^{-35}$ m (value of the Planck length in our four-dimensional spacetime) and the Planck length in $D$-dimensional space, $\ell_{Pl}^{(d)}$, in the form

$$L_{C}^{(d)} = \left(\frac{\ell_{Pl}^{(d)}}{\ell_{Pl}}\right)^{2 - A} \ell_{Pl}^{(d)}.$$ (1)

If the relation for the number of extra dimensions $d = D - 4$ is used, the abovementioned equation can be written as

$$\left(\frac{L_{C}}{L_{Pl}}\right)^d = \left(\frac{\ell_{Pl}^{(d)}}{\ell_{Pl}}\right)^{d+2} \ell_{Pl}^{2},$$

which means that the size of the compactified dimension $L_{C}^{(d)}$ is known when the respective Planck length in $D$-dimensional spacetime is fixed. Taking the logarithm of (1), the relationship between the compactified size $L_{C}^{(d)}$ and the Planck length $\ell_{Pl}^{(d)}$ of the $d$-dimensional space of extra dimensions is given by the equation

$$\log L_{C}^{(d)} = \left(1 + \frac{2}{d}\right)\log \ell_{Pl}^{(d)} - \frac{2}{d} \log \ell_{Pl},$$ (2)

where $\log$ denotes the logarithm with respect to basis 10. The corresponding Planck mass in $D$-dimensions in the so-called natural units, $h = c = 1$, is defined by the relation

$${m_{Pl}^{(d)}/\ell_{Pl}^{(d)}} = 1.$$ (3)

Inserting this relation into (2) expresses the size of the extra dimension $L_{C}^{(d)}$ by the corresponding Planck mass $m_{Pl}^{(d)}$ in the form

$$\log L_{C}^{(d)} = \left(1 + \frac{2}{d}\right)\log m_{Pl}^{(d)} - \frac{2}{d} \log \ell_{Pl},$$ (4)

which requires length and mass to be expressed in Planck units also termed natural units. In natural units, the Planck mass is given by $m_{Pl}^{(d)} = G_{Pl}^{(d)} = 1.22 \times 10^{19}$ m and the Planck length $\ell_{Pl}^{(d)} = G_{Pl}^{(d)} = 8.17 \times 10^{-35}$ m. In order to compare our results with the recent data from Chapter 6 of [24] as depicted in Figure 1, mass values must be converted from

![Figure 1: The picture (programmed in Tikz) looks similar to the pictures polyphonie or measure individualisée des niveaux of the famous painter-poet Paul Klee. The plot shows the Planck mass in $D$ dimensions, $m_{Pl}^{(d)}$, versus the size of the extra dimension, $L^{(d)}$, using (1) that is in natural units (nu). However, the abscissa has been relabeled to express mass in the more common units GeV/c$^2$ and the ordinate was rescaled to express length in SI units (m). It is to be noted that the scale on both axes is logarithmic. The six straight lines in white are the graphical representation for the extra dimensions $d = 1, \ldots, 6$ ($D = d+4$), that is, $d = 6$ corresponds to the case of superstring (supersymmetry) that is formulated in 10 dimensions. There are seven differently colored regions that are explained in the text. The most striking results is that none of the white lines $d = 1, \ldots, 6$ does intersect the green areas.](image)
natural units utilised in (4) into SI units shown in Figure 1 employing the following two relations, namely
\[ m \approx \frac{h c}{\sqrt{\beta}} \times 5.62 \times 10^{-26} \text{ m}^{-2} = 10^{16} \text{ m}^{-2} \]
whereas length values are calculated as
\[ l \approx \frac{1.98 \times 10^{-30} \text{ m}}{\text{m}} \approx \frac{5.62 \times 10^{-26} \text{ m}}{\text{SI}} \] 8.

The resulting curves for the six extra dimensions (D = 5, ..., 10) depicted in Figure 1 were calculated from (4) employing the above conversion factors. Equation (4) represents a set of straight lines with the slope parameter depending on the extra dimension D = 1, ..., 6.

It is to be noted that Raychaudhuri and Sridhar [24] are still using a lower bound of 60 µm for the validity of Newton’s law, but the newer results from Sushkov have extended the range of Newtonian gravity down to the microscale of approximately 1 µm which puts a further stringent constraint on the size of extra dimensions.

Moreover, the LHC recently explored physics down to a scale distance of approximately 10^{-20} m, which can be seen from Heisenberg’s uncertainty relation Δx Δp ≥ ℏ/2. Together with the energy of the two colliding proton beams at 7 TeV (per colliding nucleon in the center-of-mass-system), the corresponding length \( λ_{\text{LHC}} \) is obtained as
\[ λ_{\text{LHC}} = \frac{hc}{2E} = 1.973 \times 10^{-7} \times 7.14 \times 10^{-14} = 10^{-20} \text{ m}, \]
where \( hc = 1.973 \times 10^{-7} \text{ eV m} \) was employed. As the LHC did not find (and according to EHT cannot find) any new matter particles, this distance, or a somewhat smaller one, can be taken as the fundamental length, and therefore, it seems reasonable to choose this value, i.e.
\[ \ell_{\mu}^{(0)} = 10^{-20} \text{ m for } D \geq 5. \]

It should be noted that \( \ell_{\mu}^{(0)} \) (i.e. \( m_{\mu}^{(0)} \)) in Figure 1 is a variable that is, nevertheless, subject to severe constraints as can be visualised from the different colored areas. In the following, the abovementioned value of \( \ell_{\mu}^{(0)} \) will be used to calculate the size \( L_{\mu}^{(0)} \) of the extra dimensions D = 5, ..., 10.

Inserting the value \( \ell_{\mu}^{(0)} = 10^{-20} \text{ m} \) in the equation for \( L_{\mu}^{(0)} \), the value of the spatial extension in the fifth-dimension is given by
\[ L_{\mu}^{(0)} = \frac{\ell_{\mu}^{(0)}}{\ell_{\mu}^{(0)}} = 10^{\mu} \text{ m} \]
or 10 million km, that is, the extra spatial dimension extends over an astronomical distance. In 1921, Kaluza’s extension of Einstein’s GR was finally published utilising a five-dimensional theory that aimed to describe both gravity and electromagnetism. Later, in 1926, Klein postulated a curled up microscopic fifth dimension in order to be in agreement with quantum mechanics. At that time, however, the experimental constraints discussed above were not known that put a stringent limit on the size of the microscopic fifth dimension. The size of the fifth dimension therefore is not a free parameter. It is obvious that such a large five-dimensional space does not exist; otherwise, shortcuts through this dimension would have been taken a long time ago. Thus, a five-dimensional world cannot exist as described in a recent article [25] speculating that the 750 GeV/c^2 boson of spin 0, believed to have been seen at CERN (but now retracted), is coming from a fourth spatial dimension. The existence of such a dimension now is experimentally ruled out by the measurements of Sushkov (below) that have proved the validity of Newton’s law down to the microscale, as will be discussed in the following paragraph. In particular, any physical model that proposes the graviton of being capable of propagating into a fourth or fifth spatial dimension – suggested to explain the weakness of the gravitational interaction – most likely cannot be correct.

There are, however, further difficulties with the fifth dimension (compact and curled up, described by \( \text{S}^5 \times \text{S}^1 \), that is, our spacetime plus a circle) and the unification of physical interactions. Kaluza (and later Einstein) attempted to unify gravitation and electromagnetism. In five dimensions, the metric tensor is denoted by \( g_{\mu
u} \) where \( M, N = 0, 1, 2, 3, 4 \) that is a 1+4 dimensional world (sometimes the fifth coordinate is denoted by index 5, i.e. \( \varphi = g_{\phi} \) becomes \( \varphi = g_{\phi} \)). The four entries of the fifth row and column are identified with the field \( A_{\mu} \), and there is the additional scalar \( \varphi = g_{\mu
u} \). The field \( A_{\mu} \) has been identified with the electromagnetic four-potential and \( \varphi \) must be a four-scalar. If one applies a translation around the fifth (compact) dimension, the \( A_{\mu} \) components behave like the component of the electromagnetic potential and thus are indeed related to spacetime curvature. It can be shown [24] that starting with a pure gravitational theory in five dimensions one obtains

8 In order to convert the Planck mass from natural units [m^3] into SI units [kg], one uses the conversion \( m_P = \sqrt{\frac{\hbar c}{\beta}} \times 5.62 \times 10^{-26} \text{ m}^{-2} = m_P \times 10^{16} \text{ m}^{-2} \) where \( \hbar c = 3.16 \times 10^{-5} \text{ Js} = 1.973 \times 10^{-2} \text{ eV m} \) was used. Often the mass is given in GeV/c^2 or in TeV/c^2. In order to convert from SI units to eV energy units, one has to use the factor 1 eV = 1.602 \times 10^{-19} \text{ J} and to observe that 1 kg = 9.0 \times 10^{-10} \text{ eV m}^2. Hence, the Planck mass is converted from natural units according to \( m_P = G_P = 1.24 \times 10^{18} \text{ m}^{-2} = 2.176 \times 10^{-4} \text{ kg} = 1.22 \times 10^{-20} \text{ GeV/c}^2 \). In order to convert a mass from natural units [m^3] into GeV/c^2, one uses the combined conversion \( m_P = \sqrt{\frac{\hbar c}{\beta}} \times 5.62 \times 10^{-26} \text{ m}^{-2} \) where \( m_P = m_P \times 10^{16} \text{ m}^{-2} \).
both Einstein’s GR in four dimensions and the Maxwell action term for electromagnetism (denoted as \(-\frac{1}{4} \varepsilon_{\mu
u} \varepsilon^{\mu
u}\)) – if the scale factor in the fifth dimension is set to \(\phi = -1\), which was done without any further justification by Kaluza to obtain a Minkowski space. Hence, it could be concluded that electromagnetism is a gravitational effect resulting from the compact nature of the (real) fifth dimension. Thus, physics might be the result of the curvature of spacetime, and electromagnetism comes from the curvature in the fifth dimension – notwithstanding the fact that \(\phi = -1\) stands for a flat space (the Minkowski metric is the metric of the vacuum, i.e. no gravitational and no electromagnetic field). However, in 1949, Jordan [26] showed that this constraint leads to the condition \(F_{\mu\nu} F^\mu\nu = 0\). This is inconsistent with QED (quantum electro dynamics) because the Lagrangian of QED of course must contain the Maxwell action term \(F_{\mu\nu} F^\mu\nu\).

According to EHT, physics cannot be constructed from pure geometry (e.g. spacetime) because this goes against the governing fundamental physical principles as laid down in Chapter 6 of [2] This primeval topic will be briefly discussed further in Section 8. This means nothing less that the principle of duality is at the foundation of the entire Cosmos (order), governing the physical world, and therefore the two most basic, but complementary (dual) physical entities, namely, spacetime and dark energy both have to be generated at the same instant of time. The most general aspect of duality is represented by symmetry formation and symmetry breaking. As required by the general principle of energy conservation, the total energy of the Universe is always zero, \(E_{\text{Tot}} = 0\). Hence, according to duality, at any instant of cosmic time \(E_{\phi} = E_{\text{Tot}}(t) + E_{\phi}(t) = 0\), where dark energy \(E_{\phi} > 0\) – assuming that any other energy form in the Universe results from the conversion of dark energy – and the potential energy of the spacetime lattice \(E_{\text{lat}} < 0\) (Chapter Concepts of Cosmology in [2]). They are two sides of one and the same medal. Because of the inherent cosmic dynamics, the values of these two energies must be time dependent. They are the very cause of all dynamic cosmic processes. There exists an arrow of cosmic time, but the Universe eventually has to reach a turning point because of its finite time of existence (all physical phenomena are considered finite, i.e. there are no singularities in physics, only in mathematics).

Because of the periodic boundary condition in the fifth dimension \(y = y + L_{C}^{(5)}\) (circle topology), where \(y\) (as usual) denotes the spatial coordinate in the fifth dimension and \(L_{C}^{(5)}\) is the length of the compactified dimension. As a consequence of this periodicity, it turns out that the electric charge should be quantised \(q_n = n \sqrt{16\pi G_N} L_{C}^{(5)}\) (in natural units) with \(n = 1, 2, \ldots\). Using \(n = 1\), the elementary charge quantum is given by

\[
e = \sqrt{\frac{16\pi G_N}{L_{C}^{(5)}}}.
\]

Inserting the value of Newton’s constant \(G_N = 6.7 \times 10^{-39}\) GeV \(^{-2}\) and using the known value of the elementary charge \(e = \sqrt{\frac{4\pi\alpha}{\alpha}} = 0.3\) (natural units, \(\alpha = 1/137\) is the fine structure constant) the compact radius of the fifth dimension is given by the equation [26]

\[
L_{C}^{(5)} = \frac{4\pi G_N}{\alpha} = 6.7 \times 10^{-36}\text{ m}.
\]

Let us accept this value of \(L_{C}^{(5)}\) for the moment. The respective solution of the Klein-Gordon equation in five dimensions, described by wave function \(\Phi(x, y)\), where coordinates \(x = (x')_\mu, \mu = 0, 1, 2, 3\) describing our spacetime, \(y\) denoting the fifth dimension in conjunction with periodic boundary conditions, does lead to a spectrum of possible masses

\[
m_n := \sqrt{m_0^2 + n^2 / (R_{C}^{(5)})^2}, \quad n = 1, 2, \ldots,
\]

where \(m_0 = 0\) may be assumed, that is, a massless zero mode (e.g. photon). Inserting the value of \(R_{C}^{(5)} = L_{C}^{(5)} / 2\pi\), the first mass mode turns out to be \(5.1 \times 10^{17}\) GeV/c\(^2\) [24] that cannot be produced by any conceivable accelerator – unobservable particle physics. If observable masses on the TeV scale are to be produced, the (nonexisting) actual coupling constant must be smaller by a factor \(10^{-45}\) compared to the electromagnetic coupling constant – invalidating the idea of unification of gravity and electromagnetism. Thus, the origin of the electromagnetic field cannot be derived from spacetime curvature. This means spacetime curvature cannot be the source of all physical forces, i.e. most likely only gravity is described by spacetime curvature because gravity is unique in that it is directly related to spacetime via Einstein’s GR. Spacetime is the fundamental field, i.e. as soon as it was formed it did provide the stage in the form of the metric tensor \(g_{\mu\nu}\) for all the other physical force fields.

In order to unify the two interactions, the fifth dimension must provide an extremely strong curvature, which is not surprising given the strength of the electromagnetic force compared to gravity – rendering the concept of unification unphysical. This does not come as a surprise either because in Nature the concept of duality [2] (representing zero in many different ways) is realised. Therefore, the size of the fifth dimension would have to be almost equal
to the Planck length $\ell_{\text{pl}}$. Fortunately, gravitation is weak enough in order to allow a four-dimensional Universe as large as ours. This value of $L_c^{(0)}$ is many orders of magnitude smaller than the value of $10^9\text{ m}$ determined from the experimental range of Newton’s force of 1 $\mu\text{m}$ (in reality, the value $10^{-15}\text{ m}$ should be used because this is the size of a proton or neutron). Kaluza’s theory requiring the existence of an extra fifth dimension is in total contradiction with recent gravitational experiments, unknown at the time of Einstein. A five-dimensional Kaluza-Universe cannot exist, and, even if the fifth dimension is compactified, the resulting mass spectrum is unphysical.

But what about two additional spatial coordinates, forming a six-dimensional world? The formula for $L_c^{(0)}$ now takes the form

$$L_c^{(0)} = \left(\frac{\phi^{(0)}}{\ell_{\text{pl}}}\right)^2 = 4 \times 10^{-4}\text{ m}.$$ 

In 2008, see Zwiebach [23], this distance appeared to be an acceptable value for the two extra dimensions, for in 2007, the validity of Newton’s law was established down to a distance of approximately 56 $\mu\text{m}$ by Kapner et al. [27]. At that time, at distances below this value deviations from Newton’s law were deemed to be possible. For decades, a large amount of experimental work has been devoted to the search of a modification of Newton’s law, which is generally expressed in the form of a Yukawa potential, indicating an additional gravitational interaction

$$V_{\text{Y}}(r) = -G_N \frac{m_1 m_2}{r} (1 + \alpha e^{-r/\lambda}),$$

where $\alpha < 1$ denotes the strength of the interaction and $\lambda$ denotes the length scale at which the deviation from the inverse square law appears. Hence, for an experimental threshold value of $\lambda = 56\,\mu\text{m}$, a six-dimensional world appeared to be physically possible – in 2008. However, more recently, in 2011, the measurements by Sushkov et al. [28] placed much more stringent upper bounds on short-range Yukawa forces, down to the range of $0.4 - 4\,\mu\text{m}$, improving the value by Kapner et al. by about a factor of 50. As a result, since late 2011, even six-dimensional worlds are no longer possible either, given that the value for $L_c^{(0)} = 10^{-20}\text{ m}$ has the correct order of magnitude.

But what about three extra spatial dimensions, that is, a seven-dimensional space? The same procedure as above results in a value for

$$L_c^{(0)} = 10^{-10}\text{ m},$$

which would be in contradiction with gravity if one can accept that, as gravity has been proved to be correct on the microscale at about 1 $\mu\text{m}$, the gravitational field must be the field resulting from the individual atoms or molecules that have a size of the Bohr radius, which is about $10^{-10}\text{ m}$. However, a value of $10^{-15}\text{ m}$ seems to be more logical because gravity should mainly be caused by the microfields of the individual protons and neutrons in the nuclei. In this case, a spacetime with three extra dimensions is also be ruled out.

The same holds true for an eight-dimensional space. The value for $L_c^{(0)}$ as calculated from (1) is

$$L_c^{(0)} = 3 \times 10^{-13}\text{ m},$$

which would be in contradiction with gravity if one assumes the gravitational field to be the result of superposition from the individual nucleons whose size is about $10^{-15}\text{ m}$.

If gravity was actually valid down to the size of the proton or neutron, this would even be a major hindrance for string theory that is living in ten dimensions, $D = 10$, if supersymmetry is assumed. Utilizing $s^{(0)}_{\text{pl}} = 10^{-20}\text{ m}$, the length of the extra spatial dimensions is calculated as

$$L_c^{(0)} = 10^{-15}\text{ m},$$

which is about the size of the proton and thus should be noticeable in scattering experiments, i.e. the scattering cross sections calculated by employing the SM of particle particles should deviate from experimental values – which was not observed. String theory thus is in potential conflict with experiment, although with present torsion pendulums, it is principally not possible to directly demonstrate gravity at this length scale – but there are the most recent LHC results and the ACME experiment, which are discussed next.

String theory for bosons, in order to avoid ghosts (states of negative norm), requires $D = 26$ spacetime dimensions. In order to incorporate material particles, that is, fermions, superstring theory (no tachyons anymore) is the generalisation of bosonic string theory. Formally superstring theory has $D = 10$ spacetime dimensions. However, superstring theory (employing heterotic strings) needs to eliminate the extra 16 dimensions (scalar fields $x^\mu, \mu = 11, …, 26$) from the boson theory, promoting them to Majorana–Weyl fermions, but a total of 26 scalar fields has to be retained for both bosonic strings and superstrings. Because of the supersymmetry constraints, the system can be thought of as actually having only $D = 10$ of the usual scalar coordinate fields $x^\mu, \mu = 1, …, 10$, but there are 16 additional scalar fields $\phi^\mu, \mu = 1, …, 16$ in order to mimic the action of a field with only bosonic degrees of freedom in 26 dimensions. This requires the existence of
2×16 Majorana fermions or 32 fermionic fields (equivalent to 16 compactified bosons, enlarged symmetry) that have never been seen. However, supersymmetric partners must exist – a requirement not confirmed by the LHC results. Of course, a new theory could be constructed predicting these particles to exist at a cutoff mass of 10 TeV/c², to be detectable by an accelerator of 100 km circumference, possibly operational about 2050. However, such an approach bears similarities with the introduction of epicycles in Ptolemaic cosmology. Applying the abovementioned formula for \( L_{c}^{(26)} \) then leads to the extremely small value of

\[
L_{c}^{(26)} = 23 \times 10^{-20} \text{ m}
\]

in 26 dimensions, which is much smaller than the Compton wave length of the proton or neutron in our four-dimensional spacetime but is about a factor of 20 larger than the length scale produced in the LHC at 7 TeV. No energy leak (into higher dimensions at this length scale) has been reported in any of the LHC reactions. In other words, the LHC did probe the length scale at 10^{-20} m but did not find any anomalies in the scattering cross sections that appear exactly as predicted by the SM. In addition, the recently detected gravitational waves by the LIGO team (see the following discussion) of low frequency are in the range of 10^{-19} m and thus may not be able to propagate into the higher dimensions. Hence, the fields of the SM cannot have interacted with these hypothetical extra dimensions, meaning that there is no hint for their existence at 10^{-20} m.

The red region of Figure 1 is excluded experimentally because the LHC did not find any particles up to a mass of 1.6 TeV/c², and the measurements of Kapner et al. [27] showed the validity of Newton's law down to 56 \( \mu m \). The black region is excluded because of the measurements of Sushkov in October 2011 who demonstrated the validity of Newton's law down to about 1 \( \mu m \). The level of matter below the 1 \( \mu m \) range is that of molecules or atoms, the latter have a size of 10^{-10} m. Given the mass ratio of the proton and electron \( m_p/m_e=1837 \), the contribution of the electron mass to the gravitational fields of ordinary matter can be neglected. Hence, it is reasonable that the gravitational field of ordinary matter is comprised by the superposition of the gravitational microfields of the neutrinos and protons in the nuclei that are of size 10^{-15} m. That excludes the dark blue area. The recent LHC results at 7 TeV correspond to a length scale of about 10^{-20} m but no missing energy was detected in any of the scattering processes – no energy escaped into extra dimensions. Thus, the light blue area should be excluded as well. The yellow area that is to the right of 10^6 GeV (or 10^6 TeV) is excluded because of the hierarchy problem. Natural units are based on the three constants \( G, \hbar \) and \( c \). The masses of the elementary particles are much smaller, including the low mass of the Higgs boson at some 125 GeV/c², than the Planck mass \( m_{P} \). For example, \( m_p \) is about 10^{19} times larger than the proton mass \( m_p \). This riddle is termed the hierarchy problem. Therefore, the SM of particle physics is only valid up to energies much smaller than \( m_{P} \) for there are quadratically divergent quantum corrections (also termed radiation corrections) in the perturbation expansion of the probability amplitude (each term in the so-called Dyson series that describes the interaction Hamiltonian of the scattering process among the elementary particles is characterised by the power \( n \in \mathbb{N} \) of the specific coupling constant \( g \)). The numerical contributions from these higher order corrections, in order to remain small enough, require a cutoff energy (10–1000 TeV) far below the Planck energy. This is the basic reason why the Planck length in \( D \)-dimensions is \( m_{P}^{d} \gg m_{P} \) (3). If not, the higher terms of the perturbation calculations will deliver unphysical values. Hence, in order to solve the hierarchy problem of the SM a new symmetry, SUSY, was introduced more than 40 years ago to cancel all anomalies (i.e. divergent terms) – if there were not these experimental constraints as depicted in Figure 1 that are driving down the size of the extra dimensional space, \( L_{c}^{(d)} \). This means that the Planck mass in \( D \)-dimensions is going up, resurrecting the hierarchy problem as visualised by the green area in Figure 1 that is not intersected by any of the white curves for \( d=1, 2, \ldots, 6 \). The light green area ranging from 10^4 to 10^6 GeV appears to be possible for symmetry breaking of supersymmetry – where the generation of new particles should occur – but there is no accelerator on Earth that can provide these energies. The dark green energy area might be possible with a supercollider of about 100 km circumference – if this machine can be realised. However, none of the six curves is intersecting the green area. It is therefore exceedingly unlikely that supersymmetry exists in those extra dimensions as presently assumed.

Of course, domain walls in the form of D-branes (see below) may be introduced, but now at least the thickness of these domain walls must be smaller than 10^{-20} m. This may, however, be interpreted as just another attempt to escape (since the early 1980s, starting with the (false) prediction of the decay of the proton) the experimental facts – by adding another epicycle to the model. But what does this mean to the propagation of gravitational waves? The interactions in string theory do mimic those of general relativity at long wavelengths, so string theory usually is interpreted as a quantum theory of gravity. A domain wall could be acting like a high-pass filter (i.e. an electronic filter that passes signals with a frequency higher than a
certain cutoff frequency while attenuating signals below the cutoff). Thus, the amount of attenuation for each Fourier component of a gravitational would depend on the feature of the domain wall.

The concept of extra dimensions, apart from going against the principle of duality, appears to rest on shaky experimental foundations and with it those advanced physical theories that are based on it. The original six-dimensional theory of Kaluza-Klein seems to be incompatible with the measured range of Newtonian gravity and has become untenable.

### 2.2.2 Higher Dimensions Challenged by MICROSCOPE

The European MICROSCOPE satellite (MICROsatellite à Traînée Compensée pour l’Observation du Principe d’Équivalence) was launched in April 2016. Its mission is to test the weak equivalence principle of GR which requires that the gravitational mass $m_G$ of a body (responsible for the strength of the gravitational interaction) equals its inertial mass $m_i$ (measuring the temporal change of momentum). According to GR, this is a genuine equality, that is, $m_G = m_i$. However, because of the existence of higher dimensions, string theory is predicting a deviation from this principle at $\eta = 10^{-15}$. There is already a hint from experiment that this may not be the case, as Adelberger (1999) claimed to have already determined such a value from Hubble data, rendering the supersymmetric prediction incorrect, but his result is considered nonconclusive. The MICROSCOPE satellite [29] will decrease this limit further by two orders of magnitude, down to $10^{-15}$. Based on the results of Kramer and Wex (Tab. 7 in [2]), we are convinced that GR will pass this test as well, that is, $\eta < 10^{-15}$, invalidating the concept of higher external spatial dimensions. The U.S. planned STEP (Satellite Test of the Equivalence Principle) experiment to be launched in 2018 has the goal to measure a value of $\eta$ as small as $10^{-18}$.

### 2.3 Dark Matter Wanted

The night sky abounds with stars and, as we know today, our Milky Way galaxy should comprise about 100 billion stars, whereas the optical universe may contain some 100 billion galaxies, all seemingly held together by the force of gravity— but currently only about 5% of matter is visible (known). For the remaining 95%, there is the long standing riddle in the form of the unknown nature of dark matter and dark energy. The concept of dark matter was invented by the Caltech astronomer Zwicky already in 1933 to explain the missing matter in the Coma cluster. Astrophysical observations have proved the existence of dark matter through its strong gravitational effects (e.g., gravitational lensing) – it is the glue that is holding galaxies together. In other words, without it our Universe would fly apart. However, the baryonic dark matter concept has been challenged by the most recent observations (October 2016) by McGaugh et al. (Section 2.3.2).

#### 2.3.1 No Dark Matter from Particle Physics

In particular, the particle of dark matter, the proposed neutralino with a mass of about 1 TeV/$c^2$ was not found by the LHC. These findings are in complete accordance with the recent ACME (Advanced Cold Molecule EDM experiment) of 2014 [30] that determines an upper limit for the electron dipole moment. So far, the electron appears to be perfectly round, and hence no new particles with masses of up 1 TeV/$c^2$ should exist. These measurements are further confirmed by the U.S. LUX (Large Underground Xenon) experiment [31]. Since its inception in 2013, not the slightest hint for reactions caused by dark matter particles has been found. It is also not likely that dark matter particles will be found by the planned large xenon detector (1000 kg of Xe) at Gran Sasso, Italy, because their mass is now known to be above the LHC threshold of 1.6 TeV/$c^2$. These experiments strongly suggest that string theory may be losing its preeminence as the leading unified theory of the four fundamental forces.

#### 2.3.2 Dark Matter from Astrophysics

Astrophysical observations carried out since 1933, starting with Zwicky at the California Institute of Technology,
have proved the existence of dark matter, requiring some kind of exotic particle that has (almost) no interaction with photons. Its presence is felt only through gravitational interaction. For instance, the rotation velocity of atomic hydrogen gas at a distance about four times far out as the optical galactic radius is far too elevated with respect to the amount of visible mass (derived from the relationship of luminosity of the stars and their associated masses), thus deviating substantially from Newton’s gravitational law. These observations have been confirmed not only for the Coma cluster (e.g. Zwicky who determined a value of about 100 for the ratio of dark to visible matter) but also for many other galaxies in the course of the past 40 years. In addition, the phenomenon of gravitational lensing owing to the presence of dark matter has been unmistakably demonstrated, for instance, in the case of the Abell 2744 super cluster. In 1983, Milgrom put forward the so-called MOND (MOdified Newtonian Dynamics) hypothesis [32, 33] that correctly describes the dynamics of stars and gas within galaxies, without providing any physical argument. The numerical predictions of MOND are correct, but in the meantime dark matter has been discovered, so that the original intention of MOND is no longer valid. However, any valid theory of gravity must be able to match the MOND predictions because they reproduce the observed data, including the most recent data by McGaugh et al. measured more than three decades after MOND. In a series of papers, McGaugh et al. [4, 5] (further references are given in this article) found that the distribution of dark matter, characterised by its radial acceleration value (towards the galactic center) $g_{dm}$, follows directly from the baryonic mass (stars and gas). The universal relation established

$$g_{dm} := g_{obs} - g_{bar} = \frac{g_{bar}}{\exp\left(\frac{g_{bar}}{g'}\right) - 1}$$

is written entirely in terms of the baryons, reflecting a strong coupling between dark and baryonic mass, but is independent of dark halo models. The acceleration scale $g'$ is the well known empirical radial acceleration constant, often expressed by $a_0 = g' = 10^{-10} \text{ m s}^{-2}$. Although the above empirical relation might suggest that dark matter particles do not exist – in accordance with the latest LHC data – because of the unique dependence on the baryonic mass. However, the presence of dark matter has been convincingly demonstrated by gravitational lensing. The problem is aggravated further by the missing dark matter inside galaxies, according to the measurements by Bidin et al. (see the following discussion).

Based on the tightness of the radial acceleration relation together with the absence of residual correlations based on the measurements of McGaugh et al. the need of a revision of the standard dark matter paradigm is suggested. Given the measured scale of validity of Newton’s law, a new physical mechanism, rather than a new gravitational law, is suggested for the dark sector providing the required coupling for baryon mass and dark energy/dark matter.

An attempt, without the modification of Newtonian gravity, was published by the authors [2, 34, 35], based on the polarisation of the dark energy field inside a galaxy (there is no or not much dark matter, next section) caused by the high density of normal matter. Furthermore, a modified Newtonian gravitational law might have a long-term effect (billions of years) on the stability of planetary or star orbits against perturbations (cosmological numerical simulations?), the virial theorem (equidistribution of potential and kinetic energy), or the principle of equivalence – topics not investigated by the authors. In addition, the classical approximation of Einstein’s field equations exactly gives Newtonian gravity. However, it now seems evident from the measurements of McGaugh et al. that exotic baryonic matter particles cannot be the source for dark matter, and the numerous experiments currently under way should not detect anything at all (in accordance with all of the earlier experiments).

### 2.3.3 Dark Matter Missing within Galaxies

In 2010, a paper by Bidin et al. (ESO) [36] showed no evidence for dark matter within 4 kpc above (or below) the galactic plane. In 2012, a second paper by Bidin et al. (ESO) [37] confirmed the 2010 results and demonstrated the absence of dark matter in the solar neighborhood. Their analysis is based on the kinematics of 412 stars (the so-called tracer population) located at a distance of 1–4 kpc (kilo parsec is denoting a distance, where 1 pc =3.262 ly =3.086×10^{16} \text{ m}) from the galactic mid-plane (termed height, denoted by coordinate $z$). They claim to have derived a local dark matter density that is an order of magnitude below the standard value of $0.3 \pm 0.1 \text{ GeV cm}^{-3}$.

These results challenge both the current understanding of the spatial distribution and nature of the galactic dark matter as well as its role in providing the necessary (missing) mass. As these 412 stars do not exhibit any special features, there is no reason to assume that the situation will be different for the other stars in our galaxy. According to astrophysical observations (above), dark matter is amassed in the halo of a galaxy, but this dark
matter cannot affect the rotation curves of stars that are within the halo. Hence, if dark matter density is only one tenth of what it was assumed to be, dark matter could not be the cause for the apparent deviation of the rotational speed of stars orbiting the galactic center that is in violation of Newton’s gravitational law. Many velocity profiles for the azimuthal velocity (the circumferential direction denoted by angle \( \theta \)) and measured by the Doppler shift of the rotation curves for the hydrogen H I, 21 cm line, out to the radial limits of the data have been taken for spiral galaxies, observing an almost constant rotational velocity value, starting at radial distances of 2–5 kpc from the galactic center. Therefore, the results of Bidin et al. are highly unexpected, as the presence of dark matter is the very cause for the deviation from Newton’s law, which requires that \( v(r) = G M/r \), i.e. the rotational velocity varies inversely to the square root of \( r \). On the other hand, a flat rotation curve means that the total mass \( M_r \) of the spiral galaxy within some radius \( r \) has to increase linearly with \( r \), which is in stark contrast to the observed luminosity of the spiral galaxy. In other words, the missing dark matter, according to Bidin et al. and the flat rotational curves are providing an enigma giving rise to the question about the physical phenomenon that is acting in place of the nonexisting dark matter.

However, in a subsequent paper by Bovy and Tremaine [38], Institute of Advanced Study, Princeton these findings were challenged and classified as incorrect, that is, the claim by Bidin et al. having determined a local density of dark matter an order of magnitude below the standard value must be erroneous. The reason is, according to Bovy and Tremaine, that Bidin et al. assumed that the mean azimuthal or rotational (star) velocity \( v(r, z) = v(z) \) for galactic rotation curves, where \( r \) is the distance from the galactic center, \( \theta \) is pointing in the direction of galactic rotation, and \( v(r, z = 0) \) denotes the velocity of a star in the galactic mid-plane (i.e. a cylindrical coordinate system is used and the galactic disk is in the plane \( z = 0 \)). In other words, Bidin et al. have assumed that the deviation from Newton’s law not only is true for the galactic disk (plane) but also holds for the stars rotating above or below. That is, for a height \( z \neq 0 \) (i.e. above or below the galactic disk), the azimuthal velocity should be a function of both \( r \) and \( z \), and the approximation of Bidin et al. namely that the radial velocity gradient (the index \( \theta \) is omitted) \( \partial_r v(r, z) = \partial_r v(r, z = 0) = 0 \) is invalid. If this is the case, then dark matter density is present as expected and no anomaly exists.

More than 2 years later, in late 2014, Bidin et al. provided a detailed analysis [39] of the arguments by Bovy and Tremaine, demonstrating that their original assumption of a vanishing radial velocity gradient \( \partial_r v(r) = 0 \), indeed only is a rough approximation, but still is accurate enough to maintain their 2012 assertion for a practically vanishing dark matter density (compare Fig. 8 in [39]). Even at the distance of the solar system (about 8.5 kpc) from the galactic center, the absence of dark matter should have a detectable effect on the shape of the rotation curve since the Keplerian velocity already is noticeably different from the flat rotation curve, which is assumed to be produced by dark matter. However, such a deviation from the flat rotation curve was not observed. The riddle remains in finding out the nature of the unknown matter acting within the galaxy instead of the missing dark matter.

2.3.4 Missing Dark Matter questions Big Bang

In brief, 83% of the matter in the Universe is currently missing. Dark matter particles should have been formed in the (hot) Big Bang that marks the very beginning of our Universe approximately 13.82 billion years ago, according to recent Planck satellite data [40] – if the Universe was produced by such a hot Big Bang. As the Big Bang concept is directly connected to these experimental data, the total absence of dark matter particles is not in accordance with the hot Big Bang concept. In addition, the hot Big Bang requires an unphysical event, namely the existence of a very high-energy density concentrated in an exceedingly small volume. The assumption of an initial false vacuum will not solve this problem. The fundamental question remains, how such a configuration (enormous amount of energy trapped in a small volume) should have come to exist at all. If McGaugh et al. [4, 5] were correct with their interpretation that is one of three options, namely that flat rotation curves are the result of new dynamical laws, i.e. MOND, rather than dark matter, the hot Big Bang hypothesis becomes more questionable. Their data are based on the Spitzer Photometry and Accurate Rotation Curves (SPARC) database of 175 galaxies of widely different type and show only very little scatter. That is, the connection between baryonic mass and rotation velocity is pronounced and no adjustable parameters were used. Indeed, the one-to-one correspondence between the acceleration resulting from the baryonic mass, \( g_{\text{obs}} \), and the observed acceleration, \( g_{\text{obs}} \), may be considered as a hint that the baryons only are the source of the gravitational potential. In this case, the laws of dynamics need to be altered, replacing the dark matter concept. However, according to EHT, this is not the case, Newtonian dynamics prevails, but, instead, dark matter particles, which are of negative mass, do reside in the so-called dual space (imaginary time coordinate, see above) rather than in four-dimensional spacetime. Only
their gravitational potential is experienced in our space-
time, but there are no dark matter particles present.

Moreover, the existence of dark energy, about 68% of the total energy in the Universe, remains a complete
mystery. According to particle physics, there is no dark
energy particle either. The deviation from Newton’s law
of gravitation as observed by McGaugh et al. may be
explained by the polarisation effect on the dark energy
distribution by the high matter density within galaxies (a
factor of 10^7 compared to matter density in intergalactic
space) – according to EHT there exist two dark energy par-
ticles that are repulsive and attractive with respect to ordi-
nary matter. The attempt of a derivation has been given in
[2, 34, 35], where the MOND equation was obtained.

2.3.5 Atoms of Space and Time and Quantum Gravity

Recent data from the ESA Integral satellite (INTErnational
Gamma-Ray Astrophysics Laboratory, launched by a
Proton rocket from Baikonur in 2002 in a highly eccentric
orbit from a perigee of 10,000 km to an apogee of 153,000
km) [41] are contradicting theoretical results from loop
quantum theory with respect to the size of the graininess
of space. The task of Integral is to measure γ rays and X
rays (that cannot penetrate through the atmosphere of
the Earth) in the energy range from 15 keV to 10 MeV. In
contrast to Einstein’s GR, quantum theory requires space
to comprise a lattice (the well-known atoms of space and
time of Heim as well as Smolin and Rovelli), thus ulti-
mately possessing a discrete structure that need not be
the Planck length. According to the predictions of loop
quantum theory, the grainy structure of space should
cause a difference in the polarisation of soft and hard γ
rays emitted by powerful γ-ray-bursts or from supernova
remnants (e.g. polarised light from the Crab Nebula 6500
ly from Earth in 2006), as they propagate through space.
Experimenters have increased their measuring accu-
ricacy 10,000 times and are certain that this effect, which
must have accumulated over the large distance of 6500
ly, should have produced a detectable signal – which,
however, was not seen. The conclusion from the Inte-
gral satellite measurements is that the lattice spacing of
spacetime should be about 10^{-48} m or smaller, far below
the Planck length of 10^{-35} m. Could this mean that the
scale when quantum gravity becomes important, which
is believed to be indicated by the Planck mass, has to be
shifted to a much higher value? Obviously, the theoretical
predictions are not in accordance with experiment, which
seems to be the rule rather than the exception with the
advanced physical theories. Compared to the simulation
results of CDT (above), at a length scale of 10^{-48} m, spac-
time has ceased to be four-dimensional and should have
separated into two-dimensional subspaces, that is, there
are spectral dimensions of dimension two. Therefore, it
may be that a four-dimensional quantum gravity is not
needed. A two-dimensional quantum gravity theory does
already exist. Moreover, if general relativity is valid down
to the scale of about 10^{-48} m the Planck length is at least
10^{13} times larger and there is no need to quantise gravity,
that is, gravity can be kept classical while particle physics
can be described in the form of quantum field theory.
Hence, matter does no longer exist at the length scale at
which space becomes discrete. In other words, might it
be possible that radiation corrections at this length scale
have ceased to exist? Furthermore, in 2009, data from
ESA’s Integral γ-ray observatory also disproved theories
that some form of dark matter explains the mysterious
radiation in the Milky Way, known since the 1970s.

It is not at us to tell Nature
how she has to be...

Richard P. Feynman
The Character of Physical Law, 1965

3 Troubling Experiments and
Observations II: Contradictions
and Gravitational Phenomena

In this article, a totally different type of experiment is dis-
cussed for which no physical explanation presently exists.
This summary comprises recent experimental data for the
size of the proton and the lifetime of the neutron as well
as yet (non-conclusive) preliminary results for the exist-
ence of extreme gravitomagnetic and gravity-like fields. If
the latter fields existed, that were (tentatively) measured
to be many orders of magnitude larger than calculated
from Einstein’s GR, this could be interpreted as a first hint
for additional gravitational bosons and a possible inter-
action between electromagnetism and gravity resulting
from a new kind of symmetry breaking. If the strength of
these fields could be confirmed, gravitational engineering
might become a reality.

3.1 Experimental Contradictions for Protons
and Neutrons

In this section, two different types of experiments are pre-
sented that are independent on the existence of higher
dimensions, but whose results are totally unforeseen and cannot be explained by either the SM of particle physics or any of the so-called advanced physical theories. The outcomes of the first experiment might be explained by utilizing quaternions [42] developed over 150 years ago by Hamilton to extend complex numbers. The second experiment might indicate new forms of symmetry breaking at low temperatures in conjunction with novel types of gravitational bosons.

For several years, the radius of the proton was measured by two experimental groups. The results of the two groups are mutually exclusive, but each group recently confirmed their measured value of the proton radius. Furthermore, the enigma of neutron lifetimes also remains unresolved. Recently, two expert groups have reanalysed their data and confirmed their conflicting experimental findings [43]. Hence, if the experimenters are correct, the size of the proton and the lifetime of the neutron do depend on the measuring technique, that is, different physical properties are seen depending on the applied measuring processes. This enigma will be discussed further in part two of this article.

3.1.1 Protons of Different Size

The details of the experimental techniques utilised for determining the radius of the proton are not of concern, but it is clear that the size of the proton must not depend on the measurement procedure itself. However, as it turned out, this is exactly the case. The proton radius can be determined from both muonic hydrogen (the electron is replaced by the much heavier muon particle, and thus, it is much closer to the nucleus) or by scattering measurements [44]. Measurements of the energy levels of muonic hydrogen found a proton radius of about 0.84 fm (0.84×10^{-15} m), which is significantly lower than the proton radius of about 0.879 fm from the scattering experiments (a beam of electrons is directed into a hydrogen gas, i.e. consisting mostly of protons, measuring the flux of the scattered electrons). Current measurements of the energy difference of the energy levels of the ground state (1s, that is, s indicates that there is no orbital angular momentum) and the next higher excited state (2s) are accurate to a few parts in 10^{15} [44]. The electron in the s state has a nonzero probability of being inside the proton, and while being inside does feel the attractive electric force due to the positive charge of the proton, effectively reducing the binding energy. The time the electron is spending inside the proton of course increases with the size of the proton radius. Hence, the proton radius should have a detectable effect on the electron energy levels. The proton radius determined by this technique was measured to be 0.879 fm. The other technique replaces the electron by the heavier muon (207 times heavier) and thus increases the time the muon spends inside the proton by a factor 207 [2]. The effect of the proton radius on the energy level therefore is more pronounced. Surprisingly, the measured proton radius, determined as 0.8409 fm, was significantly smaller (compared to the measurement uncertainty) than for the scattering technique. Quantum electrodynamics (QED) is very well validated, so it is highly unlikely that some unknown effect of QED is behind these conflicting data. Instead, the authors are suggesting a drastic extension of physics by extending the system of numbers from real to quaternionic etc., that is, the solutions of the equation of the Planck mass \( m_p^2 = \frac{\hbar c}{G_N} \) will allow for material particles that may have positive real (+m), negative real (−m), or quaternionic (i.e. i m, j m, k m) masses. The meaning and far reaching consequences of these novel masses are discussed in [2] and will be explored in our companion paper [3] in an attempt to explain the physical phenomenon, along with a numerical estimate, that is behind the differences in the proton radii as well as the most recently found discrepancies in the neutron lifetime, that will be discussed next.

3.1.2 Neutrons of Different Lifetimes

The two different measurement techniques, the bottle (counting the number of the remaining neutrons) and the beam (counting the number of the resulting protons) methods, have measured a difference of eight seconds in the neutron lifetime, which is significantly larger than the measurement uncertainty. This means that the number of protons (beam technique) is too small compared to the number of the remaining neutrons (bottle method). As a result, it seems that some of the protons have disappeared (at least temporarily), not obeying the normal decay scheme of the neutron according to the weak interaction, that is, \( n \rightarrow p + e^- + \nu_e \). It is unlikely that the experimenters have underestimated the uncertainty in their results. Over the years, comparisons have
shown that the various bottle and beam experiments agree with one another. Therefore, the effect probably has revealed a new physical phenomenon, but, at the same time, exotic physics in the form of new particles as has been suggested is ruled out – because no new matter particles up to the mass range of 1.6 TeV/c² were found. Hence, the straightforward explanation that a hitherto unknown particle may be responsible for a novel channel of the neutron decay must be seen as less tenable. A hint for the enigmatic behavior of the neutron may lie in the fact that the experiments are conducted at low temperatures [3]. Any attempt to solve the riddle of the neutron lifetime may require drastic assumptions on the nature and types of matter that are existing and thus cannot be obtained from the physical models developed beyond the SM of particle physics.

3.2 Einstein’s General Theory of Relativity Revisited

Having discussed numerous experiments that profoundly affect the SMs of particle physics and cosmology, there remains the second pillar of contemporary physics, namely Einstein’s general theory of relativity. So far, \textit{GR} has passed all experimental tests and observations as now will be demonstrated. This, however, does not mean that novel physical phenomena cannot exist beyond the scope of \textit{GR} (e.g. in the form of extreme gravitomagnetic field experiments that shall be described below).

3.2.1 Completeness of Einstein’s Theory of General Relativity?

On 11 February 2016, the LIGO and VIRGO Collaboration groups [45] reported on the detection of gravitational waves as predicted by Einstein’s \textit{GR} in 1916. The signals were actually measured in September 2015, but the teams took time to verify their results most likely to avoid the embarrassment of the BICEP2 experiment [46]. It is to be noted that there was already a Nobel prize for the indirect detection of gravity waves in 1993 (Hulse & Taylor). Hence, their direct measurement is not a surprise at all. However, there is the hope to enter the age of gravitational wave astronomy. Most important, recent observations by Kramer and Wex, MPI Bonn, Germany and Jodrell Bank Centre for Astrophysics, University of Manchester, UK as depicted in Figure 2 are proof that any valid theory of relativity must give the same predictions as Einstein’s \textit{GR} (except for the interior of black holes), hence practically must be equivalent to \textit{GR}. Thus, the theory of general relativity is not ready to vacillate in any form as recently suggested by some astrophysicists, for instance, as published by Bonneau and Fontez [48]. Consequently, any modification of the gravitational law, as proposed by the MOND hypothesis, in order to match observed rotational velocities of star systems (about the galactic center) located at the outer rim of a galaxy, has to be rejected. Furthermore, while elliptic planetary orbits are stable in our four-dimensional world with respect to small perturbations, any MOND like force law acting over billions of years should eventually lead to instability. Instead, the observations of Kramer and Wex in combination with the measurements of McGaugh should be interpreted as a novel, independent experimental proof for the existence of dark matter. However, the dark matter concept does not seem to work inside galaxies as numerical simulations have demonstrated. Dark matter does, however, explain the formation of large scale cosmological structures (e.g. filaments). Nevertheless, it is correct to state that the numerical predictions of the debated MOND hypothesis have been confirmed by the recent measurements of McGaugh [4, 5, 49, 50]. It is, however, incorrect to consider the astrophysics observations of McGaugh as a blow to \textit{GR} [48]. The explanation for MOND, then, cannot follow from a modified gravitational law. In short, dark matter works on the cosmological scale but fails on the galactic scale (Chap. 8 in [51]). The question therefore remains: what is the gravitational phenomenon responsible for the MOND acceleration as measured by McGaugh? The discussion will be resumed in our companion paper [3].

3.2.2 Challenge for Einstein’s Theory of General Relativity: CDT

In a totally different context, Einstein’s \textit{GR} has been further tested for about two decades by an entirely different set of experiments, based on computer simulation (considered to be experiments) under the label causal dynamical triangulation (CDT) with surprising results. The CDT model of quantum gravity is nonperturbative, numerically (Monte Carlo simulation) calculating the Feynman path integral over the class of causal geometries, employing the Einstein–Hilbert action of \textit{GR}. These computer simulations have revealed that spacetime in the absence of matter possesses a de Sitter
The topology of the Universe is that of a simply connected manifold. This is the usual assumption for the Universe, which means that there is only one direct path for a light ray to travel from a source to an observer, i.e. there are no holes. Of course, mathematically more complicated topologies can be conceived, e.g. a 2D torus or a two-hole pretzel. This is not supported by the CDT calculations, nor does such a topology fit Occam’s razor. Most important, it is neither required by observations. In 2003, well-known cosmologist Liddle wrote in the second edition of his introduction to cosmology on page 122: No evidence of nontrivial topology has been seen, and upcoming cosmic microwave background observations should make definitive tests. In the third edition [52], 2015, he writes again on page 124: No evidence of non-trivial topology has been seen, and upcoming cosmic microwave background observations should make definitive tests, with most cosmologists expecting topology to be ruled out as an interesting possibility ... and indeed, discovery of topology of the Universe would be in conflict with standard inflationary cosmology models. A very comprehensive discussion on the topology of the Universe can be found in the recent comprehensive book by Ringström [53]. This means that, in particular, faster than light motion in GR via wormholes is ruled out by CDT [54–57]. Realistic spacetime topologies do not seem to allow traversable wormholes, and thus, interstellar travel via wormholes is unphysical. The formulation by Ambjorn et al. makes unmistakably clear that wormhole-based space travel has to be relegated to the realm of science fiction. We quote from the article published by Ambjorn et al. [54] from Scientific American in March 2008:

One implication may come as a bit of a disappointment to science-fiction aficionados. Science-fiction stories

---

10 Willem de Sitter was a Dutch astronomer at the university of Leiden who cooperated with Einstein in 1917 on the solutions of the Einstein field equations.
commonly make use of wormholes ... the viability of wormholes now seems exceedingly unlikely.

The importance of the CDT computer simulation experiments cannot be overestimated but here only a few salient features shall be mentioned.

1. Spacetime above the Planck length is four-dimensional (no higher dimensions).
2. The evolving spacetime possess a de Sitter topology (closed universe), i.e. is spherical (no wormholes, no time travel etc.).
3. There is no multiverse and no anthropic framework. From the superposition of the various paths in the Feynman path integral, all other universes cancel out.

The MC simulations lead to the additional conclusion:

- The path integral employed uses Lorentzian invariance, which most likely renders quantum gravity theories as well as variations of GR that predict deviations from this principle, unphysical.
- However, a repulsive gravitational force (with respect to the spacetime field) in combination with causality (time ordering) is needed in the form of Einstein’s cosmological constant \( \Lambda \) [that eventually might depend on time and location, that is, \( \Lambda(x, t) \)] in all computer experiments; otherwise, the simulated spacetime becomes unphysical, i.e. has an infinite number of dimensions.

The de Sitter spacetime \( dS^{3,1} \) (three spatial coordinates and one time coordinate) of the Universe (see the extensive discussion in Chapter IX.10 by Zee [58]) is different from four-dimensional (flat) Minkowski spacetime. The spatial metric of a \( dS^{3,1} \) space has inherent positive curvature, even in the absence of matter. Therefore, space \( dS^{3,1} \) can be embedded only in a five-dimensional space Minkowski space \(^{11}\). That is, \( dS^{3,1} \) spacetime represents GR with a positive cosmological parameter \( \Lambda > 0 \) (meaning negative pressure, that is, expansion), which is a measure of the positive curvature of spacetime. The topology of the Universe thus does not seem to exhibit exotic differential structures or complex topological invariants, for a sphere is maximally symmetric. However, this global symmetry may be broken by the distribution of matter, possibly leading to a fractal dimension of spacetime, because the Universe is no longer uniform, i.e. its spatial extension should (slightly) depend on direction, causing small directional anisotropies.

### 3.2.3 Unruly Gravitational Constant \( G_n \)

Another mystery is discussed, namely the contradictory measurements of the gravitational constant. Four precision experiments disagree on the numerical value of Newton’s gravitational constant, \( G_n \), as shown below. If there were only two experiments, the discrepancy could reflect measurement errors, but this interpretation is highly unlikely in the case of four experiments. Measured results of the gravitational constant have failed to converge and different measurement procedures are delivering substantially different numerical values. Recently, several new experiments have been reported to measure Newton’s gravitational constant \( G_n \) by applying different measuring techniques. These experiments have resulted in widely different numerical values for \( G_n \), which means that a deviation occurs already in the third decimal place

\[
G_n = 6.67 \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{s}^{-2},
\]

where \( x \) denotes the first uncertain digit. Recent experimental values for \( G_n \) are listed below (see also the comprehensive work of Schlamminger, e.g. www.nature.com/articles/nature13507, 28 June 2014)

\[
\begin{align*}
G_n &= (6.67 \pm 1.0) \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{s}^{-2} \quad \text{from Wikipedia, 2010 [59]} \\
G_n &= 6.67 191(99) \times 10^{-11} \text{ kg}^{-1} \text{ m}^{-1} \text{s}^{-2} \quad \text{from Nature, June 2014 [60]} \\
G_n &= (6.67 515 \pm 0.61) \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{s}^{-2} \quad \text{from Phys Rev, July 2014 [61]} \\
G_n &= (6.67 586 \pm 0.54) \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{s}^{-2} \quad \text{from Phys Rev, July 2014 [61]} \\
G_n &= 6.67 369 677 \times 10^{-11} \text{ m}^3 \text{kg}^{-1} \text{s}^{-2} \quad \text{from theory EHT, 2004 AIAA [62].}
\end{align*}
\]

Numerous attempts were published to explain the discrepancies in the measured results, which are far above the limits of random and systematic errors. Most recently, Anderson et al. [63] claimed to have found that measured values of \( G_n \) are oscillating, that is, are time dependent, with a period of \( 5.899 \pm 0.062 \text{ yr} \) and an amplitude of

\(^{11}\) It should be remembered that a \( D \)-dimensional Minkowski space has one time coordinate of positive signature and \( d \) negative spatial signatures, that is, the metric is given by \( ds^2 = (dx^0)^2 - (dx^1)^2 - \cdots - (dx^D)^2 \). Remember that \( dx^0 = ct \), \( dx^i = x^i \) and \( dx_{-i} = -x_i \) etc. for the \( d \) spatial coordinates.
interactions known in current physics. The major difference between Gravity and electromagnetism is that electromagnetic fields can only be generated by large masses, e.g. planets or stars. In Einstein’s time around 1915, they were the only known interactions, and Einstein devoted the rest of his career trying to unify these two forces, but also searched for an interaction between electromagnetism and gravity as already surmised by Faraday.

However, during the past two decades, several experimenters have reported on the generation of extreme gravitomagnetic or gravity-like (acceleration) fields in the laboratory. Three serious experiments will be presented below. There are three different possible experimental sources for extreme gravitomagnetic experiments, namely by Tajmar et al. and Graham et al. whose experiments were carried out in the laboratory as well as the GP-B experiment, launched into a 640-km low earth orbit (LEO) in 2004. GP-B was not devised for the detection of extreme gravitomagnetic or gravity-like fields but might have inadvertently generated these fields in space.

These three completely different experiments may have produced extreme gravitomagnetic fields and gravity-like fields (acceleration fields) not generated by rotating large masses, i.e. gravitational phenomena might have been detected outside the range of GR. From 2006 to 2011, Tajmar et al. now at TU Dresden, Germany, published a series of experiments claiming to have observed extreme gravitomagnetic and gravity-like fields (acceleration fields) [64, 65], produced by rotating cryogenic Nb rings, having small masses of about 400 g. The strength of these fields was up to 18 orders of magnitude larger than predicted by GR. In 2007, a similar experiment was published by Graham et al. utilizing a rotating cryogenic lead disk [66]. These measurements were not conclusive (the accuracy of the laser gyroscope was not sufficient to produce a standard deviation of five sigma necessary to claim to have measured a novel effect). The authors reported a null experiment. However, a detailed analysis [35] showed that their measurements also saw the same (strange) phenomenon reported earlier by Tajmar et al. termed parity violation, wherein gravitomagnetic fields produced by the cryogenic ring or disk vary by order of magnitude in their field strength, depending on the sense of rotation of the ring (disk), i.e. clockwise (CW) or counterclockwise (CCW). Furthermore, the gyroscope signals recorded by Graham et al. were not entirely random.

Moreover, in 2004, a third experiment, termed Gravity Probe-B (Stanford University and Lockheed Martin), was launched by NASA in order to measure the gravitomagnetic field of the (rotating) Earth as predicted by GR (Lense and Thirring 1918). However, once in orbit, the gyroscopes were subject to anomalies in the form of large unexpected misalignments, delaying the evaluation of the final data for several years [1]. Tajmar and Graham carried out their completely different type of gravitational experiments in the laboratory, while GP-B measurements were taken in orbit around the Earth at 640 km altitude. All three experiments have in common that they are operating rotating gyroscopes at cryogenic temperature. In GP-B, the Earth was used as a test body and measuring time was about 10 months, since the frame-dragging effect predicted by GR accumulates over time. On the other hand, the cryogenic Nb ring of some 15 cm diameter used by Tajmar et al. in combination with a measuring time of a few seconds, cannot, according to GR, generate a detectable gravitomagnetic field. Compared with the predictions of GR their observed gravitomagnetic field would equal the field strength produced by a rotating white dwarf. In November 2011, Tajmar published a further paper [67]. He had repeated his experiments using a different experimental configuration, termed Setup D and E. The signal strength was now reduced by about two orders of magnitude compared to his earlier experiments. Since Tajmar et al. did not find a physical explanation for this behavior, the reinterpreted their previous results as acoustic vibrations. However, in late 2014, the three experiments were analyzed in detail (for a comprehensive discussion, see [34, 35]), and it was concluded that the gravitational anomalies observed could have been (at least partly) caused by the presence of extreme gravitomagnetic fields. At present, the experimental situation is not conclusive and additional experimental effort is needed either to
confirm or to refute the existence of these fields. However, theoretically they are predicted by the physical model of the authors, termed EHT.

4 Advanced Theories and Retarding Experiments

From the recent experimental data and astronomical observations presented in the previous section, it is obvious that, on the one hand, they most likely contradict the underlying concept, namely the existence of extra spatial dimensions, which are at the root of all the advanced physical theories beyond the SM, developed over the past 40 years. In particular, the flurry of new particles predicted by the super theories does not exist, nor does it seem that the underlying concept of extra, curled up spatial dimensions holds up to physical reality. Hence, the physical concepts of, e.g. superstring theory (10 dimensions) or, including the additional bosonic scalar fields, superstring theory has 26 dimensions + scalar fields along with topological spaces like Calabi-Yau etc. [23] appear to be mathematical entities only, not realised in Nature.

In addition, the dependence of the magnitude of the polarisation of light on (cosmological) distances as predicted by loop quantum theory has been shown to be incorrect by comparison with ESA Integral satellite data. Furthermore, recent astronomical data are questioning the role of the hot Big Bang as the primeval cause for the creation of the Universe because no dark matter particles have been found and, according to most recent LHC data, cannot exist up to a particle mass of 1.6 TeV/c^2. No magnetic monopoles were ever observed. Moreover, so far particle physics has not presented any clue regarding the nature of dark energy that comprises about 68% of the energy of the Cosmos as measured by the Planck satellite data in 2013.

According to these results of the most recent experiments in particle physics, galaxies cannot exist because they would fly apart due to the missing mass, a prediction in stark conflict with physical reality. Furthermore, real higher dimensions were ruled out experimentally at length scales down to about 10^-4 m according to three recent independent experiments performed with torsion balances (Sushkov October 2011). This length scale was further reduced by the LHC accelerator results as well as the eEDM measurements of the ACME experiment down to a length below the subatomic scale of approximately 10^-20 m. With the detection of the Higgs boson, the LHC has confirmed the SM of particle physics as of the late 60s of the previous century. In other words, one may say that particle physics seems to be back at the level of 1964 when Higgs and colleagues postulated the so-called Higgs boson or, at least, to Weinberg’s and Glashow’s work in the early 70s, when electromagnetism and the weak interaction were unified. All of the advanced theoretical models (superstring theory, supergravity, supersymmetry, grand unification theory as well as the existence of D-branes etc.), developed in theoretical physics over the past 40 or 50 years, therefore need to be reconsidered as being ingenious mathematical constructs, but may not exist as physical entities.

Similar to particle physics, there is the SM of cosmology, based on the existence of the (nonphysical) hot Big Bang, whose relics are believed to have been found in the cosmic background radiation (CMB), detected in 1965 by Penzias and Wilson. The dark matter particles themselves, as predicted by the Big Bang, however, are still missing. Moreover, dark energy is not accounted for in the SM of cosmology [68], nor is there any hint from particle physics about the nature of this energy [69].

Furthermore, there are three major areas of physics, where measurements are outright contradictory. Recent measurements of the Newtonian G_N gravitational constant are revealing another deep rooted problem in current physics because measured results seem to contradict each other. If the specified experimental inaccuracies are taken serious – and there is no reason for not believing the experimenters – experimental results of G_N already deviate in the third digit. So far, these topics were not addressed by theorists.

The previously mentioned so-called extreme gravitomagnetic experiments may have generated extreme gravitomagnetic fields in the laboratory and in space at the temperature of liquid He. As string theory claims to represent a unified theory of all physical interactions, including gravity, these experiments would be in contradiction to string theory. Extreme gravitomagnetic fields that are up to ~18–20 orders of magnitude larger than predicted by the Lense–Thirring effect of GR, are clearly outside GR, and cannot be mediated by the postulated spin 2 graviton. Such a phenomenon requires the existence of additional gravitational bosons that are not predicted in the string theories.

If only a single experiment existed whose measurements are leading to an anomaly, one might be tempted to argue that some unknown physical phenomenon might exist, but in general, the overall theoretical picture seems to be in order. However, this is not so. There are now numerous experiments in particle physics, astrophysics, and also in gravitational physics that have revealed not only massive contradictions between the so-called advanced theory and experimental data but also are forcing us to admit that there
is a major rift between experimental data and our most fundamental understanding of physics. These completely unexplainable facts are pointing to a most severe crisis in physics. Even the convenient loop hole, often successfully employed, namely the postulation of novel particles now seems to be ruled out. Therefore, a new direction is needed that may lead to a drastic revision of our physical Weltbild [2]. In the companion paper [3], we will present novel ideas that might solve (hopefully) at least some of the riddles presented by the abovementioned experimental data.

The collection of experiments and observations discussed above seem to invalidate the basic concept of extra dimensions that is instrumental for all of the advanced physical theories and also question the nature and role of dark matter and dark energy. The so far (nonconclusive) gravitomagnetic experiments are pointing to the existence of additional gravitational bosons that would require an extension of Einstein’s GR. Hence, uncertain as to what this number is, it may turn out that our current knowledge of gravity is too limited. Therefore, before the construction of a new O(10) TeV collider is envisaged, these experiments, as an alternative, should be repeated utilizing more sophisticated equipment because they are many orders of magnitude simpler (cheaper), much easier to perform (only handling of LHe is required), and would deliver experimental data much more rapidly.

Physics ultimately is an experimental science and the massive information conveyed to us by the recent experimental data obtained from numerous diverse and independent sources is demanding a deep rooted explanation. It is obvious that modifications in the leading unification theories need to be considered; otherwise, these conflicts with experiment would have already been resolved. At the same time, it has become clear that several of the leading concepts of advanced theoretical physics are now less tenable as they are in a fundamental conflict with experiment.

In summary, considering the above experiments in their entirety, it is evident that their results put severe constraints on any novel physical theory. In particular, the existing extensions of the SMs for particle physics and cosmology in the form of string theory, supersymmetry, higher dimensions, Anti-de Sitter space, moduli spaces, loop quantum gravity, and much discussed wormholes are suggested to not reflect physical reality but, rather, are only mathematical constructs not realised by Nature – otherwise, they must have had an impact on the data. As a direct consequence, there seem to be no supersymmetric particles in Nature. Furthermore, the concept of higher dimensions, key to string theories, appears to be equally unlikely. Dark matter particles have not been found, but there is proof for the existence of dark matter. The nature of all pervasive dark energy remains obscure. Fundamental experiments on the radius of the proton and the lifetime of the neutron, the building blocks of nature, seem to be in conflict with each other. Even the measurement of Newton’s gravitational constant produces contradictory values. At present, the coupling constants of Nature cannot be explained. There seems to be no relationship between these entities. Their existence is a mystery.

5 Four Fundamental Forces?

Physics, as we know it today, is based on the belief of the existence of exactly four fundamental forces. There are two long-range forces (interactions), namely electromagnetism and gravitation. Gravitation is believed to be always attractive, while electromagnetism can be both attractive and repulsive. In current physics, it is assumed that forces between particles are mediated by special particles, termed bosons. The bosons that mediate long-range forces between the charged particles, i.e. particles having mass and/or electric charge, are the hypothetical graviton and the photon, respectively. The other two interactions are the weak force (β decay, radioactivity) and the strong force (holding together atomic nuclei), which are of short range, i.e. their range is about 10−15 m.

On the other hand, current physics has no explanation for the existence of exactly four fundamental forces, that is, there is a belief only on the existence of four fundamental interactions as, for instance, expressed by Sarkar [70]. The question therefore arises, are there any additional fundamental physical interactions?

Newton published his gravitational law in 1687 that was eventually extended by Einstein’s general theory of relativity (GR), published in 1915. Newton considered time absolute, while Einstein’s view led to a merger of space and time, i.e. spacetime. Gravitation is caused by geometry, that is, it is equivalent to the curvature of spacetime. However, there was a novel aspect in Einstein’s GR, not present in Newton’s law of gravity. In analogy to the magnetic field of electrodynamics, rotating massive bodies (planets and stars) are assumed to generate a similar kind of gravitational field. Einstein’s general relativity GR is predicting that any rotating massive body (Earth) drags its local spacetime around, called the frame-dragging effect, generating a so-called gravitomagnetic field B_G. This effect, predicted by Lense and Thirring in 1918, however, is far too small to be seen in a laboratory on Earth. For this reason, the Gravity Probe-B (GP-B) experiment was launched in 2004 by a NASA-Stanford University-Lockheed Martin team after more than 40 years of preparation. The experiment was subject
to unforeseen major gyroscope misalignment, much larger than the Lense-Thirring effect. After several years of data analysis, GP-B finally confirmed the existence of this effect within approximately 15% as predicted by GR. As analyzed in [35], this misalignment may have been caused by the generation of (unknown) extreme gravitomagnetic fields. Upon the publication of GR, Einstein sought to unify the two long-range interactions, gravity and electromagnetism, and also sought for an interaction between these two forces – in vain, until the end of his career.

In the 1970s, Weinberg and Glashow succeeded in unifying the weak and the electromagnetic force. Perhaps, it may also be possible to unify gravitation and the strong force? Both gluons (carrier bosons of the strong interaction) and gravitons (the spin 2 bosons of the spacetime field that, in the linearised case, is a tensor of rank 2, represented by $h_{\mu\nu}$) are carrying charge and thus are subject to gluon–gluon interaction as well as graviton–graviton interaction. As gluons are spin 1 particles, a graviton might comprise two gluons?

Because the experimental basis presented above provides no evidence for advanced physical theories in higher dimensions, the question arises are there alternative physical principles that could replace these concepts, which of course need to be drastically different. If such principles exist what would be their physical consequences? Some aspects of these fundamental questions will be addressed in the subsequent section.

Before the task of the unification of physical forces can be tackled, it seems to be necessary to first establish a classification scheme for all particles, fields, and physical interactions in order to provide the basis for the range of the unification to be achieved. The mere belief of the existence of four fundamental forces is not sufficient. If, for instance, the LHC found an additional gravitational boson (Section 1), a unified theory would have to be entirely different from string theory, etc. Moreover, in case extreme gravitomagnetic fields existed, present theoretical physics would have no clue how such a unified theory could be constructed. In the following section, novel physical ideas are presented in an attempt to at least shed some light on the group structure (symmetries) in providing an alternative approach for a more complete description of the physical inventory of the Cosmos.

The more important matter is that ideologies preclude discovery.


### 6 Gravitational Engineering

In 2004, the Advanced Concepts Team of the European Space Agency (ESA) commissioned a study on the possible interplay of quantum physics and gravity [71] to examine theoretical concepts for the inclusion of gravitomagnetic fields in the study of the properties of rotating superconductors, with the aim to eventually explore the prospects of generating gravitomagnetic fields in the laboratory. Thus, propellantless propulsion might become a possibility. However, as it turned out – and this did not come as a major surprise – no physical mechanism could be identified capable to generate gravitational fields strong enough to be of relevance for space propulsion. However, since that time additional experiments have been performed. So far, no experimental proof for the existence of extreme gravitomagnetic fields has been delivered – but anomalies were observed [72].

Extreme gravitomagnetic fields would have far reaching consequences for technology but require novel physics. The Maxwell equations of electrodynamics are fundamentally linear. Einstein’s equations of GR are basically nonlinear but can be linearised for weak gravitational fields and are then termed the Einstein–Maxwell equations. These equations hold true in all circumstances, except in the vicinity of black holes. In a similar way, the equations describing the existence of extreme gravitomagnetic and gravity-like fields – which must be outside GR – are called the Einstein–Heim–Maxwell equations (Chapter 7.4.1 in [2]). They are also linear but must be supplemented by additional equations accounting for the conversion of electromagnetic into gravitational fields that is supposed to appear at cryogenic temperatures by symmetry breaking (and possibly at higher ambient temperature depending on the material composition of the ring).

In the companion paper [3], these equations will be discussed in more detail, but here only the resulting axial acceleration from the ring-disk configuration as depicted in Figure 3 is of interest for technological applications. The force per unit mass due to the generated extreme gravitomagnetic field $\mathbf{B}_{gp}$ that is acting on the spacecraft itself is given by $g_{z}$. $N$ is the number of turns within the outer ring (Fig. 1). Introducing the so-called symmetry

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12 The subscript $gp$ stands for the gravitophoton that is a novel gravitational boson [2] resulting from the interaction of electromagnetism and gravity. In EHT there are six gravitational bosons and the graviton is one of them.
breaking constant $\alpha_{sb}$, which is calculated in [2] utilizing two entirely different procedures, namely a pure set algorithm and the Coleman–Weinberg potential as shown by Kaku in [73]. The resulting acceleration equation can be written in the simplified form

$$g_G = \alpha_{sb} \frac{v^2}{c} N \omega = 20 \frac{v^2}{c} N \omega,$$

(5)

where $v_a$ denotes the average circumferential velocity of the rotating ring/disk combination, $\omega$ the angular velocity, and $\alpha_{sb}$ the general coupling factor given by the equation

$$\alpha_{sb} = 1.51 \alpha \alpha_{wp} \left( \frac{G^G_{pp}}{G^G_{pp}} \frac{m}{m_p} \right) = 20,$$

where $\alpha = 1/137$ is the fine structure constant, $\alpha_{wp} = 1/212$ the so-called gravitophoton constant derived in [2, 74, 75], and $m_e$ and $m_p$ denote the electron and proton mass, respectively. In EHT, there exist three different gravitational constants termed $G_{pp}$, $G_{wp}$, $G_{q}$, where $G_{pp}$ is defined as the gravitational hadron–hadron coupling constant, contrasted with the gravitational hadron–lepton interaction denoted by $G_{wp}$. The gravitational interaction between two atoms is given by Newton’s constant $G_{n} = G_{n} + G_{wp}$. If the interaction with the spacetime field is included, then the gravitational constant is named after Einstein $G_{p} = G_{n} + G_{q}$, that are discussed in [2] as well as in the companion paper [3]. The value of $G_q = 10^{-18} G_p$ is very small and thus may be neglected in most calculations but, in principle, leads to a difference in inertial and gravitational mass. This value is in good agreement with the numerical value 20, obtained from the abovementioned set algorithm, which has not directly to do with physics but rests on pure numbers. In a similar way, for instance, the value of the fine structure constant $\alpha$ can be calculated using the same set algorithm. That the value of $\alpha_{sb}$ calculated by these two totally unrelated methods is giving the same numerical value does not appear as a mere coincidence. Somehow the values of the dimensionless coupling constants seem to be governed by pure mathematics and not by physical theory, that is, their values cannot be derived. Furthermore, there seems to be a relationship among the various coupling constants. There is also the open question of the temporal constancy of the coupling constants. The proposed laboratory experiment, termed Heim experiment, as described above should produce a relatively large acceleration of

$$g_G = 2.5 \times 10^{-3} g,$$

(6)

where $g$ denotes the acceleration of the Earth. This fairly strong acceleration field acting in the vertical direction should be easily detectable, provided of course that the theoretical concepts presented here are actually realised (at least approximately) by Nature. Even if the calculations were off by an order of magnitude, an acceleration ten times weaker would be considered a genuine breakthrough. The actual acceleration of the spacecraft cannot be established theoretically because the extreme gravitomagnetic field $B_{wp} \sim \omega$ is valid above the disk only, but its real spatial distribution is not known. This is the same behavior as in superconductivity for the London equations. Because of energy conservation, the kinetic energy ($>0$) of the spacecraft is to be obtained by a (minuscule) expansion of spacetime that is lowering the respective structural energy ($<0$) of the spacetime lattice [2]. However, the grid spacing may be about $10^{-48}$ m as suggested by the ESA Integral experiment, a value that is far below the Planck length! This effect could be considered as being similar to the Mössbauer effect, that is, a large volume of spacetime is assumed to be involved in this propulsion effect. It is to be noted that the atoms of space are supposed to be forming a fully entangled lattice. The actual gravitomagnetic force on a material body, which might also depend on its geometry, however, needs to be determined experimentally.
You can have as much junk in the guess as you like, provided that the consequences can be compared with experiment.

Richard Feynman
*Character of a physical law*, p. 164, M.I.T. Press, 1965

Realistically, it all depends on many unknowns,..., and the clues we can get from experiment.

Edward Witten
*Unravelling string theory*, NATURE, Vol 438, 22 December 2005

7 Discussion I: Physical Reality of Extra Dimensions

The two prominent theoretical physicists Feynman in 1965 and Witten in 2005, each one in his own characteristic language, are pointing out the instrumental role of the experiment as the final arbiter for any physical theory.

When the SM had reigned triumphant for three decades, shortly before the LHC became operational in 2008, many theoretical physicists were convinced not only to discover the Higgs boson (predicted 1964) of the SM but also cited compelling theoretical reasons for the belief on the existence of novel physics. Nine years later and with zero evidence for new physics from the LHC [76] as well as numerous clues from all of the current experiments this situation has not changed. Rather, the situation has become worse, for no supersymmetric particles emerged up to the TeV range – cf. compare with Dine from 2001 [77] – that is, instead the SM was proved to be valid in this energy range. In particular, the neutralino, the SUSY candidate for dark matter, proved to be nonexistent. Consequently, the LHC has been classified by theorists as an O(1) TeV machine, incapable of providing the necessary energy to reach the supersymmetry breaking energy scale – which, according to present theory, is completely unknown.

However, in order to reflect physical reality, the more likely alternative may be to assume the nonexistence of extra dimensions – based on the numerous clues from the experiments, gathered over the past four decades and summarised in Figure 1 – and to search for a viable alternative theoretical concept. As suggested by these authors, it should be considered to replace the concept of extra real dimensions by the idea of extra number systems (Section 2).

For 40 years, every time a new generation of accelerators became available, they soon demonstrated zero evidence for higher dimensions (strings) and, in addition, invalidated the few (observable) predictions made by this theory. For instance, in the 1984 article by Raby [14], supersymmetry predicted the existence of squarks at 40 GeV and initially data from the UA1 collaboration at CERN were believed to have seen anomalies (physics outside the SM) that could have been interpreted as a supersymmetric process involving squarks and antisquarks. When this turned out to be wrong, hope was placed on the upcoming 320 GeV proton–antiproton collider at CERN. However, again, no supersymmetric particles were seen, and therefore the next generation of high-energy accelerators was due in the form of Fermilab. Since then, in order to escape experimental evidence, supersymmetric phenomena were continuously shifted into regions of higher energy. Today, the LHC is at a combined beam energy of 14 TeV with highly increased luminosity, features that were hardly conceivable in the late 1970s, but there is no evidence for this unifying type of symmetry.

It is a strange fact that the LHC data confirmed all features of the SM of particle physics (living in four-dimensional spacetime), whereas none of the physical features that are based on the existence of extra spatial dimensions were confirmed. As discussed in Section 2.2, the principle of duality seems to be the most basic principle of Nature. Hence, geometry as the single cause of physics (all physical interactions from geometry) is not in accordance with this principle. As described in Section 2.2, rather, both spacetime and dark energy (which is the cause root for all energetic processes in the Universe) were created at the same instant of time.

The present situation is that we now got stuck at the experimental end, because waiting for the next collider generation, simply (by theorists) denoted as an O(10) TeV machine, would require a gigantic 100 km super-collider, consuming humongous resources – if it can be realised at all in the coming decades? The fate of the U.S super-collider should be remembered. As the LHC construction and, in particular, the current ITER project (fusion demonstrator, not fusion reactor, and energy of the future) have shown the time schedule for these extreme devices will be subject to formidable delays, without considering their inherent cost overruns and operation issues.

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13 In the words of M. Dine: Over the next decade, low-energy supersymmetry will be confirmed or ruled out. If not observed at the LHC, our ideas about supersymmetry and the hierarchy are simply wrong. Large dimensions as a solution to the hierarchy problem are perhaps harder to rule out. ... It would be desirable to make a similar statement about large dimensions. That is what the present paper is about.
Extrapolating the history of the past 40 years, theory may soon ask for an O(100) TeV machine, impossible to built on Earth, that then would resemble Fermí’s (fictitious) Globatron, an accelerator placed in low Earth orbit—which is technically unfeasible. Perhaps a Lunatron could be conceived (cost and time unknown)? – if there were an existing Moon basis (requiring a cooperation of ESA and CERN) – that is, particle physics would be entering the realm of pure speculation or unobservable physics. By definition, these models cannot be invalidated (falsified) by any experimental data, and according to Popper, those models cannot claim to be a theory. Hence, any statement that a particular model so far has not been ruled out by experiment must be rejected as baseless – otherwise, physics losess its status as a science. It is obvious that string theory cannot be validated in the foreseeable future.

Therefore, in this article, a set of recent experiments and observations from high-energy physics, gravitational physics, and astrophysics were collected in order to provide all currently existing experimental clues from very diverse fields of physics. Fact is, that these clues all seem to contradict the fundamental assumption of the so-called advanced physical theories, namely the existence of extra spatial dimensions. Those theories developed over the past five decades, such as superstring theory, supergravity, supersymmetry, loop gravity, or the existence of multiverses crucially depend on these higher dimensions. Recently, the range of Newton’s law of gravitation was experimentally lowered to the distance of 1 μm ruling out the original six-dimensional Kaluza–Klein theory. Electromagnetism cannot be a gravitational effect of higher-dimensional spacetime, and no unification can be achieved. As Newtonian gravity is valid on the micro-scale, it seems logical to assume that the gravitational field observed comes from the individual atoms and molecules (size 10−10 m). As the proton (neutron) mass is about 2000 times larger than the electron mass, it appears plausible to neglect the gravitational effect of the electrons (assuming that the gravitational constants of leptons and hadrons do not substantially differ, in case they turn out to be different). Thus, it is reasonable to expect the gravitational field arising from matter to be produced by the individual protons and neutrons in the nuclei, whose size is about 10−15 m. For string theory in D=10 dimensions (i.e. extra dimensions d=6), the compactification length is about ℓ(50)C=10−15m. Therefore, one should see a deviation from Newton’s law if string theory were correct because the gravitational field of the proton (neutron) should propagate into the extra dimensions of size 10−15 m (cf. Fig. 1). However, this has not been observed.

Recently, the LHC reached its final beam energy of 2×7 TeV corresponding to a length of λ=10−20 m. Applying this value and employing the argumentation of Raychaudhuri and Skridhar [24], the fields of the SM of particle physics – defined in four-dimensional (flat) Minkowski space – cannot have propagated in any of the extra dimensions at about 10−20 m. Even if the SM were confined by some unknown physical mechanism to a slice of thickness 10−19 m of the D=4+d bulk space (or D space), as assumed in the ADD model (first suggested by Arkani-Hamed, Dimopoulos and Dvali in 1998 [24], hence the acronym ADD), there obviously is a potential conflict with the LHC data. The ADD model and its variants use the mathematical fact that the calculated gravitational coupling in the five-dimensional bulk (now ruled out by the measured validity of Newton’s law down to 1 μm) is substantially stronger than the actually observed value in four dimensions.

LHC experimentalists have not seen any massive amount of missing energy which should be case if the true mass scale m(10)D of gravity for a space of d- extra dimensions is approximately in the range of the beam energy. The modified Newtonian potential in D=4+d dimensions should be of the form \[ V(r) = \frac{m_1 m_2}{(m_1 m_2)^{1/(d+4)}} \frac{1}{R^d} \], where R is the radius of the curled up dimensions (Chapter 1.6 in Zee [78]) and \( G_N = m_N^2 \) was used. By contrast, measurements at all energy levels have shown a perfect conservation of energy, requiring a four-dimensional spacetime. No gravitons have escaped into higher dimensions.

What happens if extra dimensions smaller than 10−20 m are considered? Are there any experimental constraints at this length scale? The recently detected gravitational waves by the LIGO team [45] that are in the range of 10−19 m would not be able to propagate in these extra dimensions, and thus gravity would, at least partly, be barred from entering the extra dimensions. Thus, the original (key) idea that gravity is free to propagate in all the dimensions being the only interaction that can probe the compact dimensions, is no longer correct.

The conclusions resulting from these experimental constraints are both sobering and staggering because the existence of extra dimensions seems to be in conflict with experimental data at all length scales probed so far. Though there is not (yet) enough experimental evidence to claim that extra dimensions have to be ruled out, there is substantial evidence that this idea has become unlikely. Physics in four dimensions does not follow from the pure geometry of a higher dimensional space. In particular, the original six-dimensional Kaluza–Klein theory proved to be no longer tenable. Alternatives need to be investigated.
The situation is reminiscent at the ether, invented by the physicists of the late 19th century, suspected to be the hypothetical medium for the propagation of electromagnetic waves. After several experiments, Michelson and Morley in 1887 finally demonstrated a null effect for the movement of the Earth on the speed of light c, and this concept had to be abandoned, replaced by Einstein’s SR in 1905.

Science deals with reality, and psychology with our ability to accept it.

George Zweig
Particle Physics: A Los Alamos Primer, 1984

8 Discussion II: Extension of the Fundamental Laws of Physics

The LHC did not see any of the predicted new fermions, based on the concept of extra dimensions. Now, the second part of the statement by Zweig needs to be accepted too. By contrast, the SM of particle physics, based on our four-dimensional spacetime, was completely confirmed. Especially there is no hint on the existence of the dark matter particle, which causes a major problem for the existence of large-scale structure in our Universe and on the Big Bang itself. Moreover, astrophysical observations question the presence of dark matter within galaxies (galaxy clusters need up to fifty times more dark matter than visible matter in order to stay together) and also clearly ruled out the claim of loop gravity on the dependence of the magnitude of the polarisation on the frequency of light with distance. Astrophysical numerical simulations show that the model of cold dark matter (CDM) is in agreement with the observed large structures of the Universe (superclusters and clusters of galaxies), but on the small scale, namely on the galactic scale, the CDM model is not capable of reproducing the angular momentum of galaxies according to observations. In addition, the predicted large number of satellite galaxies has not been observed, i.e. they are absent from our own Milky way galaxy. Once more, it has been demonstrated that the book of Nature is the most difficult to understand.

If there were a single experiment only, physicists and astronomers may be inclined to disregard its results, as happened, for instance, with Zwicky’s dark matter hypothesis in the early 1930s. However, the set of independent experiments presented does not allow one to believe that something might have gone wrong with the experiments to arrive at these strange answers.

In addition, particular attention should be given to the CDT (causal dynamical triangulation) results, a new type of experiment, obtained from extensive computer simulations, which are based on the nonperturbative (i.e. exact, nonlinear) solutions of Einstein’s equations, which suggest that wormholes do not exist and spacetime is simply connected, i.e. wormholes may only be mathematically admissible solutions of Einstein’s field equations but are not realised by Nature. Hence, the idea that (nonexisting) wormholes are equivalent to entanglement, expressed symbolically by \( ER = EPR \) (see above), does not seem to be feasible. Furthermore, according to CDT simulations, the Universe (without matter) has a de Sitter topology (positive curvature) \[79\], which does not seem to be compatible with the assumption of an Anti-de-Sitter space of negative curvature, necessary for the above equivalence of wormholes and entanglement. There are no astronomical observations that suggest a complex topology of the Universe, that is, a simply connected domain with a de Sitter metric appears to be sufficient (Occam’s razor). According to CDT, spacetime is four dimensional, which is in accordance with the latest experimental data on the range of Newton’s gravitational law, that has now been extended down to about 1 μm.

Moreover, recent cosmological observations proved the existence of dark matter and confirmed the existence of a small acceleration towards galactic centers, numerically equivalent to the MOND hypothesis. However, MOND only works on the galactic scale, not for clusters of galaxies. Most important, observations from binary star systems by Kramer and Wex validated Einstein’s theory of general relativity in the nonlinear range. Hence, currently considered modified gravitational models as dark matter replacement in order to explain this acceleration seem to be in conflict with observation. The latest (indirect) confirmation of GR came on 16 March 2016 from the Integral satellite \[80\] that did not see any emission from a transient source in the form of hard X-rays or γ-rays that might have accompanied the gravitational waves detected by the LIGO team. This is in accordance with GR that predicts that the two black holes should not produce electromagnetic radiation at any wavelength (except if a neutron star were involved). Moreover, integral satellite measurements of the polarisation of photons have reduced the graininess of spacetime down to a level of 10^{-48} m, far below the Planck length of 10^{-35} m. Therefore, quantizing the spacetime field might no longer be a necessity in order to unify the interactions of physics at the Planck energy of 10^{19} GeV. Up to now, no dark matter particle has been found despite an intensive search during the past 40 years. Earlier confirmations on the possible existence of a dark matter particle by the Fermi satellite (detecting γ rays of energy between
10 keV and 300 GeV) and Pamela satellite as well as the AMS experiment on board of the ISS were not confirmed by recent Planck satellite data [51] and thus are to be considered false alarms.

Are there possible physical alternative concepts? A different but (yet) non-conclusive set of three experiments performed in the laboratory and in space was discussed above that may have measured extreme gravitomagnetic fields as well as gravity-like fields that have to be outside general relativity. These fields are many orders of magnitude larger than predicted by general relativity and thus would point to novel gravitational phenomena as well as gravitational bosons. Of particular interest would be the generation of an axial gravity-like field (i.e. a gravitational acceleration field) in the laboratory employing a rotating ring-disk configuration as shown in Figure 3 that is operating at cryogenic temperatures. There are ideas that, by proper material composition, a high-temperature field generation device might be possible, similar to the phenomenon of high superconductivity.

For physics to remain a science, it is necessary that it be subjected to experiment, which means that physics neither can follow majority decisions (remember 100 authors against Einstein) nor can it be ruled by authority. There is also no oracle of Delphi, forecasting what to expect from Nature. More realistic physical alternatives may have to be considered. For instance, the experiments that might have seen extreme gravitomagnetic or gravity-like fields, could be repeated within a short period at low cost (compared to accelerators). If their presently (nonconclusive) results can be confirmed, then an interaction between gravity and electromagnetism may exist as believed by Faraday and also searched for by Einstein. This would be a sign that the solution by string theory, claiming of having unified general relativity and quantum physics, cannot be correct because additional gravitational bosons need to exist to make this kind of interaction possible.

So far, it can be concluded that Einstein's view of gravity has been fully validated, but, at the same time, there is mounting evidence that gravity may have a far richer structure than Einsteinian gravity alone, e.g. consider the problem of the value of the gravitational constant (above). Thus, it seems that gravity as conceived by Einstein himself is not complete, a view that most likely would have confounded Einstein, who spent decades in proving the incompleteness of the quantum world, but, at the same time, was deliberating an interaction between electromagnetism and gravitation. But if those experiments that might have observed extreme gravitomagnetic fields can be confirmed, then an expansion of Einstein's view of gravity is inevitable.

The physics behind this kind of gravitational technology, briefly discussed in the previous section, is based on the existence of gravitomagnetic and gravity-like fields and will be presented in our second paper [3]. These fields – if experimentally confirmed – could lead to novel technology termed gravitational engineering and could serve as a means for propellantless propulsion [2], actively researched by aerospace industry in the 1960s [81] and in NASA's breakthrough propulsion physics program from 1996 to 2001 [82].

In the companion paper [3], a collection of novel physical concepts is presented under the name EHT, being derived from a set of basic founding principles mentioned above. Utilizing these ideas, the fundamental physical problems reported in this article are addressed, and an attempt is made to construct a physical model in accordance with recent experimental results. EHT is formulated as a major revision with respect to the nature and type of matter that is existing in our spacetime. As a consequence, the concept of spacetime itself has to be extended to (hopefully) solve the riddle of dark matter and dark energy. The aim is to resolve some long standing issues, for instance, the whereabouts of dark matter and the reason for the existence of dark energy.

First, and most important, the set of the governing fundamental physical principles has to be established that must be based on generally accepted phenomena. They are reflecting the basic qualities on which the Universe is resting. From the ensuing constraints of their implementation in conjunction with the physical coupling constants, that are obtained from the realm of pure mathematics (i.e. outside of physics), the quantitative physical laws are following. They must be both simple and powerful reflecting Occam's razor. Then, in a second step, a mathematical formulation may be attempted. Foremost is the principle of duality, followed by the principle of finiteness (arrow of time, no stationary stated, and cosmic dynamics), in particular the finite time of existence, in conjunction with the principle of optimisation and organisation (total energy zero) as well as the principle of quantisation (because of the finiteness of all physical entities, there are no infinities or singularities in physics).

These straightforward principles are placing major constraints on any physical theory [2] and also have far reaching consequences for any cosmological model, requiring, for instance, that the expansion of our Universe ultimately has to reach a turning point. In addition, the duality principle may require to modify the quest for unification. As Nature has shown over and over again, single phenomena are not observed. There is the particle–antiparticle duality, the wave-particle (point-like) duality...
of matter, or the spacetime-dark energy duality [2] etc. Hence, the search for a unification of all physical forces may remain unsuccessful because it may be possible only to unify the weak force with electromagnetism and the strong force with gravity. There may, however, exist an interaction between these two remaining forces, generating a relationship between the two long-range interactions of electromagnetism and gravity (e.g. in the form of the described gravitomagnetic experiments).

9 Conclusions

Weighing the experimental evidence presented, we think that a paradigm shift in our understanding of the Cosmos should be considered, with the possibility of paving the road to a different age (as pointed out in Chapter 11 of [2]), marked by an overthrow of the present Weltbild of physics, in particular, concerning the nature of matter and physical reality.

Before the next collider generation actually is being built – if this ever happens –, the relatively simple gravitational experiments discussed above should be repeated at several laboratories applying a much more sophisticated equipment. If the results of these experiments could be confirmed, then it is evident that Nature has chosen a different path than utilizing extra dimensions.

The physical alternative proposed is to replace the extension of spatial dimensions by the extension of the system of numbers, first suspected by Pythagoras and extensively discussed by Sir Roger Penrose in his comprehensive œuvre, e.g. [83] etc. As will be presented in [3], this approach should be leading to both different types of symmetries (groups) and suggests additional types of matter.

In 1946, the U.S. government funded a comprehensive feasibility report, prior to any hardware activities, termed Preliminary Design of an Experimental World-Circling Spaceship by Clauser at Douglas Aircraft Company [84] that marked the beginning of the era of spaceflight. Given the current theoretical and experimental hints, we seem to be in a similar situation today regarding the preliminary design of a gravitational-field propulsion device. Whether the success story will turn out to be similar cannot be decided at the moment. On the other hand, it is evident that for a risk averse society the chance of success is close to zero.

Finally, the question that naturally arises in this context is What’s Next? The attitude in which this question could be answered is described in a complete manner in the public lecture by N. Seiberg of 2013 [85] entitled What’s Next?

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