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SCIENTIFIC MODELS AND A COMPREHENSIVE PICTURE OF REALITY

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In questo quaderno de "La Nuova Critica" viene presentata una serie articolata e mirata di papers che si sono venuti raggrumando, in modo diverso, a partire da alcuni lavori presentati in occasione dello svolgimento di una Conferenza Internazionale dal titolo "Scientific Models and a Comprehensive Picture of Reality", che ha avuto luogo in Helsinki nei giorni 21 e 22 Maggio 2016 sotto l'egida della "Finnish Society for Natural Philosophy" in collaborazione con "The Physics Foundations Society". Il quaderno è stato curato da Tuomo Suntola ed Avril Styrman.

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Tuomo Suntola and Avril Styrman

INTRODUCTION

This Special Issue of *La Nuova Critica* contains papers based on the presentations given in the two-day workshop *Scientific Models and a Comprehensive Picture of Reality,* arranged by the Finnish Society for Natural Philosophy together with The Physics Foundations Society on May 21-22, 2016 in Helsinki. The workshop called for philosophers, physicists, and cosmologists to bring forth novel aspects about scientific models and the challenge of making nature understandable. Contemplation about the postulates of the models, their testability, and criteria for evaluating them was encouraged in the workshop.

The first day of the Workshop was dedicated to the status and philosophical foundations of theories in physics and cosmology. In his review on the status of theories of cosmology Prof. Jayant Narlikar stated his concerns about the high degree of hypothetical entities in standard cosmology, and the general lack of interest towards relevant alternatives. Dr. Heikki Sipilä reviewed applications of the zero-energy formulation of the conservation law of energy as a fundamental law of nature behind observed physical reality. Dr. Julian Barbour presented his ideas of the nature of time and its connection to the development of structures. Dr. Tuomo Suntola introduced the holistic Dynamic Universe Model which discloses the linkage between local and the whole and describes the observable physical reality in terms of absolute time and distance. Lic. Phil. Avril Styrman introduced the Principle of Economy as an evaluation criterion of theories, which compares the accuracy of predictions and the magnitude of metaphysical commitments of theories, and applied it in evaluating the Standard Cosmology Model and the Dynamic Universe Model.

The second day of the workshop was focused more on philosophical aspects of the picture of reality – complemented with Prof. Ari Lehto's presentation on his findings of the Period Doubling (or Frequency Halving) process as a universal mechanism behind the buildup of stabile structures starting from the Planck dimensions – extending to elementary particles and celestial and cosmological structures. Prof. Ilkka Niiniluoto focused on the concept of *truthlikeness*, i.e., on the distance between predictions of a theory and observations reflecting the true state of nature. Prof. Atocha Aliseda contemplated logical systems and argued for a schema set of structural rules as a demarcation criterion to distinguish logical systems from those which are not. This question was then exported to physics as the following one: what counts as a cosmological system? This view allows arguing for a comprehensive picture of reality while giving space to a plurality of systems. Dr. Mikael Karimäki focused on connections between fundamental physical constants as links between the three legs of physics: Quantum Physics, Statistical Physics, and Relativistic Physics.

A general conclusion of the discussions in the Workshop is that both physicist and philosophers appear to accept the metaphysical bases of the present theories for granted and limit the evaluation of the theories mainly to their internal logic and the accuracy of predictions.

There are two major problems with the metaphysical postulates of the present paradigmatic theories. First, theories of different branches of physics are mutually contradictory and thus cannot be unified. Second, the theories do not open up an understandable picture of reality – which should be a primary challenge of physical theories. The problems are intimately interrelated: a comprehensive and understandable worldview cannot be built on mutually contradictory foundations. It looks like empiricism and mathematics have captured the role of metaphysics. The basic assumptions of the theories are not acknowledged as metaphysical postulates but considered as "empirical facts" and mathematical necessities. Further, to save the theories from falsification, they are complemented with free parameters to match the predictions to observations. Accepting this, theories obtain the role of mathematical descriptions of observations instead of serving as real building blocks for a comprehensive picture of reality.

For a real step forward, we should identify and acknowledge the metaphysical commitments implicit in the theories and extend the philosophical evaluation to the metaphysical choices and the coherence of theories – not only for each theory separately but for a unifying framework for theories covering all branches of physics.

The Workshop program and links to the presentations can be downloaded at
http://www.protsv.fi/lfs/luennot/2016_Workshop/Program.pdf

Jayant Narlikar

WHAT SHOULD WE EXPECT FROM A MODEL OF THE UNIVERSE?

[**Abstract**] Cosmology is the branch of astronomy that deals with the large scale structure of the universe and with the issues of its origin and evolution. As man's ability to view the cosmos grew and parallelly his ability to reason based on scientific evidence also grew, the subject underwent a transformation. From a largely speculative and philosophical exercise it changed to an important scientific endeavour in which facts and theories go hand in hand.
Certainly, when one looks at the wonderful array of telescopes and detectors that modern technology has provided, one sees the reason for the boldness displayed by today's theoreticians. But boldness in formulating theories must rest on a solid factual basis. To what extent is today's cosmology based on solid facts? To what extent is it speculative? Does it meet the scientific requirement of testability? I will try to answer these questions against the historical backdrop of evolution of the subject.
Facts and speculations are both essential for a healthy growth of science. Facts tell us all that we know to be true about the universe and make up our current experience. Speculations allow the human mind to break out of the confines of the current experience and to think of scenarios that may appear quite strange. However, all such speculations must ultimately be checked against facts, if they are to form part of science.

1. Karl Popper's Doctrine

Before coming to modern cosmology, I would like to begin with the doctrine associated with Karl Popper. It lays great stress on verifiability of a model or a theory. Thus, if we have a model of any physical phenomenon or event, we should ask what predictions the model makes that can be tested and verified? If the model makes a verifiable prediction and our verification process gives it “a clean chit”, then the model survives. If, on the other hand, it does not pass the model, then this failure makes us reject the model. Thus, Popper’s rule is loaded towards rejection of a hypothesis. It tells us when to reject the model but does not allow us to accept it under any circumstances. Despite this apparent “one-sidedness” the Popper doctrine provides a safe way through the evidence available for a model.

I will return to this doctrine in my discussion later.

How has cosmology fared under these criteria? Having briefly reviewed how man has reached the present level of understanding of the cosmos, I will come to critically examining the current status of the subject and try to answer the following question:

Is Cosmology, as practised today, a science?

This may seem to many readers, a rather strange question to ask, particularly by me despite having worked in this field for over four decades.

2. Ancient cosmologies

Most developed societies in ancient cultures worried about the question about the origin and nature of the cosmos. The ancient Indian cosmology had the concept of the *Brahmanda:* the Cosmic Egg that contained the whole universe. All aspects of the living and the non-living matter was contained in the cosmic egg. The Nordic cultures had the concept of a Norse *World Tree*: the tree which carried the universe on its roots and branches. Concepts like these are today treated as highly imaginative speculations and no more: because they did not have any support in facts.

Susceptibility to facts began to appear in theories more than two millennia ago, especially amongst the Greeks. The scientific approach required that theories could be proposed and tested for their predictions. If the predictions of a theory failed to meet the facts, the theory would have to be abandoned or modified. Symptoms of being on the wrong track for a theory therefore would be its need for frequent modification.

An initially popular idea that failed when facts could not support it was the Pythagorean concept of the central fire. These followers of Pythagoras believed that the Earth goes round a *'Central Fire'* with the Sun lying outside its orbit. The critics of this theory asked: why don't we see the central fire? To explain the lack of visibility of the Central Fire, the Pythagoreans proposed that there exists a *Counter-Earth* that came in between the fire and the Earth, thus blocking the view to the former. The Counter-Earth moved exactly in such a way as to block the Earth's view of the Central Fire. This explanation worked for a while until some people asked: Why don't we see the Counter-Earth? To this the reply given was that Greece existed on the opposite side relative to the Counter-Earth! However, some travellers went to the 'opposite side' and still could not find it. Needless to say, that the theory died a natural death. I will recall this episode later in this article when discussing modern cosmology.

The epicyclic theory of the Greek

A theory that required more and more additional assumptions to prop it up and had ultimately to be abandoned was of course, the epicyclic theory of the Greeks. This theory was based on the Aristotelian view that all natural motions are in circles. Aristotle preferred circles because they have symmetry, namely any arc of it can be placed congruently on any other part of it. This is nothing but the translational symmetry as we go round the circle. For similar reasons Aristotle also preferred the sphere amongst all other surfaces. The modern cosmologist also goes in for similar symmetry arguments (of homogeneity and isotropy) when modelling the universe.

However, the planetary orbits refused to fit into this pattern. So to make them fit, the Greeks invented epicycles, that is a sequence of circles in which the centre of the *nth* circle moves on the boundary of the *(n-1)th* one, all of these drawn around a fixed Earth. By a suitable choice of parameters this construction could fit the motion of a planet over limited duration. It had to be redone for another period after the first one broke down. It was a rather elaborate but clumsy exercise but it was sustained for 16-17 centuries, because the intelligentsia believed in a geocentric framework controlled by Aristotelian views of the universe. Ultimately the correct solution was given by Kepler in terms of elliptical orbits of planets. (A mathematician will tell you that you can approximate elliptical motion by a series of epicycles over limited periods.) Thus, the Aristotelian insistence on circles was against factual evidence.

3. Majority view is not necessarily correct

The fate of the epicyclic theory tells us that there is no guarantee that a speculation is correct just because a majority believe in it. This dictum has been demonstrated in science time and again. A striking example of this in cosmology about a century ago is seen in the way astronomers viewed bright nebulae.

A nebula is a cloudlike object which is visible in different colours and can be contrasted with the point-like appearance of stars. Our Milky Way Galaxy has several such nebulae. However, the question was: Are all such cloudlike objects part of our Milky Way? A small minority of astronomers believed that quite a few of these were galaxies in their own right, and they looked tiny because they were very far away. The majority view was, however, quite firmly otherwise and can be summed up in the following extract from a popular book on astronomy written about a century ago:

> *"The question whether nebulae are external galaxies hardly any longer needs discussion. No competent thinker, with the whole of the available evidence before him, can now, it is safe to say, maintain any single nebula to be a star system of co-ordinate rank with the Milky Way…."*
>
> Agnes Clerke, The System of the Stars, 1905

The firmness of the tone of the authoress merely reflects the firmness of view felt by the majority of astronomers who worked on stars and the Milky Way. However, with the advent of better telescopes and spectroscopy, this view was falsified within a couple of decades. Most of the nebulae were shown to be extragalactic and were galaxies in their own right. Edwin Hubble who made the discovery that the universe is expanding was mainly responsible for this change of perception. Indeed, by 1925, astronomers had come to accept that there are millions of galaxies in the observable universe and that our Milky Way is just one amongst many.

We now begin with some data which show that they backed astronomical speculations.

Where speculations were backed by facts

Let me now describe briefly a case where speculation *was* backed by facts. Newton's Law of Gravitation may be considered such a speculation, if we take the falling apple episode to indicate Newton's speculation that a universal force exists in the universe which attracts the Moon towards the Earth just as it attracts the apple towards the Earth. However, Newton did not stop at this speculation. He worked out from Kepler's laws what force attracts the planets to the Sun so that they move around it in Keplerian ellipses. To work out this problem based on his own laws of motion, Newton created and used a new branch of mathematics, which today is known as 'calculus'. He deduced that the force would have to be governed by the inverse-square law. Using calculus, he solved the reverse problem too: What orbits would planets have if they were attracted by a force as per the inverse square law? Again, he got bound orbits to be ellipses.

How did this hypothesis fare with *new* observations? For, a good scientific theory not only explains what has been found, but also explains new observations. Two separate events verified Newton's law: (I) the arrival of Halley's comet and (ii) the discovery of Neptune. Let us briefly look at these events.

Comets come near the Earth every year. Some of them are quite bright and can be seen with the naked eye. It was Edmund Halley, a friend of Newton's who had noticed that comets had been sighted in the years 1066, 1456, 1531, 1607 and 1682. Taking the last four sightings it was clear that there was a period of 75-76 years between appearances. Taking cue from planetary periods, Halley conjectured that these visits were by the same comet orbiting the Sun in a highly elliptical orbit with a period of this order, under Newton's law of gravitation. He predicted the next arrival of the comet in 1758. Although he was not alive to see his prediction come true, others were impressed by the arrival of the comet as predicted and it was named after Halley.

The second example relates to the observed discrepancies in the motion of planet Uranus that had been discovered by William Herschel in 1781. As a planet, it was expected to follow a Keplerian orbit, now well explained by Newton's law of gravitation. However, by the 1830s, the departure from the predicted trajectory was causing concern. In the 1840s J.C. Adams in Cambridge, England and U.J. J. Leverrier in Paris had independently concluded that the discrepancy was not due to any breakdown of Newton's law, but because of the existence of an as yet undiscovered planet nearby whose gravitational influence was causing the observed perturbations. This prediction, ignored at first by the important British and French astronomers, was subsequently verified by Galle in the Berlin Observatory who succeeded in locating the new planet. It was named Neptune.

Perhaps it is worth contrasting the above example with the "Counter-Earth" hypothesis. Both Neptune and Counter-Earth were not known before they were predicted. Neptune's existence was confirmed by observations whereas Counter-Earth's was not and additional hypothesis had to be framed as to why it could not be seen. This contrast illustrates the difference between a successful speculation and an unsuccessful one. If we apply Popper's rule, we can make this distinction clear.

Repeatability of a scientific experiment

A scientific experiment should be repeatable and not a one-shot affair. Even in astronomy stellar evolution provides examples of 'repeated experiments', vide the stars in the H-R Diagram. (This is short for 'Hertzsprung-Russell diagram so named after the two astronomers who independently thought of generating it by plotting the luminosity of a star against its surface temperature.) A typical star is an experiment in stellar structure. The theory of stellar structure tells us how to compute the luminosity (L), radius (R) and surface temperature (T) of a star, given its mass (M). Thus the theoretician can predict the L, R, T values for the Sun, given its mass. The theory is right if these values check out OK.

However, the matter does not end there. One can ask, how would these physical values change if the mass were different. The theory of course predicts the answer. Observers have to find stars of different masses and apply the theory to them. Such an exercise also checks out OK for a large number of stars.

This is what the repeatability of an experiment is all about. Notice that unlike his laboratory counterpart who can vary the experimental parameters as needed, the astrophysicist does not enjoy that luxury of altering his experiment. Rather he has to view the system from afar *with no facility of controlling it.* Nevertheless, as mentioned just now, he can still verify his theory by studying many stars. It is because he can do so and has done so that lends credibility to his theory of stellar structure. He could not have claimed such a credibility if he were able to test his theory for only one star, the Sun.

With these remarks, I now turn to modern cosmology.

4. Standard cosmology

The brief history of the beginning of modern cosmology is as follows. In 1915 Albert Einstein formulated what he considered the *final* version of general relativity. He hoped it to be a comprehensive theory replacing Newton's 'universal' law of gravitation. In 1916 Karl Schwarzschild used Einstein's equations to work out the gravitational influence of a spherical mass M on spacetime geometry, in an otherwise empty universe. At the other extreme, Einstein attempted in 1917 the model of a static homogeneous and isotropic model of the universe. His attempts to get such a model from his 1915 equations, however, were unsuccessful and he needed to modify them still further by adding an extra term of particular relevance to cosmology.

This was the so-called 'lambda-term' which in Newtonian language implied an extra universal force of repulsion between any two particles that increased in proportion to their distance apart. Thus, the force was small and negligible at the Solar System level, but became significant at cosmological distances. With this force Einstein could obtain a static model in which attractive gravitation was balanced by the λ-repulsion. The static model held sway for about a decade since astronomers had not found any evidence for large scale motions in the universe.

During 1922-24, however, Alexander Friedmann produced mathematical models of the universe in which there was a systematic large scale motion. In fact, a typical model described an *expanding universe*; that is any two points in the universe would be moving apart from each other. As the general belief those days was in a static universe, these models were looked at by most cosmologists including Einstein as mathematical curiosities. In 1927 Abbe Lemaitre, for example rediscovered Friedmann models and his work also went unrecognized. Lemaitre, however, had made a clear prediction of the velocity distance relation, based on the then available observations. This prediction, two years ahead of Hubble's is not widely known. Lemaitre's classic paper is proudly displayed in the Institut d'Astrophysique in Liege.

These 'mathematical curiosities' soon became reality when after a decade-long series of observations of galaxies and their spectra, Edwin Hubble announced in 1929 the velocity-distance relation that led to the acceptance of the expanding universe. This relation, now known as Hubble's law, tells us that any galaxy seen by us at distance R is moving radially away from us with a velocity $V = H \times R$, where H is a constant called the *Hubble constant.*

It did not take theoreticians long to realize that this was precisely the relation to be expected from the Friedmann-Lemaitre models. If one associates a scale factor $S(t)$ with the expanding universe, so that the distance between any two points at epoch t increases in proportion to the scale factor, then these models tell us that $H = [dS/dt] / S$. Thus, we can say that these theoretical models had anticipated the universal expansion. This was therefore confirmation of a speculation by facts, a speculation that was initially not believed, even by Einstein.

Is the universe decelerating?

Einstein swung over to the other extreme when it was discovered that the universe is not static: he felt that the λ-term was an unnecessary baggage for general relativity to carry. In a paper written with de Sitter in 1932, Einstein opted for the simplest of the Friedmann models, one in which both the λ-term and the curvature of spatial sections (t = constant) were zero, and matter is pressure-free dust. This model came to be known as the *Einstein de Sitter model*. Following Einstein, most cosmologists took $\lambda = 0$ and preferred to work with essentially three kinds of models in which the space sections are (i) flat or (ii) with positive curvature or (iii) with negative curvature.

If the λ-term is not present, the Friedmann models predict a *decelerated expansion*. Indeed, the scale factor $S(t)$ can be related to the Hubble constant H, and a deceleration parameter q by $qH^2 = -[d^2S/dt^2]/S$. For the Einstein - de Sitter model, we have $q = 1/2$. The big bang models in favour during the period 1960-1980 had $q > 0$, and attempts were made to measure its value by extending the Hubble velocity-distance relation to larger and larger distances. The astronomer measures the velocity spectroscopically by measuring the spectral shift (the proportionate increase in the wavelength of a line) normally denoted by the symbol z. Likewise, distance is estimated by measuring the apparent brightness on the magnitude scale and denoted by m. Most observations of the m-z relation unequivocally claimed that this result was established. The odd one out those days was the steady state model, which had $S = \exp Ht$, and so, $q = -1$. However, it was ruled inconsistent with observations because it described an *accelerating* universe. I will return to this test later.

It is worth mentioning that the model of the steady state universe did not come through the general theory of relativity. In 1948 Herman Bondi and Tommy Gold proposed this model from a general principle which they called *the Perfect Cosmological Principle*, which supposed that the universe is homogeneous and isotropic as well as unchanging with time. An excellent introduction to this model is provided in Bondi's book *Cosmology*. A different approach leading to the same model came from Fred Hoyle who cast the steady state model in a general relativistic framework with the modification that it has a negative energy density

Creation Field. Because of space limitations we will not go into details here.

But we mention that Bondi regarded the steady state model as an ideal subject for the application of Popper's ideas.

The counts of radio sources

One illustration will suffice. Radio astronomers have been using their latest observing techniques to test cosmological models. To appreciate the main issue involved, consider a simple Euclidean model which has radio sources, each of luminosity L. Let the (uniform) number density of these sources be n. Then if we count these sources to distance R, we will get $N = 4\pi R^3/3\times n$ of them. They will all be brighter than the most remote of them. Taking the flux received from such a source to be $S = L/4\pi R^2$. Thus, if we plot log N against log S, we should get a straight line with slope -1.5.

Cambridge radio astronomers in the late 1950s claimed that they got a steeper slope of -1.8. The steady state theory gave a slope of -1.5 at high flux flattening to -1.4, -1.3 etc. Thus, this was claimed as a disproof of the steady state theory. Later Hoyle and I showed that the steep slope could be explained by local inhomogeneity. This example, however serves to demonstrate the care needed in drawing conclusions. Also, we note that density parameter can be used in classical Friedmann-Lemaitre models to fit any data. Thus, these models are not really testable.

The early hot universe

While observers were trying to determine which Friedmann model fitted observations of galaxies best, theoreticians were examining the physical properties of the Friedmann models. All models seemed to lead to the conclusion that the scale factor was zero at some epoch in the past. At this epoch, the Hubble constant became infinite. Known as the *big bang* epoch this signified the creation of the universe in a singular and explosive event, when the density and temperature of matter as well as radiation were infinite. Mathematically speaking this instant defied any attempts at quantitative physics, which is why one uses the adjective 'singular'. Conditions soon after the big bang were so different from the present universe, that the extrapolation of present physical laws to those epochs was considered highly speculative.

Nevertheless, in the 1940s George Gamow made a daring extrapolation of known physics to the early epochs when the universe was 1-200 seconds old! [For comparison, the present epoch is believed to be around 10-15 billion years from the big bang.] He used thermodynamics and nuclear physics to study the physical behaviour of the universe, which he assumed at that stage to be mainly containing neutrons and protons, light particles like electrons, positrons, neutrinos, etc., and of course photons. Using this brew he hoped to demonstrate that *all* chemical elements were made in that early era.

Gamow's speculations on primordial nucleosynthesis achieved partial success: they worked for light nuclei but failed for nuclei like carbon, oxygen or heavier nuclei than these. Gamow's calculation redone with improved nuclear data shows that of the 200-plus isotopes known, the calculated abundances of light nuclei like D, He, Li, Be, B are generally of the right order when compared to the observed abundances. For the production of heavier nuclei one has to look for stellar environments.

However, Gamow's work had another positive fallout. The prediction was made by two of Gamow's younger colleagues, Ralph Alpher and Robert Herman that the universe today should have a relic *thermal* radiation background with a temperature of 5K. This prediction was verified and found right when in 1965 Arno Penzias and Robert Wilson detected isotropic microwave background radiation (MBR) at 3K.

The big bang cosmology can therefore take credit for making three successful predictions, namely, the expansion of the universe, the creation of light nuclei and the presence of a relic background. However, there are some technical issues that need to be mentioned in the context of MBR.

a. Can we call this a prediction? A prediction precedes observational checks. It is commonly assumed that the discovery of the MBR was first made in 1965. This is historically not true. The background had already been detected by McKeller in 1941, but its significance had not been realized. McKellar had found that in the spectra of some galactic stars, upper levels in certain molecules had been populated, which could happen if there were a radiation bath around. Using the relative population densities McKellar had estimated the temperature of the radiation bath to be 2.3 K. This was not too far off from the present-day value of 2.73K.

b. The temperature of the relic radiation cannot be determined by the early universe calculations. The estimate 5K of Alpher and Hermann was guess-work rather than any theoretical calculation. Indeed, on later occasions Gamow himself had guesstimated the temperature variously at values between 7K to 50 K.

c. The concept of a radiation background in the universe did not originate with Alpher and Herman. There had been other previous predictions of a radiation background with temperature of ~ 3K by Eddington and others. These predictions had used starlight as the basis. Recently, Jean-Claude Pecker, Chandra Wickramasinghe and I have repeated Eddington's calculation to show that based on the recent stellar data, the radiation of all stars in the Galaxy, if thermalized, produces a temperature of around 4 degrees absolute.

d. In 1955 Bondi, Gold and Hoyle had shown that if all helium were made in stars in the steady state universe, the resulting radiation on thermalization would have a temperature 2.8 K.

Nevertheless, the physical basis of this approach of Gamow is securely based in known physics. The speculations about the early universe could be raised to the level of a sound physical theory because the physics used in the nucleosynthesis calculations was based on known applications of thermodynamics, statistical mechanics and nuclear physics. The validity of the general theory of relativity was, certainly stretched severely. The solar system tests confirm the validity of relativity at the Schwarzschild parameter $\{2GM/c^2R\}$ of $\sim 4 \cdot 10^{-6}$, whereas in cosmology we are stretching the credibility of the theory to a curvature parameter ~ 1. This theoretical leap of going from weak to strong field was, however, justified by the principle of equivalence. That is, one uses locally inertial region to apply the flat-spacetime physics and then extends the same to curved spacetime by using covariance of physical equations. I will return to this point later.

The astronomical base is, however, not so secure for the following reason. Direct astronomical observations of distant galaxies and quasars go as far as $z \sim 6$-10, say. That is to the state when the scale factor was around 10% of its present value. The big bang models show that even if we have much better telescopes, we still cannot observe the universe coherently beyond a redshift of a 1000, for the universe is opaque beyond $z \sim 1000$. *However, the hot universe calculations go back to redshifts as high as* $z > 10^9$. *In short cosmologists are talking about a phase in the history of the universe that is not observable.*

So, today's observations of light nuclear abundances and the origin of CMBR (Cosmic Microwave Background Radiation) at best provide consistency checks on the early universe calculations. They do not guarantee that the scenario is unique. The one crucial tool of science, namely experimentally checking the direct consequences of a theory is not available here.

Further, the universe being a 'one and only' system, the above sequence of primordial nucleosynthesis followed by a relic radiation background is not a 'repeatable experiment'. It happened only once. By contrast, stellar nucleosynthesis *is* a repeatable experiment, since we can find many stars in which the process is taking place at different stages.

Astroparticle physics

Nevertheless, the discovery of MBR and successes of primordial nucleosynthesis persuaded many cosmologists to be more daring and to push their investigations of the early universe even closer to the big bang epoch. These efforts are sometimes identified with the studies of the 'very early universe' whereas the Gamow-Alpher-Herman work was limited to the 'early universe'. How ”very early” does the former mean?

It is here that cosmologists were tempted to form a partnership with particle physicists to generate a new branch called 'astroparticle physics'. The idea here is that the physics to be used in the discussions of the very early epochs would be supplied by the particle physicists, whereas the cosmologists will supply the background scenario in which the particle physicists would test their theories. For example, consider theories and experiments in particle physics that have shown that unification of the electromagnetic with the weak interaction will take place at particle energies of ~100 GeV. The Salam-Weinberg model works very well at this energy level. Using the extrapolations of these ideas, particle theorists are looking for a further unification of the above 'electro-weak' theory with the strong interaction. Calculations suggest that this 'grand unification' may be achievable at particle energies of ~ 10^{16}GeV. These energies are beyond the range of particle detectors by several orders of magnitude. So, testing them in the laboratory like any other physical theory seems out of the question. How then can such a work be confirmed? For, without any experimental check a physical theory remains a speculation. To get round this impasse particle physicists use the big bang models. These show, that by going sufficiently close to the big bang epoch one gets a high enough temperature wherein particles have energies of the order 10^{16}GeV. So the hot universe provides them with a high energy particle accelerator. On the cosmologist's side the need for a physical theory to tell what was the universe like very early on, forced them into the arms of the particle physicist.

> So the expectations on both sides may be summarized thus:
>
> ***Particle physicist***: Since the big bang is a well-established paradigm and secure as a theory of cosmology let me try my speculations of very high energy particle physics in this background…
>
> ***Cosmologist***: Since particle physicists know what they are talking about, let me apply their well worked out theories to test my speculations of the very early universe.
>
> ***Fact is that both sides are using speculations only***!

The recent CERN accelerator commonly known as LHC (Large Hadron Collider) is often publicized as generating a post-big bang type environment. The energy it produces is, however, no more than 10,000 GeV, whereas the unification epoch needs energy of the order of ten million billion GeV. Thus, an energy gap of a thousand billion separates the achievable reality and required theoretical expectation.

For example, the temperature of grand unification is achieved in a big bang model when the age of the universe is ~10^{-36} second. We can attach a meaning to the time temperature relationship provided we have confidence in our basic thermodynamics being applicable. Thermodynamics and its underlying statistical mechanics is well established in flat spacetime. To apply it to curved spacetime one resorts to the principle of equivalence which allows the flat spacetime physics to be applied in a locally inertial coordinate system. [This is like applying Euclid's geometry on a small enough region of the Earth's surface to ensure that a 'flat-Earth' approximation holds!] This was the justification in the calculations used by Gamow and his colleagues for primordial nucleosynthesis. In that era, the locally flat (or inertial) volume did contain a large enough number of particles to legitimize the use of statistical mechanics. However, when you consider the very early universe at the grand unification era, you discover, that a locally inertial region hardly contains *one particle*! Thus, it becomes ridiculous to apply the concepts of thermodynamics as straight extrapolations of flat spacetime physics. This aspect was first pointed out by Padmanabhan and Vasanthi in 1982.

The notion of inflation

However, nothing can better demonstrate the highly speculative turn cosmology has taken than the popularity enjoyed by the idea of inflation. This concept rests on the idea of phase transition at the breakdown of the grand unification of the three fundamental forces. Since the phase transition signifies a change of state of matter from a unified theory to one in which the electroweak theory separates from the strong interaction, the physical change is reflected in the way the universe expands. The phase transition does not occur instantly but over a short interval and during that interval the universe expands very rapidly (with $S(t) = \exp at$, $a \sim 10^{36}\ s^{-1}$). This is known as the *inflationary* phase. It is claimed that the universe must have gone through such a phase, if some conceptual problems associated with the big bang models have to be resolved. These are referred to as the "Horizon Problem", the "Monopole Problem", the "Flatness Problem", etc. I will not go into those problems except to mention that although these problems were known to exist for a long time, they were ignored until the idea of inflation appeared on the scene to solve them!

As a physical theory, let us ask if it follows the usual guidelines to which a scientific theory aught to be subjected. First, is the physics behind 'inflation' well and independently tested? Secondly, has inflation been directly observed or is it observable in principle? Lastly, does it describe a repeatable event that can be observed in other contexts? The answer to all these questions is a resounding NO. We have seen that the nature of particle / high energy physics at the energy 10^{16} GeV is not yet determined by physicists. Further, as mentioned earlier, inflation is believed to have taken place well before the epoch of redshift 1000, prior to which the universe was not observable by astronomical observations. That it is not a repeatable phenomenon is clear from the conditions that are supposed to give rise to it…they do not occur in the universe again. In short we are asked to accept a paradigm which is founded on insecure physics, is neither observable nor repeatable.

However, the earlier example of Pythagorean counter-Earth comes to mind when we see how this idea is presented. First it was argued that if there were a grand unified theory, then it would necessarily lead to the existence of massive magnetic monopoles. Then it was estimated that their relic density today would be abnormally high, by some fifteen orders of magnitude. In short, if one goes by the standard results followed by the grand unified theories, one runs into an embarrassingly high relic quantity of magnetic monopoles. The only way to avoid this catastrophic conclusion would be through inflation, for then these monopoles would be diluted away. Thus, from a null observation (no monopoles seen today) one is apparently able to claim confirmation of two speculations, namely

1. A grand unified theory operated in the very early epochs.
2. Inflation took place in the very early epochs.

Can two speculations together add up to a fact? Apparently, they do if you are an astroparticle physicist!

Dark matter: Emperor's new clothes?

From 1975 onwards astronomers have been receiving evidence indicating the presence of dark matter considerably in excess of visible matter in the universe. This evidence is in the form of flat rotation curves of neutral hydrogen clouds going round spiral galaxies and from the dynamics of clusters of galaxies. If one follows the Newtonian laws of gravitation and dynamics, then the observations force one to have dark matter in addition to the visible matter. However, if one is willing to modify these laws, the presence of dark matter may not be required. Following Occam's razor, cosmologists opt for dark matter.

What can dark matter be made of? Prima facie, there are many possibilities, e.g., black holes, very old white dwarfs, brown dwarfs and planets of Jupiter size, etc. However, these alternatives are all of objects made of normal baryonic matter. But, if dark matter turned out to be wholly baryonic, it will pose problems for the big bang. First, if one assumes all the observed matter to be baryonic, the amount of deuterium produced in primordial nucleosynthesis would have been extremely low, too little to explain the observed abundance. Secondly, the process of making large scale structure would create fluctuations in the radiation background, far larger than observed today.

Now the normal process of testing a scientific theory is to make predictions and check them with observations. By this standard, the presence of dark matter should have taken away the two major predictions of big bang cosmology, namely the production of light nuclei and the existence of a relic microwave background. However, instead of following this paradigm, cosmologists have sought to modify the normal assumption that matter in the universe is baryonic. Instead they argue that dark matter may be made of esoteric particles generated by the grand unified, supersymmetric and other speculative particle theories: e.g. wimps, massive neutrinos, supersymmetric particles, etc. In short, the assumption of what the majority of matter in the universe consists of is based on highly speculative particle theories rather than on the baryonic option that does not require any speculative assumption. This is done so that the big bang paradigm is propped up.

As yet there is no direct astronomical or laboratory evidence for non-baryonic dark matter. Yet the confidence with which it is asserted that such matter exists in far greater quantity than the normal baryonic matter reminds one of the story *Emperor's New Clothes* by Hans Christian Anderson.

Claims for dark energy

Post-1999 there has been an upsurge in confidently made assertions by cosmologists on the presence of dark energy, quintessence, branes, etc. These are extensions of the cosmological constant idea first introduced by Einstein into general relativity (and later withdrawn as being unnecessary). What is the evidence for this idea?

The spurt in these speculations started with the claim in 1999 by several observational cosmologists that supernovae at high redshifts are significantly dimmer than the nearby ones. These observations can be explained by assuming, that the universe is accelerating, which in turn leads the general relativist to the λ-term. However, such a claim should be moderated by at least three uncertain factors. Do we know that distant supernovae are of the same brightness as the nearby ones? This aspect has still not been properly sorted out. Do we know for certain that intergalactic dust is not making distant supernovae dimmer? Again, working counter-examples suggesting that dust may be playing a major role have been suggested. Finally, are we certain that gravitational lensing is not playing a role in amplifying distant supernovae and thus making all calculations subject to change?

Beyond this, it is also claimed that having a non-zero cosmological constant helps in fitting data on the angular power spectrum of inhomogeneities of the microwave background. The most popular ideas on formation of large scale structure also rely increasingly on λ, besides on the esoteric (non-baryonic) dark matter. In fact, it is now argued that the MBR, structure formation and supernova measurments allow one to determine the cosmological parameters so accurately that one can now talk of 'precision cosmology'.

Before we get carried away by this new euphoria, let us assess dispassionately the role of the cosmological constant. A balance-sheet for λ may be prepared as follows.

Previous studies (1960-80) using the *m-z* relation revealed several practical pitfalls in the claims to measure the deceleration or acceleration of the universe. Recall that in those days the claim that the universe is decelerating was made so firmly that the steady state theory, the only one to predict an accelerating universe was ruled out. These and other uncertainties persist in the supernova *m-z* test also as just mentioned. But these have been largely ignored because current theoretical speculations in cosmology find it attractive to have a positive nonzero λ.

It has been the previous history of the λ-term that cosmologists have resurrected it whenever they felt the need to do so in order to explain all the observations. If the observations change or get discredited, then back it goes into mothballs! So, it remains to be seen how long it maintains its present popularity.

The present compulsions for λ are (a) It solves the age problem. The ages of models of the universe with a non-zero λ are large enough (about 13-14 billion years) to accommodate the oldest known objects in the universe. (b) It explains some of the observations of fluctuations of the radiation background as well as dimming of distant supernovae. (c) Its origin can be linked to inflation. There are hopes of relating the present value of this constant to the inflationary phase.

However, this term comes with a baggage of problems too. Some of these are: (a) Why and how did λ drop by 108 orders of magnitude from inflation to the present epoch? For this is what must happen if the origin of this term lies in inflation. (b) How is 'dark energy' typified by λ related to the rest of the forces of nature? This is not yet understood.

5. General comments

Let me summarize the discussion of modern cosmology in terms of four comments:

A. The studies of the very early universe are highly speculative both in terms of astronomy and particle physics.

B. They describe a scenario that is not expected to repeat. Although quantum mechanics also started with esoteric looking ideas, these gained credibility through *repeated experiments*. Take for example, Bose statistics. It seeks to apply an abstract mathematical concept to microscopic indistinguishable particles. We may not be able to see these particles, yet the predictions about their collective behaviour are very clearly verified in the laboratory.

C. Normal physics, e.g., statistical mechanics as extrapolated from flat spacetime is unusable in the early spacetimes of very high curvature.

D. Direct observations of the universe extend up to densities of matter ~ 200 times the present value, whereas the extrapolations to the very early universe extend to ~ 10^{87} times the present value. Nowhere in physics are theories extrapolated (that too without some verification) over such a range.

So, I return to the question I raised in the beginning of this lecture and answer it in the following long sentence:

Although remarkable strides have been made both in theory and experiment in physics, and telescopes of various kinds have enlarged man's capacity to observe the universe, by the normal criteria of close interaction between theory and observation, cosmology, as it is practised today, has far too large a speculative element to qualify for the title of a scientific discipline.

Heikki Sipilä

THE ZERO-ENERGY PRINCIPLE AS A FUNDAMENTAL LAW OF NATURE

[**Abstract**] The expanding universe does work against gravity. Based on this, as early as the late 1930s Pasqual Jordan first suggested that the mass energy of stars and the negative gravitational energy of the universe are equal and the total energy of the universe is zero [1]. This hypothesis has been known to some physicists; e.g. Richard Feynman discussed this topic in his teachings on gravitation in the 1960s. However, this idea and its implications have not been widely known, since during recent years, the zero-energy principle has appeared again in several papers without any reference to earlier works. Tuomo Suntola found the zero-energy principle when studying energy balances in spherically closed space. In Suntola's model, the universe is described as a three-dimensional expanding surface of a four-dimensional sphere. The same was proposed by Richard Feynman, but he did not develop the idea further. It appears that Mach's principle, the relation of the local to the whole, and the zero-energy principle are closely connected. Suntola's model links local phenomena to the rest of space; Mach's principle gets a quantitative explanation, and the velocity of light in space is linked to the expansion velocity of space in the fourth dimension. Observational evidence that the universe is a three-dimensional surface of a four sphere is discussed.

1. Zero energy principle and Mach's principle

The origin of inertia was an unsolved problem in classical mechanics. In the early 1900s, Ernst Mach proposed that locally observed inertia follows from the interaction between the accelerated mass and the mass in the rest of space – the concept known as Mach's principle. When working on the general relativity theory, Albert Einstein had high respect for Mach's ideas, and he tried to include Mach's principle in the theory. The solution, however, was different. Einstein based the general theory of relativity on the equivalence principle which equalizes gravitational and inertial masses. The equivalence principle does not disclose the origin of inertia but it is enough to link the gravitational acceleration to inertial acceleration required by general relativity. The equivalence principle has been verified experimentally at very high accuracy at a specific gravitational potential [2], however, there are no corresponding tests at different gravitational potentials.

Dennis Sciama studied inertia based on Mach's principle in his paper *"Origin of Inertia"* [3] published 1953. This was Sciama's topic in his thesis work done under Paul Dirac. Paul Dirac usually had no PhD students, and Sciama was later proud that he had done this work under him. Sciama developed a theory of gravitation and found that the gravitational bonding energy of a particle is the same as its rest energy. He wrote, *"… Equation implies that the total energy (inertial plus gravitational) of a particle at rest in the universe is zero"*. He also continues *"if local phenomena are strongly coupled to the universe as a whole, then local observations can give us in-formation about the universe as a whole"*.

Obviously, the zero energy principle has been known by physicists but has remained a curiosity, maybe, because it has consequences challenging the present theories. Richard Feynman dis-cussed this topic in his lessons on gravitation 1962-1963. The notes of his lessons are published as *Feynman Lectures on Gravitation* [4]. Feynman wrote *"If now we compare this number to the total rest energy of the universe,* Mc^2*, lo and behold, we get the amazing result that* $GM^2/R = Mc^2$*, so that total energy of the universe is zero"*. No reference is given in the book, but it is evident that this topic has been discussed by physicists.

It is evident that there is a conflict between the zero-energy principle and the general theory of relativity. If we suppose that, in the expanding universe, the mass and gravitational constant do not change, then the velocity of light must change. Apparently, this controversy has stopped the further development of the zero-energy hypothesis. Feynman suspected that Mach's principle has no physical basis. Perhaps this is the reason that he doesn't even mention the name Mach in his well-known textbooks *"Feynman Lectures on Physics"*.

The zero energy principle and Mach's principle are closely connected. Andre Assis from State University of Campinas, Brasilia has studied Mach's principle and he wrote [5]: *"This remarkable relation connecting three independent and measurable (or observable) magnitudes of physics is a necessary consequence of any model that seeks to implement Mach's principle."*

Despite of Feynman's negative opinion Mach's principle is not forgotten. One of the main themes in *Gravitation and Inertia* by I. Ciufolini and J.A. Wheeler [6] is that *"… mass energy there fix space-time here and therefore inertia here … "*.

2. Suntola's solution

Tuomo Suntola solved the problem of the apparent controversial connection between natural constants in the zero energy principle. As the first postulate in his Dynamic Universe Model (DU), the conservation of energy is a fundamental principle in the whole universe from the atomic scale to cosmic distances [7,8]. The second postulate is that space is described as the three-dimensional surface of a four-dimensional sphere. In the DU, the dynamics of space (contraction/expansion) is determined by the zero-energy balance of the energies of motion and gravitation in the structure. In such an approach the rest energy of the mass appears as the energy of motion due to the expansion of space in the fourth dimension in the direction of the 4-radius of the spherically closed space. For the observer, the velocity of light is constant because atomic clocks and the velocity of light change at the same rate [see This Issue, T. Suntola, footnote 2, page 59].

For local phenomena, the DU gives, at high accuracy, the same predictions as general relativity. At the cosmic scale the DU predictions differ from the corresponding GR predictions. One remarkable result is that the DU gives a precise relation between the brightness and redshift of supernovas without any adjustable parameters like the density parameter and the "dark energy".

The DU gives a quantitative solution to Mach's principle: Local inertia appears as the work done by an accelerated mass object against the gravitation due to the mass in the rest of space. The DU model explains several phenomena which the standard model does not explain. Such are, e.g., the faint sun paradox [9] and the development of the length of the day during last billion years which is observable from coral fossils [see This Issue, T. Suntola, Figure 4, page 48].

3. Current status in contemporary physics

In contemporary physics, inertia is explained as an interaction between mass and the Higg's field. Mach's principle is rejected. The connection between inertia and gravitation is not explained. This means also that, at the cosmic scale, the conservation of energy is rejected. It is concluded that the expansion of the universe is accelerating due to dark energy. Nobody knows what the dark energy is except that it is a necessary fitting parameter in the model.

In standard physics and especially in cosmology phenomena are explained by tuning parameters which means that theories cannot be falsified anymore. This situation is very sad for the understanding of the nature and development of physics.

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JULIAN BARBOUR

THE ORIGIN OF TIME, STRUCTURE AND BEAUTY

[**Abstract**] Without the experience of the change of things, we could never have formed the idea of time. I will show how one can formulate a law of change of the universe from which precise properties of time follow, specifically: what it means to say that a second today is the same as a second tomorrow, why experienced time has a direction even though the law does not distinguish a direction, and why time seems to have begun at the Big Bang although in fact there may be another universe on the other side of the Big Bang in which the direction of experienced time is the opposite or ours. A key aspect in our experience of time is the growth of structure. I will show how this too is mandated by a law of change. Finally, time and structure play an essential role in our experience of beauty, which thus also seems to be inseparably linked to the universe's fundamental law of change.

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Tuomo Suntola

RESTRUCTURING OF THE SCIENTIFIC PICTURE

A HOLISTIC APPROACH TO RELATIVITY, COSMOLOGY AND THE ESSENCE OF A QUANTUM

[**Abstract**] The ultimate purpose of a scientific model is to make nature understandable. Nevertheless, the major physical theories do not fit into the natural observational reality where time and distance have unequivocal meanings. Should we abandon an understandable reality or rethink the theory? In a holistic approach to space as a zero-energy system, we can identify relativity as a direct consequence of the finiteness of the total energy in space. Instead of describing relativistic effects in terms of distorted time and distance, the effects can be described in terms of locally available energy – thus saving the universality of the coordinate quantities, time and distance, essential for human comprehension. The zero-energy approach can be built on direct empirical evidence – it shows unification via unified expressions of energy and energy conversions rather than unifying force interactions. The zero-energy approach leads to precise and mathematically simple predictions of cosmological observables without additional parameters like dark energy and cures the conceptual gap between macroscopic physics and quantum mechanics.

1. Introduction

One of the cornerstones modern physics and the related picture of relativity rely on is the *relativity principle* originally proposed by Galileo Galilei in the early 1600s. Galileo was both an empiricist and a mathematician; he concluded that same rules of accelerating motion apply in experiments made at rest and in a uniform motion relative to the surface of the Earth. Motion was primarily characterized in terms of the velocity relative to an observer. In its modern form, the relativity principle demands that *the laws of physics have the same form in all admissible frames of reference*. In the late 1800s, it was found that such a demand was not fulfilled in linear Galilean reality. For saving the assumed laws of nature, like the Newtonian laws of motion or the summation of velocities, the linear Galilean reality had to be replaced with observational reality where time and distance in a moving frame of reference are functions of the velocity of the frame relative to the observer. Such a solution was first formulated as the special theory of relativity and by further reclaiming the Newtonian *equivalence principle* equating the inertial and gravitational acceleration, as the general theory of relativity.

The relativity theory, including both the special and general theories of relativity, can be characterized as a kinematic theory structure with velocity as the main attribute of motion, and acceleration as the main attribute of gravitation. In relativity theory, the laws of nature apply when observed in local "proper time" and "proper distance", e.g. whatever is the state of motion or gravitation, the frequency of an atomic clock is constant for an observer in the same frame of reference. Observations related to phenomena in other frames of reference are matched with coordinate transformations adjusting distances and the flow of time in the frame observed, e.g. the frequency of an atomic clock in a frame moving relative to the observer or closer to a mass centre in common with the observer is predicted to lose time due to the slower flow of time in the frame observed. When properly applied, time dilation and length contraction as well as the gravitational red/blue shift predicted by the relativity theory explain observations on clocks and electromagnetic radiation but confuse the concept of time, simultaneity and the overall structure of space.

In this treatise, we raise the question whether the time dilation and length contraction are actual properties of reality, or are they "epicycles" in modern physics; are time and distance really functions of the velocity and gravitational state relative to an observer or are the clock frequencies, and more generally, the rate of physical processes functions of the motion and gravitational state the processes occur? The way out from the epicycles in the antique planetary model was the Copernican "system approach" which allowed basing the description of planetary motions on force balances and the conservation of energy in the system.

To extend the system approach to whole space, space shall be understood closed and finite. For closing space as a 3-dimensional entity we need the fourth dimension. The simplest and most natural shape for closing space is the 3-dimensional "surface" of a sphere with radius in the 4^{th} dimension – just like we close a 2-dimensional entity to form the surface of a sphere with the radius in the third dimension. Space as a closed spherical structure allows the analysis of the dynamics of whole space just by assuming the balance of motion and gravitation in the system. The dynamics of space as a whole can be seen as the source for all energy available within space; the multitude of structures and manifestations of energy *in* space are then derived conserving the energy created by the dynamics *of* space.

We will find that the "relativistic effects" in space are direct consequences of the finiteness of the total energy and the conservation of the zero-energy balance in space. Relativity in zero-energy space is expressed in terms of locally available energy instead of distorted time and distance like in the framework of the relativity theory. The states of motion and gravitation are studied primarily as energy states that determine the locally observed physical phenomena. Clocks in motion or the vicinity of mass centres do not lose time due to different flow of time but the frequency of the clocks is reduced due to the reduced available energy. In zero-energy space, time and distance are universal coordinate quantities. The velocity of light is linked to the velocity of space in the fourth dimension, the expansion velocity of the 4-dimensional sphere. Consequently, the velocity of light decreases in the course of the expansion. All velocities *in space* are linked to the velocity *of space*. The sizes of gravitationally bound systems in space expand in direct proportion to the expansion of space as a whole. Zero-energy space

- shows the mechanism of the energy build-up in space and produces predictions for the past and future development of the expansion of space

- shows relativistic phenomena in absolute time and distance – in terms of locally available energy (instead of dilated time and contracted length)
- produces cosmological predictions that fit observations with high accuracy without parameters like dark energy and density parameters
- discloses the linkage between local and whole in all interactions in space (Mach's principle)
- shows the essence of mass as the wavelike substance for the expression of energy

In the following, the description of space as spherically closed zero-energy entity is referred to as the Dynamic Universe Model (DU) [1-3].

2. Spherically closed space, the zero-energy balance

Space as a closed energy system

For a system approach and for applying the conservation of energy, we need to define the system to be studied. For determining the total energy, the system shall be closed. The simplest geometry for closing a 3-dimensional entity is to describe it as the 3-dimensional surface of a 4-dimensional sphere with the fourth dimension as the radius. In such a structure all points in space are at equal distance from the centre of the 4D-sphere. We may assume that, as an initial condition, all mass is uniformly distributed in space. There is the gravitational attraction of mass in whole space resulting in a shrinkage force towards the 4-centre of the structure – or in terms of gravitation as potential energy, the spherical structure has potential energy convertible into the energy of motion via contraction of the 4D-sphere towards a singularity. The energy of motion gained in contraction is paid back to the energy of gravitation via expansion of the structure by passing the singularity. In the contraction, space releases potential energy and gains energy of motion, in the expansion space releases the energy of motion and re-establishes potential energy. In book-keeper's terms, the energy of motion gained in contraction is a loan from the potential energy – which is paid back in the expansion. Based on observations, we are now in the expansion phase – objects in space look like receding from us equally in all directions. However, we as observers, are not in the centre of space; in spherically closed space receding of objects look essentially the same for an observer anywhere in space. The centre of space is not in the 3D-space but the centre of the 4D-sphere.

Space as the 3D surface of a 4D sphere is not a new idea – it has been proposed, e.g. by Albert Einstein in 1917 [4] and Richard Feynman in his Lectures on gravitation in the early 1960's [5]. In both cases, an obstacle came from the theory of relativity which defined the fourth dimension a time-like dimension. In DU, with metric fourth dimension, it is essential that time as a universal scalar operates equally for phenomena both in the three space directions and the fourth dimension. Such a situation allows determining quantities like velocity and momentum in the fourth dimension which is absolutely necessary for solving the dynamics of space as a whole.

The expansion of space as the 3D-surface of a 4D-sphere means that all mass in space has velocity in the fourth dimension, the direction of the 4-radius of the structure. Motion in the fourth dimension is not observable to comoving observers in 3D space; the energy of motion due to the velocity in the fourth dimension is what is used to call the rest energy of mass, $E_m = mc^2$, which suggests that the velocity in the fourth dimension is equal to the velocity of light, c, in space. In homogeneous space, with all mass uniformly distributed in the 3D surface of the 4D sphere, the gravitational energy of mass m anywhere in space is

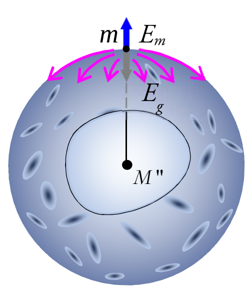


FIGURE 1. The balance of the energy of motion and energy of gravitation in spherically closed space.

due to all other mass in space. Due to the spherical symmetry, the integrated gravitational energy is equal gravitational energy caused by mass *M"* at the centre of the 4D sphere, Figure 1. Mathematically, the balance of motion and gravitation can be expressed in terms of the zero-energy energy equation as the sum of the gravitational energy, E_g, and the energy of motion, E_m, of test mass *m* as

1. $$E_{tot} = E_m + E_g = mc^2 - m\frac{G \cdot M''}{R_4} = 0$$

which allows solving the 4-velocity *c* in terms of the gravitational constant, *G*, the 4-radius R_4, and the mass equivalence *M"* of the total mass M_Σ in space, Figure 2. When integrated over whole 3D space, the mass equivalence at the centre of the 4D sphere obtains the value $M''= 0.776 \cdot M_\Sigma$. Applying the numerical value of the gravitational constant $G = 6.674 \cdot 10^{-11}$ [N·m²/kg²], the 4-radius as the Hubble radius about 14 billion light years, and the total mass calculated from the Friedman critical mass density, the contraction/expansion velocity of space in the fourth dimension is

2. $$c = \pm\sqrt{\frac{GM''}{R_4}} \approx 300\,000\ [\text{km/s}]$$

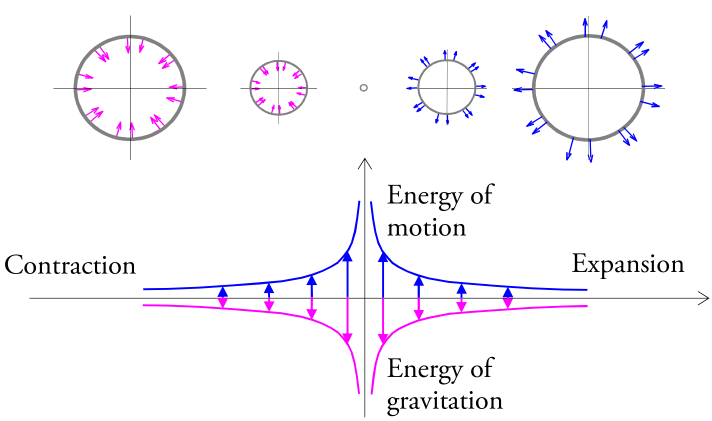


FIGURE 2. The buildup and release of the rest energy of matter via contraction and expansion of spherically closed space.

which is equal to the velocity of light. It can be shown that, due to the zero-energy balance, the maximum velocity in space and the velocity of light in space are equal to the velocity of space in the fourth dimension. This breaks one of the cornerstones of the theory of relativity, the constancy of the velocity of light. The 4-velocity of space decreases in the course of the expansion due to the increase of the 4-radius, which means that also the velocity of light in space decreases with the expansion. The present annual degradation of the velocity of light is about $\Delta c/c = -3.6 \cdot 10^{-11}$ /year. In principle, such a change would be observable with atomic clocks, but the frequency of atomic clocks is directly proportional to the velocity of light[2]. When Richard Feynman introduced the idea of space as the 3D surface of a 4D sphere in his lectures on gravitation, he also pondered the equality of the total rest energy and gravitational energy in space [6], but he never drew the conclusions of that "great mystery".

As shown by equation (1) and illustrated in Figure 2, the rest energy, E_m, of mass m is counterbalanced by the global gravitational energy, E_g, arising from the rest of mass in space. The rest energy can be seen as the local expression of energy and the global gravitational energy as the non-local energy of a mass object, which illustrates the unbreakable linkage of local and the whole – and the role of the global gravitational energy as the "anti-energy" to the rest energy, thus completing the zero-energy balance.

As a consequence of the conservation of total energy, and the balance of motion and gravitation, any interaction in space is linked to a related interaction with the rest of space. The buildup of kinetic energy in space reduces the rest energy of the object in motion which is observed, e.g., as a reduction of the ticking frequency of atomic clocks in motion. The interaction of local and the whole is an inseparable characteristic of all phenomena in space. Inertial work is the work done in reducing the gravitational interaction between the object accelerated and the rest of space – just as proposed by Mach's principle.

3. The laws of nature

Newtonian reality and relativity

In mathematical physics, Newton's laws of motion and gravitation [7] have been considered as primary laws of nature. Newton's second law of motion, linking acceleration to inertial force, $F=ma$, means that the velocity of a mass object increases linearly without limits as long as there is a constant force acting on the object. Newtonian mass is considered an unchanged property of an object. As shown by Walter Kaufmann's experiments in 1902 [8], this is not the case; observations on electrons accelerated to velocities approaching the velocity of light challenged Newton's law by suggesting mass increase with velocity. The special theory of relativity saves Newton's second law by applying coordinate transformations that propose an apparent increase of the mass of the object in the frame of reference moving relative to the observer [9]. Both Newtonian physics and the relativity theory rely on the relativity principle which demands that *the laws of physics have the same form in all admissible frames of reference*.

Human comprehension of observational reality relies on time and distance as coordinate quantities. Explanation of observations with coordinate transformations required by the relativity principle means adjusting the observational reality to make the observations obey the assumed laws of nature. *The challenge is to identify laws of nature that apply in all observational environments – without relying on coordinate transformations confusing the human comprehension*.

Fundamental laws of nature

In the Dynamic Universe framework, Newton's second law is not considered a fundamental law of nature, but an approximation that applies in restricted circumstances. A more general law of motion can be derived from the conservation of the overall zero-energy balance in space. Such an approach studies local frames of reference as energy frames and characterizes the status of objects in terms of their energy. In the theory of relativity, which is a kinematic approach, the increased mass of an object in motion is explained as a consequence of the velocity. In the Dynamic Universe, the increased mass comes from the energy contribution needed in building up the kinetic energy. Accordingly, the state of motion is related to the system releasing the energy converted into kinetic energy. *A state of motion in the DU is characterized as an energy state – it is the result of all the energy conversion history behind the state. Such an approach links any state of motion in space to the state of rest in hypothetical homogeneous space which serves as an initial condition and a universal reference at rest for all states of motion in space*.

In the DU framework, Aristotle's *entelecheia* as a natural trend for potentiality to actualize can be seen as a fundamental law of nature. It leads to the zero-energy principle, which Gottfried Leibniz stated as his view when criticizing Descartes' laws of motion: *The total amount of force in the world is conserved both locally and globally with the result that there is always as much force in a cause as in its effect*. In modern terms, Leibniz's "force" means energy, which was identified as the integrated force first in the 19th century. Leibnitz's statement can be interpreted as the global balance between the gravitational energy released and the kinetic energy acquired. In his script *Essays in Dynamics* [10], Leibniz states the same: *There is neither more nor less power in an effect than in its cause*.

Basic constituents of the DU model

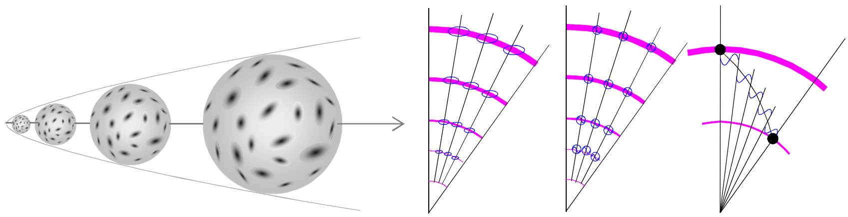
The Dynamic Universe Model is a holistic approach to the description of the physical reality. It studies space as 3-dimensional entity spherically closed through the fourth dimension of metric nature. The dynamics of space is based on the zero-energy principle equating the energies of motion and gravitation in the structure. For conserving the overall energy balances in space, all local phenomena in DU space are associated with the effect of the rest of space. *Such a linkage results in the relativity of observations without a separate relativity theory. Relativity in DU space means relativity between local and the whole rather than relativity between an observer and the object observed*. DU model applies time and distance as universal coordinate quantities essential for human comprehension and omits, as unnecessary, postulates like relativity principle, equivalence principle, the constancy of the velocity of light, and the Lorentz transformation. DU model shows mass as the wavelike substance for the expression of energy; mass expresses energy through motion, gravitation, electromagnetic interaction, and radiation. In the DU, localized mass objects (particles) can be described as mass wave resonators and quantum states as energy minima of resonant mass wave structures.

4. General features of the Dynamic Universe

Cosmological appearance of DU-space

DU-space is characterized as the 3-dimensional surface of a 4-dimensional sphere. DU space is now expanding along its 4-radius with the energies of motion and gravitation in balance. The current length of the 4-radius is about 14 billion lightyears, based on the experimental value of the Hubble constant, $H_0 \approx 70$ (km/s)/Mpc. Unlike in the present interpretation of the general relativity based standard cosmology model, the Friedmann-Lemaitre-Robertson-Walker or FLRW-cosmology, the expansion velocity of DU space decreases with the increasing 4-radius. Due to the higher expansion velocity in the past, the age of expanding space, the time since the singularity that converted the contraction phase into the expansion phase, is about 9.3 billion lightyears when measured using current length of the year and the current velocity of light.

The energy balance in space links all local phenomena in space to space as a whole. All distances in space increase in direct proportion to the expansion of the 4-radius of space and all velocities in space are linked to the 4-velocity of space which also determines the velocity of light in space. Radii of galactic and planetary orbits increase in direct proportion to the increase of the 4-radius. This is an essential difference from the standard cosmology model, which claims that local systems conserve their dimensions in the course of the expansion [11]. In the DU, galaxies expand, but atoms and structured matter do not expand with the expansion of space, Figure 3.



(a) (b) (c) (d)

FIGURE 3. (a) Space as the 3D surface of an expanding 4D sphere. (b) gravitationally bound local systems like galaxies expand with the expansion of space, (c), atoms and structured matter do not expand, (d) the wavelength of electromagnetic radiation increases in direct proportion to the expansion of space.

The linkage of planetary orbits to the expansion of space means, e.g., that the length of the year and the number of days in a year have changed in the course of the expansion. Empirical evidence of such a change can be found from coral fossils: About 400 million years ago, the number of days in a year was about 400, and 800 million years ago about 450 [12–15]. The DU prediction for the development of the number of days in a year matches well with the coral fossil data as shown in Figure 4. Standard cosmology does not produce a prediction for the number of days in a year.

In the solar system, an indication of the increase of orbital radii comes from the "faint young Sun paradox". In the early epoch of planets when the 4-radius of space was about 10 billion lightyears, the intensity of the Sun is estimated to be about 70% of its present intensity [16]. How could the geological formation of the Earth and the flow of water in Mars occur? According to the DU prediction, the planetary orbits at that early epoch were 10/14 = 70 % of their present value. Taking into account that the radiation intensity is proportional to the inverse square of the distance, the intensity of solar radiation in the early epoch was about twice its present intensity. Accordingly, temperatures on Earth and Mars were substantially higher than they are today, which is well in line with the geological development of the planets and the development of early life. Standard cosmology does not give an answer to the

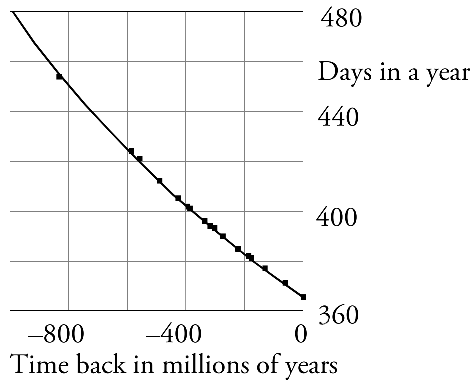


FIGURE 4. The development of the length of a year in current days during the last 1000 million years. The squares are the observed counts of the number of days in a year in fossils [83–86]. The DU prediction curve comes from the effects of the expansion on the orbital and rotational velocities of the Earth + an estimated linear term from the increase of the Earth to Moon distance [1].

faint early Sun paradox, suggested explanations rely on greenhouse effects.

In the Earth-Moon system the effect of the expansion can be observed in the Earth to Moon distance; 2.8 cm of the measured 3.8 cm annual increase [17] of the distance comes from the expansion of space and only 1 cm from the tidal interactions which is given as the sole explanation for the increase in standard cosmology.

Observed angular size of distant objects

In DU space, the velocity of light is fixed to the expansion velocity of the 4-radius. It means that the optical distance of cosmological objects is equal to the increase of the 4-radius during the propagation of light from the object observed. Such a situation gives a simple, unambiguous, parameter-free expression to the optical distance [1]. Recalling that in the DU, cosmological objects like quasars and galaxies expand in direct proportion to the expansion of the 4-radius, we end up with a Euclidean optical appearance of quasar and galaxy space, which means

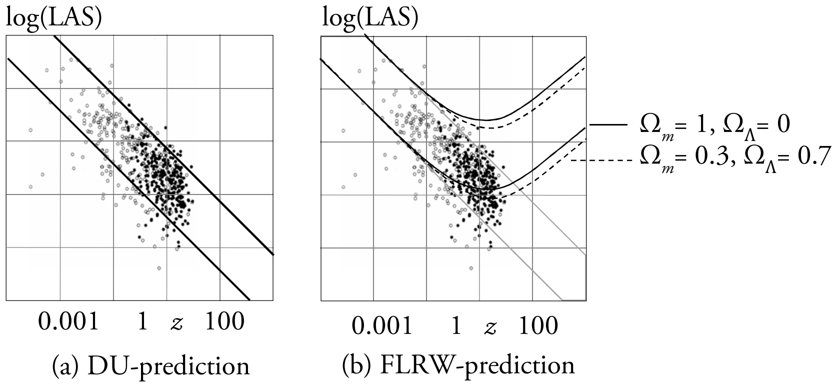


FIGURE 5. Dataset of the observed Largest Angular Size (LAS) of quasars and galaxies [19] in the redshift range $0.001 < z < 3$. Open circles are galaxies, filled circles are quasars. In (a) observations are compared with the DU prediction. In (b) observations are compared with the FLRW prediction (Table 4-VIII, row 7) with $\Omega_m = 1$ and $\Omega_\Lambda = 0$ (solid curves), and $\Omega_m = 0.27$ and $\Omega_\Lambda = 0.73$ (dashed curves). As shown by the curves in (b) the inclusion of dark energy Ω_Λ in the FLRW cosmology has only a minor effect. The Euclidean appearance of the DU prediction in (a) gives an excellent match with observations.

that the observed sizes of the objects decrease in direct proportion to the increase of their distance – as observed. This means a major difference from the prediction of angular sizes in standard cosmology which claims increasing angular size for objects with redshift, indicating their distance, is higher than $z > 1$, Figure 5. A major factor in the standard cosmology prediction comes from the relativity principle which requires that the angular size observed today is the same as it was at the time when the light was emitted when the object was closer to the observer. Such an interpretation was established in the early 1930s by the reciprocity theorem [18].

The DU prediction for the magnitude versus redshift of distant objects is obtained by combining the dimming proportional to the inverse square of the optical distance and the dilution of the power density due to the increase of the wavelength of the radiation propagating from the source to the observer in expanding space. Such a prediction has no adjustable parameters, and it applies directly to the observed bolometric magnitude. In standard cosmology, the derivation of the corresponding

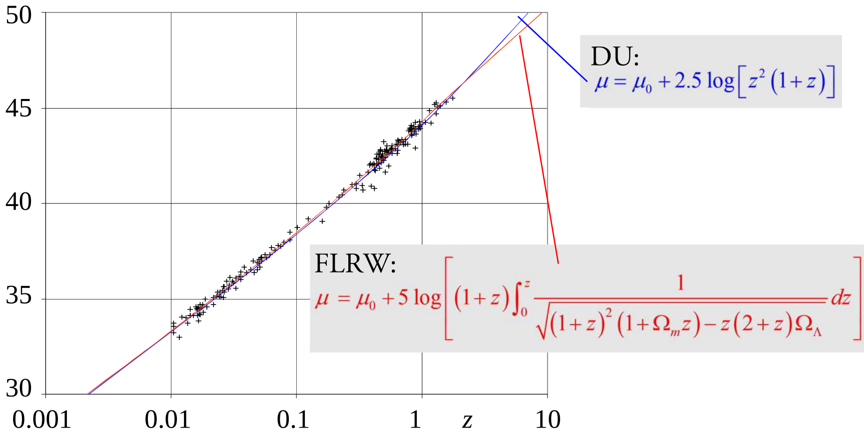


FIGURE 6. Distance modulus $\mu = m - M$, vs. redshift for Riess et al. "high-confidence" *K*-corrected dataset and the data from the HST, presented on a logarithmic scale [20]. The DU prediction (blue curve) [1] matches the observations without any adjustable parameters whereas the FLRW prediction requires density parameters Ω_m (baryonic matter) and Ω_Λ (dark matter) for adjusting the prediction. The equations of the two predictions show major difference in complexity.

prediction is more complicated; it requires an estimate of the mass density in space relative to Friedman's critical mass density, and the contribution of possible dark energy. Further, based on the relativity principle, the prediction is applied to observations converted into "emitter's rest frame" by a factor added to the *K*-correction originally used for including instrumental corrections and atmospheric dimming.

Figure 6 compares the DU prediction and the standard cosmology prediction for *K*-corrected magnitudes measured from Ia supernovas [18,1]. The proposal of accelerating expansion in standard cosmology comes from the dark energy term needed to match the prediction to the observations. The DU prediction does not need dark energy or accelerating expansion. The two predictions are essentially the same in the redshift range of current observations, but there is a clear difference between the predictions for supernovas with redshifts approaching ten. We may assume that observations in that redshift range will be available in the near future.

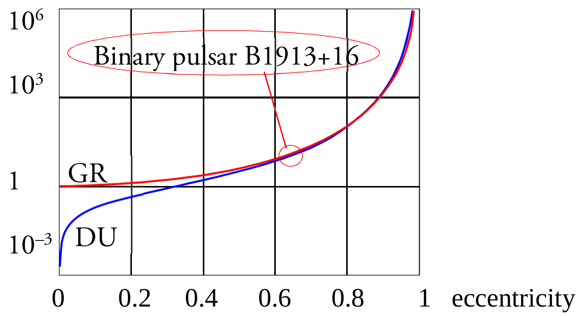


FIGURE 7. The effect of eccentricity on the shortening of the period of binary star systems. In the case of the famous B1913+16 binary pulsar, the predictions of GR and DU are practically the same [21,22].

Gravitational waves

In standard cosmology, rotation of quadrupole mass systems like orbiting binary stars emit gravitational radiation that propagates at the speed of light as ripples in the curvature of spacetime. In DU, fluctuation of gravitational potential due to motions of masses is immediate. Fluctuation of gravitational potential does not carry energy. In DU space, with metric fourth dimension, binary star systems at elliptic orbits have orbital angular momentum in the fourth dimension. Due to the periastron rotation, also the orbital angular momentum rotates resulting in shortening of the orbital period and possible balancing emission of energy waves to the surrounding space. For eccentric orbits, the DU prediction for the shortening of the period due to the energy loss related to the rotation of the 4D angular momentum is almost identical with the corresponding GR prediction based on the rotation of quadrupole mass systems. The GR prediction suggests the shortening of the period also for binary stars at circular orbits, whereas the DU prediction requires eccentricity higher than zero, Figure 7.

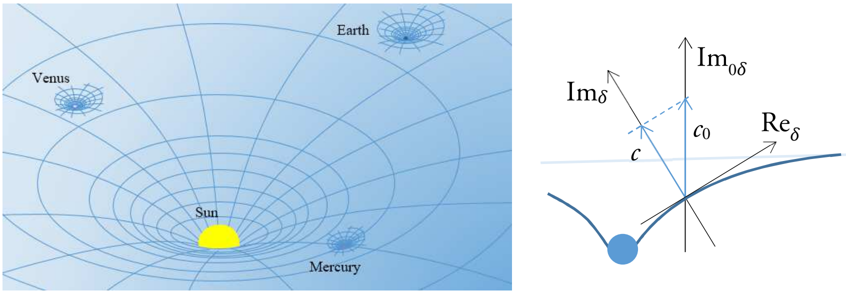


FIGURE 8. Mass centres are surrounded by local dents in space. Due to the tilting the velocity in space in the local fourth dimension is reduced compared to the 4-velocity of the surrounding non-tilted space. The local velocity of light is fixed to the local 4-velocity of space, which means that the velocity of light is reduced near mass centres in space. Buildup of dents in space occurs in several steps; dents around planets are dents in the larger dent around Sun – which is a local dent in the much larger Milky way dent.

Local structures in DU space

Conservation of energy in mass centre buildup requires tilting of local space resulting in a dent around the mass centres in the fourth dimension. Tilting of space means that the velocity of space in the local fourth dimension, and the local velocity of light in a dent is reduced. Figure 8 illustrates the 4D "profile" of the solar system.

In local dents in space, the velocity of light is reduced which is observed as bending of the light path passing a mass centre and as the Shapiro delay of light and radio signals. The reduced 4-velocity also results in a corresponding reduction in the rest energy of mass objects in the vicinity of mass centres in space. As a result, the characteristic frequencies of atomic clocks are reduced, which in the framework of general relativity is referred to as gravitational red/blue shift "due to reduced flow of time". The linkage of the velocity of light to the local 4-velocity of space means that the reference for the velocity of light and the frequency of atomic clocks is linked to the local gravitational system, e.g. the locally measured velocity of light on Earth is not affected by the orbital motion of the Earth around the Sun. Historically, this is interesting because the Michelson-Morley experiment, that in the late 19th

century failed in finding the effect of the orbital velocity of the Earth on the velocity of light, was one of the empirical bases to claim the constancy of the velocity of light. In fact, also the frequency of atomic clocks is directly proportional to the velocity of light[2], which guarantees the "observational or empirical constancy" of the velocity of light.

Planetary orbits in DU space

Dents around mass centres in DU space are closely related to corresponding dents in Schwarzschild space. Planetary orbits around mass centres are subject to periastron advance. For a single cycle in a weak gravitational field, the prediction for the perihelion advance is the same in Schwarzschild space and DU space. In a strong gravitational field as well as with a multitude of cycles in a weak field, Schwarzschildian orbits become unstable whereas they stay stable in DU space, Figure 9. The cause of instability of the Schwarzschildian orbits can be traced back to the equivalence principle behind general relativity which makes the momentum in free fall in a gravitational field subject to mass increase in the same way as it is at constant gravitational potential. The problem arising from the equivalence principle can be seen in the development of the orbital velocity relative to the escape velocity; for circular orbits with the radius smaller than 3 times the Schwarzschild critical radius, the orbital velocity exceeds the escape velocity throwing the orbiting object from the orbit.[3]

(a) (b)

FIGURE 9. Development of the orbit of Mercury in about 0.7 million Earth years (a) in Schwarzschild space [23] and (b) in DU-space [1]. The orbital radius increases with increasing perihelion shift in Schwarzschild space but remains unchanged in DU space.[3]

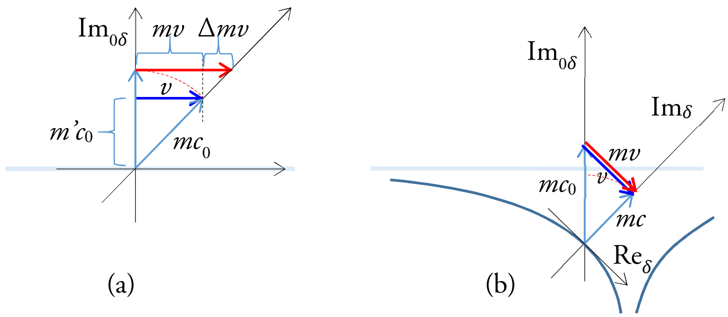
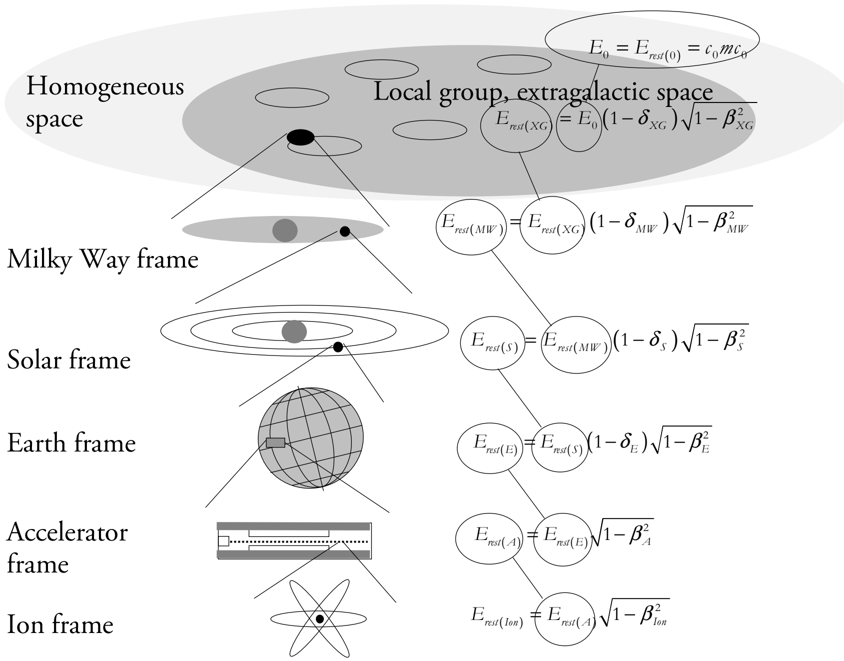


FIGURE 10. (a) In DU space, buildup of velocity v at constant gravitational potential requires insertion of extra mass Δm which results in momentum $\mathbf{p}=(m+\Delta m)\cdot\mathbf{v}$. (b) Build of velocity v in free fall in a gravitational field is obtained against reduction of the local 4-velocity of space; there is no mass insertion, and the momentum is $\mathbf{p}=m\mathbf{v}$.

In DU space, the buildup of velocity v in free fall in a gravitational field is obtained against the reduction of the local 4-velocity of space; there is no mass insert in free fall like there is in acceleration at constant gravitational potential, Figure 10. As a consequence, orbits in DU space are stable also in the vicinity of the critical radius of local singularities (black holes) in space, Figure 10(b). The orbital velocity on orbits near the critical radius approaches zero, which explains the mass maintaining the black holes.

Relativity and the system of nested energy frames

In the DU, relativity is a direct consequence of the conservation of energy and the finiteness of total energy in space. All energy expressed in space originates from the energy excitation in the contraction-expansion process of whole space, which created the rest energy of mass against the release of gravitational energy. In bookkeeper's terms, the rest energy of matter is a loan from the gravitational energy obtained in the contraction and paid back in the ongoing expansion of space. Any local energy of motion in space reduces the local rest energy and any local gravitational energy reduces the gravitational energy due to the rest of space. For understanding the energy balances in space, it is necessary



$$E_{rest(n)} = c_0 mc = mc_0^2 \prod_{i=1}^{n} \left[(1-\delta_i) \sqrt{1-\beta_i^2} \right]$$

FIGURE 11. The system of nested energy frames. The rest energy in *n*:th (local) frame is subject to reductions due to the motions and gravitational states of the local frame in all its parent frames – and is finally related to the rest energy the object would have at rest in hypothetical homogeneous space.

to follow the buildup of local energy structures, Figure 11. Any state of motion and gravitation of an object in a local frame is linked to the state of rest and unreleased gravitational energy in the local frame. The state of motion and gravitation of the local frame again is linked to the state of rest and unreleased gravitational energy in its parent frame, etc., up to the state of rest in hypothetical homogeneous space, which serves as the universal reference for all states of motion and gravitation in space. In the DU, applying the system of nested energy frames, relativity is expressed in terms of locally available energy. Locally available energy, e.g., determines the rate of physical processes like the ticking frequency of atomic clocks. There is no need for coordinate transformations, time dilation, or length contraction in the DU framework. The key is in the holistic approach – starting from the state of rest in hypothetical homogeneous space as the reference for all states of motion and gravitation in space. In laboratory tests of relativity, like those done with centrifuges or accelerators, the observer is at the gravitational state and the same state of motion as the system releasing energy to the object studied.

In laboratory tests, the observer's frame of reference defined by the special theory of relativity coincides with the local energy frame of the DU – and results in similar predictions to the phenomena studied. The situation is changed in near-Earth experiments like the observation of satellite or airborne clocks. In the DU framework, both the observer's clock and the clocks in satellites or airplanes move at different velocities and altitudes in the Earth gravitational frame, which means that each clock shall be compared to a hypothetical clock at rest, out of the gravitational interaction with the Earth. In the framework of special and general relativity, such a frame is referred to as the Earth centred Inertial (ECI) frame – its use is justified by the accelerating motion of the observer or simply as an empirical fact [24-26]. In far space experiments and cosmological observations DU adds the effects of the motion and gravitational state of the ECI frame in the solar gravitational frame and, if necessary, the motion and gravitational state of the solar frame in the Milky Way gravitational frame.

5. Summary

The Dynamic Universe means a major reorientation to the description of observable physical reality – even though all constituents of the DU are directly or indirectly available in contemporary physics. Most importantly, the DU is a system approach which identifies the observer's state in the system and links the effects of the whole to all local phenomena in space. Relativity in DU space is not relativity between an observer and the object observed; relativity in the DU resolves the locally available share of total energy in space – saving time and distance as universal coordinate quantities. The fourth dimension in the DU has metric character. However, the fourth dimension is not accessible from space; it is the direction space expands. Locally bended space in the DU looks much the same as locally bended spacetime in the framework of general relativity. The local geometry of space, however, does not convey gravitational interaction like in general relativity, but the buildup of local geometry is a consequence of the conservation of the zero-energy balance in space. In the DU framework, local bending of space reduces the local velocity of light and the frequencies of atomic clocks. In the GR framework, local bending of spacetime reduces the local flow of time observed as lowered frequency of atomic clocks.

The Dynamic Universe produces central cosmological predictions directly from the zero-energy dynamics of space. Unlike the standard cosmology model, DU predicts the past and future development of the expansion and explains the origin of the rest energy of matter in the pre-singularity contraction of space. The BigBang replacement of standard cosmology in the DU is the singularity turning the pre-singularity contraction phase into the ongoing expansion phase. The singularity may be characterized as an extreme excitation of the rest energy of matter against the energy of gravitation released, which does not necessarily mean an extreme temperature like in the hot BigBang in standard cosmology.

Mass in the DU is identified as the wavelike substance for the expression of energy; mass expresses energy via motion, gravitation or electromagnetism. DU allows mass waves of unstructured matter which may have characteristics of the undetected "dark matter" or gravitational waves propagating in space. Localized mass objects, particles, can be described as mass wave resonators with the internal wavelength equal to the Compton wavelength. A moving mass wave resonator creates the de Broglie wave as the net sum wave of the Doppler-shifted front and back waves in the resonator. Quantum states, like the electron states in atoms, appear as energy minima of resonant mass waves rather than states of discrete energies.

The Dynamic Universe is a holistic description of the observable physical reality. It shows the development of space as an unbroken chain from cessation at potential infinity in the past via extreme excitation of energy at singularity back to cessation at potential infinity in the future. In the DU framework, all phenomena in space can be described in absolute time and distance essential for human comprehension. DU relies on a minimum number of postulates and shows the "relativistic effects" – without a separate relativity theory – as direct consequences of the conservation of the overall energy balance in space and "quantum phenomena" as implications of the wavelike nature of mass and matter.

Notes

1 For understanding the nature of mass, it is helpful to open the physical message of the Planck equation, $E = hf$. When solved from Maxwell's equations, the energy emitted by a single oscillation of a unit charge (electron) to a cycle of electromagnetic radiation from a Hertzian dipole is

3. $$E = A \cdot 2\pi^3 \cdot e^2 \mu_0 \cdot c \cdot f$$

where A is the geometrical factor of the dipole, e is the electron charge, μ_0 is the vacuum permeability, c is the velocity of light, and f is the frequency of the radiation emitted. In the DU framework, a point emitter like an atom, propagates the distance of a wavelength in the fourth dimension during a cycle of radiation emitted. Accordingly, a point emitter can be considered as one-wavelength dipole in the fourth dimension. With A=1.1049 instead of A=0.667 of a one-wavelength dipole in a space direction, the constant term in (3) has the value and dimensions of the Planck constant

4. $$h = 1.1049 \cdot 2\pi^3 \cdot e^2 \mu_0 \cdot c = 6.62607 \cdot 10^{-34} \text{ [kg·m}^2\text{/s]}.$$

Equation (4) shows that the Plank constant has the velocity of light, c, as a "hidden" embedded constant. Applying (4), the fine structure constant appears as a pure numerical factor, $\alpha = 1/(1.1049 \cdot 4\pi^3) \approx 1/137.036$. To remove the velocity of light from the Planck constant, it is useful to define the *intrinsic Planck constant*, $h_0 = h/c$ [kg·m] that returns the Planck equation into form

5. $$E = h_0\, cf = h_0/\lambda \cdot c^2 = m_\lambda \cdot c^2$$

where m_λ is the mass equivalence of a cycle of electromagnetic radiation and $\lambda = c/f$ is the wavelength corresponding to frequency f. Equation (5) has the form of the rest energy of mass. Applying the intrinsic Planck constant and the Compton wavelength λ_m of mass m the rest energy obtains the form

6. $$E = m_\lambda \cdot c^2 = h_0/\lambda_m \cdot c^2$$

It can be considered that mass waves may propagate in the fourth dimension as non-structured dark matter or in space like gravitational waves. Localized mass objects can be described as resonant mass wave structures with the internal wavelength equal to the Compton wavelength. A moving mass wave resonator creates the de Broglie wave and momentum as the vector sum of the Doppler-shifted front and back waves in the resonator. Quantum states can be identified as energy minima of resonant mass wave states. The mass wave concept has potential for a comprehensible formalism of quantum mechanics and understandable "quantum reality".

2 Characteristic frequencies of atomic clocks are functions of the Planck constant, the rest energy of the oscillating electrons, and the difference of quantum numbers between the energy states the oscillating electrons occupy. Applying the intrinsic Planck constant, $h_0 = h/c$, introduced in Note 1, the characteristic frequency is

7. $$f = \frac{\Delta E}{h} = \frac{m_e c^2}{h} F\left[\alpha, \Delta(n, j)\right] = \frac{m_e c}{h_0} F\left[\alpha, \Delta(n, j)\right]$$

which shows that the frequency is directly proportional to the velocity of light and the rest mass of the oscillating electrons. In the DU framework the rest mass is a function of the velocity of the object in space, and the local velocity of light is a function of the gravitational state. Including the effects of motion and gravitation throughout the system of nested energy frames, the frequency of atomic clocks is

8. $$f = f_{(0,0)} \prod_{i=1}^{n} \left[(1-\delta_i)\sqrt{1-\beta_i^2} \right]$$

where $f_{(0,0)}$ is the frequency of the clock at rest in hypothetical homogeneous space, $\delta_i = GM_i/r_i c^2$ is the gravitational factor and $\beta_i = v_i/c_i$ the velocity factor of the clock in the *i*:th parent frame. The product in parentheses conveys the effects of motion and gravitation of the clock in the local frame as well as in all parent frames. In a local frame like the Earth gravitational frame (8) reduces to the form

9. $$f = f_{(0,0)} (1-\delta)\sqrt{1-\beta^2}$$

which is closely related to the expression of proper time in Schwarzschild space

10. $$t = t_{(0,0)} \sqrt{1-2\delta-\beta^2}$$

In the vicinity of the Earth, the difference between (9) and (10) appears in the 18:th decimal max.

3 The development of the perihelion shift in Schwarzschild's space presented in Figure 9 is based on equation

11. $$r=\frac{a\left(1-e^2\right)}{\left\{1+e\sin\varphi-\frac{GMe(3\varphi-e\cos\varphi)}{c^2a\left(1-e^2\right)}\cos\varphi+\frac{GM\left(3+e^2\right)}{\left[ca\left(1-e^2\right)\right]^2}\right\}}$$

given as equation (5.37) in [21]. The corresponding DU prediction is given as combined equations (4.2.3:26) and (4.2.3:27) in [1]. The development of the orbital and escape velocities in Schwarzschild space and DU space are based on equations given in [27] and [1], respectively. See page 51 in [1] for details. In the GR based solution [27], the orbital velocity exceeds the escape velocity when the orbital radius is smaller than 3 times the Schwarzschild critical radius, Figure 12.

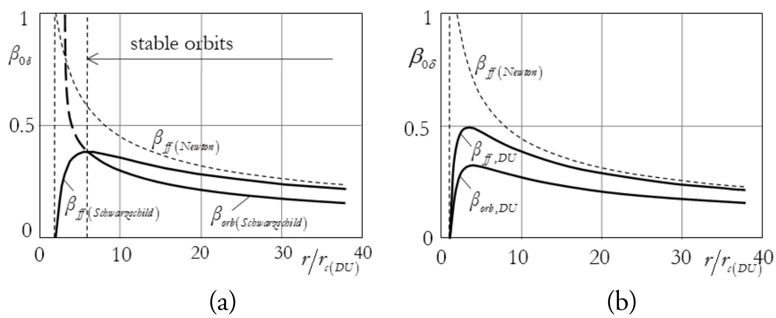


FIGURE 12. Orbital velocity, β_{orb}, and escape velocity, β_{ff}, on circular orbits in (a) Schwarzschild space and (b) in DU space. In (a) the orbital velocity exceeds the escape velocity when the orbital radius is smaller than 3 times the Schwarzschild critical radius, in (b) the escape velocity is always higher than the orbital velocity allowing slow orbits in the vicinity of the critical radius, which in DU space is half of the Schwarzschild critical radius.

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THE PRINCIPLE OF ECONOMY AS AN EVALUATION CRITERION OF THEORIES

A CASE EXAMPLE: THE DYNAMIC UNIVERSE VS. PHYSICS AND COSMOLOGY BASED ON GENERAL RELATIVITY

1. Introduction

The principle of economy favours the theory which gives the most accurate predictions; of two equally accurate theories, economy favours the one which incorporates least metaphysics. The intention is to show that were metaphysical commitments of theories openly acknowledged and simplicity and other virtues generally accepted as judges in theory choice, the progress rate of science would likely become more optimal. This article is organized as follows.

§2. The structure of theories is explained and their ontological commitments are classified in verified and unverified, where ‘unverified’ is translated as ‘metaphysical’.

§3. The historical roots of economy are opened up. It is explained why economy is needed in evaluating theories and as a point of departure to the challenges of *underdetermination*, defining *approximate truth*, incorporating *falsifiability* in theory evaluation and in tackling *stagnation*.

§4. It is shown that the process of approaching a unified explanation of all scales walks hand in hand with increasing metaphysical simplicity and general virtuousness of total science.

§5. Economy is applied in evaluating the Dynamic Universe model vs. physics and cosmology based on the General Theory of Relativity.

2. The Structure of Theories

A theory is a fusion of ontology and concepts defined in terms of the ontology. The ontology of a theory consists of *ontological commitments*. If a theory is true, nature is in the way stated by its ontological commitments.[1] Thus, all commitments to objects whose existence is supposed in a theory are its ontological commitments. Also mathematical formulas and all characterizations of supposedly existing relations or interactions between the supposedly existing objects are ontological commitments of the theory.

The ontology of a theory is a fusion of *verified* and *unverified* commitments. As depicted on bottom left of figure 1, perceptions yield verified commitments —or verified beliefs— in the existence of something. Perception has yielded e.g. the commitments in the existence of the Moon, the Sun and the Earth. These are thus verified commitments of a theory of the Solar System. As an example of a concept defined in terms of ontology, *the passage of time* may be defined in terms of the change of the objects which are supposed to exist in a theory of the Solar System.

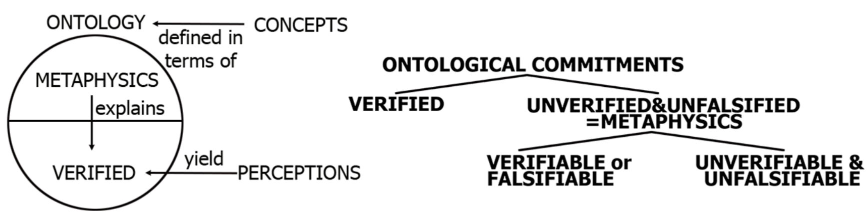

FIGURE 1. Structure of theories and classification of ontological commitments.

The verified commitments leave over questions which are answered in terms of unverified and unfalsified commitments. Such commitments are called *metaphysical*, i.e., a metaphysical commitment is a commitment to the existence of something that has not been empirically verified to exist. Metaphysical commitments function as generalisations which are induced from the verified commitments and explain the verified commitments. This can be abbreviated by saying that metaphysics explains perceptions or saves the phenomena. Metaphysical commitments are classified in two: unfalsifiable&unverifiable; verifiable-or-falsifiable.

The unfalsifiable&unverifiable commitments are not verifiable nor falsifiable by perception even in principle. Examples of such are the commitment to the existence of causally isolated worlds and different answers to the question about the centre point of the Universe. Such commitments function as unexplained explainers and central unifying ideas in theories.

The class of verifiable-or-falsifiable metaphysical commitments contains those currently unverified and unfalsified commitments which are either verifiable or falsifiable by perception. For instance, before the planet Neptune and atoms were verified to exist, the commitments to their existence were metaphysical, i.e., they were *hypothetical entities*. Once Neptune and atoms were verified to exist, the commitments to their existence ceased to be metaphysical. Although their existence was verifiable all along, this was not strictly speaking known before the actual verification. All hypothetical entities are thus metaphysical as long as these are verified to exist.

3. The Principle of Economy

The principle of economy[2] favours the theory which gives the most accurate predictions; of two equally accurate theories, economy favours the one which incorporates the least[3] metaphysics. The criterion of accuracy guarantees that economy does not favour over-simplification, whereas the simplicity criterion guarantees that economy does not favour unnecessary complexity either. In the light of the structure of theories (§2), the need for economy as an evaluation criterion is clear: as the verified part is the same for all theories, accuracy of predictions, simplicity of metaphysics other virtues are what *can be* evaluated.

SOME HISTORICAL FORMULATIONS. For Aristotle, the primary goal of first philosophy is to seek out the simplest principles:

> When the objects of an inquiry, in any department, have principles, conditions, or elements, it is through acquaintance with these that knowledge, that is to say scientific knowledge, is attained. For we do not think that we know a thing until we are acquainted with its primary conditions or first principles, and have carried our analysis as far as its simplest elements. Aristotle, *Physics,* bk. 1, ch. 1.

Ernst Mach emphasised the importance of the 'principle of economy of thought' in various works [4, 5, 6] and characterized science as a process that propagates towards an optimal economically unified description of nature: "The goal which it has set itself is the simplest and most economical abstract expression of facts" (Mach [6, p. 207]). As Mach suggested e.g. the conservation law of energy, Mach's principle (Sipilä and Suntola, this volume) and nonmechanicism in the centre of unified physics, his anti-metaphysical remarks are best interpreted as the rejection of unnecessary metaphysics that is not needed in unified science.

Various scientists and philosophers before and after Mach have expressed formulations congenial with the given version of economy. The first four of the below formulations state that there is no need to suppose more than is needed, and the last two are very close to the given formulation:

> If a thing can be done adequately by means of one, it is superfluous to do it by means of several. Thomas Aquinas [7, p. 129]

> It is vain to do with more what can be done with fewer. William of Ockham, as quoted in Russell [8, p. 472]

> We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances. To this purpose the philosophers say that Nature does nothing in vain, and more is in vain when less will serve; for Nature is pleased with simplicity, and affects not the pomp of superfluous causes. Isaac Newton [9, bk. 3, Rule I]

> ...if everything in some science can be interpreted without assuming this or that hypothetical entity, there is no ground for assuming it. Russell [8, p. 472]
>
> In scientific thought we adopt the simplest theory which will explain all the facts under consideration and enable us to predict new facts of the same kind. J.B.S Halldane, *Science and Theology as Art-Forms*, 1927. As quoted in McAllister [10, p. 105]
>
> It can scarcely be denied that the supreme goal of all theory is to make the irreducible basic elements as simple and as few as possible without having to surrender the adequate representation of a single datum of experience. Einstein [11, p. 165]

UNDERDETERMINATION. One of the clearest examples of why the simplicity criterion is needed is that the evaluation of accuracies of predictions alone faces the challenge of underdetermination:

> ...different, conflicting theories are consistent with the data; ...Given that the theories differ precisely in what they say about the unobservable... a challenge to realism emerges: the choice of which theory to believe is underdetermined by the data. Chakravartty [12]

Economy suggests that the metaphysically simplest of all theories which are equally accurately consistent with the data is to be preferred. Economy thus overcomes the challenge of underdetermination. If two theories were also equally complex and in all ways equally virtuous, we would be dealing with an overwhelmingly more advanced state of science than today.

FALSIFIABILITY. The Kuhnian [13] picture of how the metaphysical weight of a paradigm increases as time goes by raises the challenge of incorporating Popper's [14] criterion of *falsifiability* in theory evaluation: “For Popper, a theory is scientific only if it is refutable by a conceivable event. Every genuine test of a scientific theory, then, is logically an attempt to refute or to falsify it, and one genuine counter-instance falsifies the whole theory” (Thornton [15]). Theories of fundamental physics have unfalsifiable metaphysical commitments, i.e., the falsifiability criterion can be applied only to their falsifiable predictions. However, when a theory's predictions do not match perceptions, it can be saved from falsification by introducing more metaphysical commitments. Kuhn teaches that this has been the case in the past. But also the recent developments fit in the Kuhnian picture, i.e., the metaphysical weight of a paradigmatic theory of physics has increased as a function of time (§5). Unless metaphysical weights of theories count in evaluating them, scientific metaphysics can practically flow free. Economy incorporates falsifiability: as a theory is saved from falsification by adding metaphysical parameters, its relative simplicity (§§4-5) reduces, i.e., it gets less economical. By economy, increasing metaphysical complexity cannot be swept under the rug by maintaining that it is merely 'philosophical' or 'ideological'[4] or that additional parameters are 'empirical facts'.

STAGNATION. If a theory fails to give correct predictions or if its metaphysical weight increases as time goes by, it is natural to start searching for a more optimal theory: "Failure of existing rules is the prelude to a search for new ones" (Kuhn [13, p. 68]). Given that a new theory is available and if it is clearly more economically unified, the path should be open for shifting into it. The shifts should happen in orderly fashion so that they would not be treated as revolutions as Kuhn calls them, but as acceptable progress, since the new theory has been objectively judged better. Unfortunately, history shows that 'revolution' characterises paradigm shifts very well, and the enlightened state of science where theories are objectively evaluated is only a dream of a better future. Scientists typically take commitments of the current paradigm as articles of faith and are not willing to consider alternatives no matter what. Economy is thus needed in tackling dogmatism: an extreme form of stagnation which prevents a more economical theory from becoming the new paradigm.[5] It is likely that the identification of metaphysics in theories, its open explication and constant evaluation by economy would make paradigm shifts smoother and more rational, which would resolve the challenge that Lakatos [19, pp. 90-1] set himself: "Lakatos did not solve the problem he set out to solve, that is the problem of whether scientific revolutions can be rational" (Aliseda and Gilles [20, p. 468]).[6]

PESSIMISTIC INDUCTION AND APPROXIMATE TRUTH. The Kuhnian paradigm shifts also raise the challenge of pessimistic induction:

> If one considers the history ...what one typically finds is a regular turnover of older theories in favour of newer ones, as scientific knowledge develops. From the point of view of the present, most past theories must be considered false; indeed, this will be true from the point of view of most times. Therefore, ... surely theories at any given time will ultimately be replaced

and regarded as false from some future perspective. Thus, current theories are also false. Chakravartty [12]

As the current theories are false, the concept *true theory* had to be replaced by *approximately true* or *truthlike*: "The best explanation for the practical success of science is the assumption that scientific theories in fact are approximately true or sufficiently close to the truth in the relevant respects" (Niiniluoto [21, p. 10]). In turn, explicating what approximately true means a central challenge for scientific realists, who have had two broad strategies: "attempts to quantify approximate truth by formally defining the concept and the related notion of relative approximate truth; and attempts to explicate the concept informally" (Chakravartty [12]).

The formal approach can be characterized in terms of Niiniluoto's [22, p. xii] *similarity* approach where "the truthlikeness of the statement *h* depends on the similarities between the states of affairs allowed by *h* and the true state of the world." The better the predictions of a theory match perceptions, the closer the theory is to truth. Although Niiniluoto has (with other followers of Popper) perfected the notion of what it means that a theory gives correct predictions, he has left the evaluation of metaphysics and other aesthetic features to others.[7] As the evaluation of the aesthetic features *is* the informal approach, it is seen that economy is a fusion of the formal and informal approaches to truthlikeness.

4. The Virtues of Unification

The process of approaching a unified explanation of all scales walks hand in hand with increasing metaphysical simplicity and general virtuousness of total science. There is thus a small step from economy as a criterion of empirical sufficiency and metaphysical simplicity only, into a criterion that evaluates all virtues of competing theories. Figure 2 represents the transition from disunified science into an ideal economically unified theory which is the nexus of virtues: empirical sufficiency, metaphysical simplicity, unificatory power, consilience, comprehensiveness,

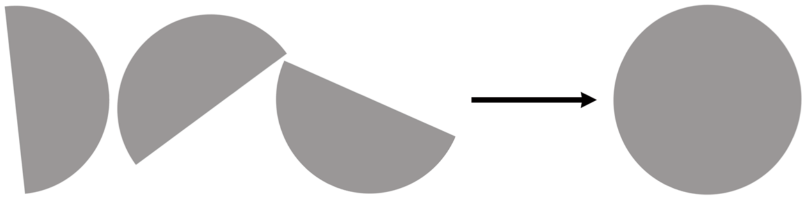

FIGURE 2. From disunified branches into unified science.

lack of ad hoc features, understandability, coherence, necessity and fundamentality. All these are interrelated with all, and only some of their interrelations are explicated. The central unifying factor behind all interrelations is unification itself, which could be added in all below titles.

SUFFICIENCY, SIMPLICITY, UNIFICATORY POWER. In figure 2 the three half-circles represent isolated theories of different scales —such as the scales of particles, planetary systems, and the Universe as a whole— and the circle represents an ideally unified theory of all scales. The circle does not represent the fusion of the disunified theories which may be incompatible, but it represents the theory that explains alone what the isolated theories explain individually. By explaining all scales with a unified postulate base, the overall quantity of postulates and parameters is minimised, whereas in isolated theories their quantity is maximised, proportionally to the degree of isolation. Even if an isolated one-scale theory were individually simpler than a unified theory of all scales, the unified theory would be *relatively simpler* than the isolated theories together: "a theory has high relative simplicity, if it explains a multitude of empirical data by means of a few independent assumptions" (Niiniluoto [23, p. 190]). The fusion of empirical sufficiency, metaphysical simplicity, comprehensiveness, internal consistency and external coherence is close to great *unificatory power* (Kitcher [24]), great *explanatory power* (Psillos [25, p. 171]) and great relative simplicity (Kaila [26, pp. 77-83]). The greater unificatory/explanatory power and greater relative simplicity, the more economically unified is the theory.

The Aristotelio-Machian ideal of unified science where everything is explained in terms of a simple set of basic postulates is implicit e.g. in

Hempel and Oppenheim's [27, p. 321] scheme of explanation, Oppenheim and Putnam's [28, pp. 13-4] *micro-reduction*, Nagel's [29] *reductionist model*, Kitcher's [8] *unification model* of scientific explanation, and Ross, Ladyman and Spurrett's [30, p. 30] *principle of naturalistic closure*. Although these models are imperfect characterizations of unification, any foreseeable model that characterizes unification and reductionism must in any case build on the same basic idea.

COHERENCE, COMPREHENSIVENESS, UNDERSTANDABILITY, CONSILIENCE. Mutual and internal consistency of all ontological commitments and definitions is a basic requirement for an economically unified theory, as an incoherent theory cannot genuinely explain perceptions. Coherence and understandability walk hand in hand whereas an incoherent theory cannot be genuinely understood. When the minimal sum of metaphysical commitments and their interrelations are explicated and as they explain all scales, the whole is understandable and its minimal size facilitates understanding it, whereas understanding several isolated theories individually requires more work, and these in any case fail to catch the unified picture of reality. A comprehensive theory does not leave central aspects of nature unexplained, and as these are explained these are also understood. This is congenial with Poland [31, p. 29]: "A unified picture of nature provides more and deeper understanding than does a view of nature that represents it as a disunified aggregate of isolated and disconnected facts." A comprehensive and coherent theory is consilient, as independent points of view, new hypotheses and observations conform to it.[8]

NECESSITY AND FUNDAMENTALITY. An ideal theory incorporates a minimal sum of optional metaphysics in addition to necessary metaphysics. A natural starting point to seeking out such a theory is the identification of necessary metaphysical commitments such as (a-c). (a) A theory may commit to the existence of several causally isolated worlds, but all sufficient theories must commit to at least one world (the actual world); the commitment to at least one world is thus necessary and provisionally also sufficient. (b) A theory may commit to the existence of past, present and future, but all sufficient theories must commit at least to the existence of the present; the commitment to the existence of the present is thus necessary and provisionally also sufficient. (c) A theory may commit to spatial infinity and infinite divisibility, but all sufficient theories must commit at least to finite space and divisibility; the commitment to at least finite space and divisibility is thus necessary and provisionally also sufficient.

It is natural to consider everything necessary as fundamental. The fundamentality of a theory that consist of necessary and optional commitments can be measured by economy: the more economical, the more fundamental. Further, in the light of the indispensability of metaphysics in theories, economical unification functions as a demarcation criterion. It is not asked whether a theory is metaphysical or scientific, but it is asked which of two 'scientifico-metaphysical' theories is more economically unified: the more economical, the more 'scientific.'

5. Evaluation of DU vs. GR

The principle of economy is applied in evaluating the Dynamic Universe model (DU) vs. contemporary physics and cosmology based on the General Theory of Relativity, which are jointly denoted as GR. It is evaluated how virtuously DU and GR manage to handle the following interrelated cases: (1) explaining tests with atomic clocks; (2) giving a geometrical picture of the Universe as a whole and compatibility with absolute simultaneity; (3) giving an account of temporal existence, the passage of time and the direction of time; (4) giving an account of expansion of the Universe, i.e., explaining the observed redshift/magnitude ratios of Ia supernovae; (5) explaining the faint Sun paradox; (6) explaining how interactions/forces are conveyed; (7) explaining the precession of the perihelion of Mercury.

Kaila's [26, pp. 77-83] formula for relative simplicity E/P is applied in the evaluation, so that in addition to accuracy of predictions and simplicity of metaphysics, also other theoretical virtues are taken into account. E denotes the phenomena or empirical data explained by the theory. P denotes the magnitude of metaphysical commitments needed in the explanations. The greater the value, the greater relative simplicity and the better the theory.

If DU and GR would explain 1-7 equally well, *E* would be the same with both and the evaluation could concentrate on *P*: the better theory has smaller *P* and thus greater *E*/*P*. However, the theories do not explain all cases equally well. An explanatory failure could be counted as a subtraction from *E*, but when the failure is acknowledged, it could in principle be fixed by adding a new metaphysical parameter in *P*. Explanatory failures could thus be counted as subtractions from *E* as well as additions to *P*, and the selection seems to be a matter of taste. The strategy of adding to *P* is applied in the below evaluation.

The basic structures of DU and GR —their basic postulates or axioms— are considered to have an equal metaphysical weight. This leaves only the implications of their basic structures to be evaluated and added to the *P*'s of DU and GR. It is hard to give specific numeric additions to *P*, for it is hard to say how should e.g. hypothetical dark energy that composes 70 % of the total energy of the Universe be weighted against hypothetical atmospheres of two planets. Therefore, explicit numeric additions are not made to the *P*'s, i.e., this evaluation is somewhat qualitative.

SUMMARY OF DU'S AND GR'S AXIOMS. The basic structure of DU is the fusion of the zero-energy formulation of the conservation law of energy in four-dimensional spherically closed space, cosmic time which entails absolute simultaneity, and instantaneous non-mechanistic gravitational interactions.[9] The basic structure of GR is the fusion of the Relativity Principle, constant velocity of light, coordinate transformations, the Equivalence Principle, and mechanistic force-conveying at the velocity of light.

CASE 1: ATOMIC CLOCKS & ABSOLUTE SIMULTANEITY.[10] Suppose that identical or sufficiently similar atomic clocks A and B stand side by side on the surface of Earth at sea level; they tick at an identical rate and show the same reading. Clock A remains at sea level while B is transported to the top of a mountain. B stays on the top of the mountain for one day. After this B is transported back to the side of A at sea level. Again, the clocks tick at an identical rate, but B shows a greater cumulated reading than A.

In DU, the ticking rate of an atomic clock is determined by its energy state: its combined state of motion and gravitation. In short, the higher the altitude, the higher the gravitational potential (and the local velocity of light) and the higher the ticking frequency of a clock; the greater the velocity (or the kinetic energy), the slower is the ticking frequency of a clock. In this test the difference of the velocities of the clocks can be disregarded, which leaves gravitation to do all explaining. Clock B has been in a higher gravitational potential and has had a higher ticking frequency than A: therefore B shows a greater cumulated reading than A. DU's interpretation is compatible with absolute simultaneity: the clocks have existed absolutely simultaneously all through the test, but they have had different ticking frequencies.[11]

In GR, the Relativity Principle states that the equations that describe the laws of physics —which determine the clocks' ticking frequencies— have the same form in all admissible frames of reference, i.e., they have been the same for both clocks. However, the clocks show different cumulated readings. The different readings of A and B are correctly predicted by the coordinate transformations, and interpreted as *differences in the flow of time experienced* by A and B, i.e., there is no time which is the same and absolutely simultaneous for A and B, but instead the frames of reference where the clocks reside have *their own/proper/relativistic times*. The flow of time is different for an object moving relative to the observer (*time dilation*) and for an object at a different gravitational state (*gravitational red/blueshift*).[12]

Consider another phrasing. (a) The Relativity Principle states that the equations and commitments of GR hold in all frames of reference, including the commitment to the identity of the characteristic emission frequencies of identical atoms in all frames of reference. E.g. the frequencies of caesium-133 atoms, the oscillators in caesium clocks, are identical. (b) The test reveals that the atomic clocks show different cumulated readings. (c) In order for (a-b) to cohere, time was postulated as an independent fourth dimension, which sustains the Relativity Principle and the equations of GR, but contradicts absolute simultaneity. If absolute simultaneity were sustained, the Relativity Principle would have to be rejected, because this would imply that the atoms have resonated in different frequencies. But one cannot reject the Relativity Principle without rejecting GR.

CASE 2: GEOMETRY OF SPACE AND ABSOLUTE SIMULTANEITY. In DU, space is strictly defined as the 3D 'surface' of a 4D sphere, where all 4 dimensions are metric, and where time is used as a universal scalar and coordinate quantity.[13] In the space-time geometry of the GR-based cosmology model, the Friedmann-Lemaître-Robertson-Walker model (FLRW), there are three space dimensions and one time dimension, and three geometrical options for the 3D space.

Whatever geometry is selected, it is geometry of space as a whole, i.e., both DU and FLRW need to talk about temporal stages of the Universe (TSUs) as wholes whose parts exist absolutely simultaneously. In other words, they both need *cosmic time*, which entails absolute simultaneity. For instance, saying that the age of the Universe is *x* years, the diameter of the Universe is *y* meters, the average density of the Universe is *v* kilograms per cubic meter, the mass of the Universe is *w* kilograms, the Universe expands at the rate denoted by the *Hubble constant*, and that a TSU has a total energy, makes no sense without absolute simultaneity. For how can the Universe have any age, size, density, mass and expansion rate *now*, if we cannot talk about all parts of the present TSU simultaneously, and if its parts have different times? Cosmologists apply cosmic time for just this purpose. Lehti[14] [39] and Janzen [40] point out several instances where cosmologists including Einstein apply cosmic time when talking e.g. about the expansion of the Universe and its geometry. One of Einstein's [41] chapters is titled: *Considerations on the Universe as a Whole*. He openly talks about the geometrical form of the Universe as a whole and about its radius: these are illegitimate without cosmic time.

In DU, cosmic time is the only time and it applies in all scales. In FLRW, there is cosmic time *and* Relativistic time, which is implied by the Relativity Principle. The problem is that absolute simultaneity is implicit in cosmic time, but the Relativity Principle contradicts absolute simultaneity and thus cosmic time, as illustrated in case 1. In steps:

(a) The Relativity Principle was postulated in Special Relativity.
(b) Special Relativity was extended into General Relativity.
(c) General Relativity was extended into FLRW.
(d) The Relativity Principle contradicts absolute simultaneity.

(e) Cosmology requires cosmic time which requires absolute simultaneity and thus contradicts the Relativity Principle.

(f) Escaping the contradiction requires either rejecting the Relativity Principle or rejecting cosmic time.

(g) Neither can be done. Rejecting the Relativity Principle would mean breaking the backbone of GR and thus also FLRW. Rejecting cosmic time would render FLRW useless.

The problem cannot be over-stated. As time is interrelated with most of quantities such as velocity, momentum, energy and force, the formation of a comprehensive and understandable unified theory has been impossible in the context of GR for more than 100 years now. However, the contradiction can be avoided by incorporating two *different and independent* notions of time: cosmic time that applies in all scales but is primarily used only in cosmology; relativistic time which is applied in talking about smaller scales only. The *P* of GR is increased in both ways: by the way of contradiction and by the way of incorporating two independent conceptions of time. This is the first example of how explanatory failures can be fixed by incorporating more metaphysics.

CASE 3: TEMPORAL EXISTENCE, THE PASSAGE AND THE DIRECTION OF TIME. The Relativity Principle implies *eternalism*, where the past and the future exist as strongly as the present.[15] According to Einstein [48] "People like us, who believe in physics, know that the distinction between past, present and future is only a stubbornly persistent illusion." It would be more objective to say that if the Relativity Principle is truly a law of nature, then past and future exist along with the present. DU does not require eternalism and is compatible with *presentism*, where only the present temporal stage of the Universe (TSU) *exists*, the past *did exist* and the future *will exist*;[16] all parts of the present TSU exist absolutely simultaneously. Eternalism entails a number of dilemmas for GR. First, all versions of eternalism are uneconomical with respect to presentism, for the existence of the present only is clearly less than the existence of the present, past and future. Presentism and two versions of eternalism are depicted in figure 3. In basic eternalism, there is no objectively existing present moment; in the *moving spotlight theory*[17] the objectively existing present is explicitly added.

FIGURE 3. Three theories of temporal existence.

Second, basic eternalism does not explain change or the passage of time, whereas presentism does. In presentism, the passage of time is defined as transition from one TSU into another TSU. Suppose that 1 is the present and thus the only TSU that exists; when the transition from 1 to 2 has occurred, 2 has become into existence and 1 has ceased to exist. In basic eternalism, change cannot be explained in terms of becoming to or ceasing to exist, as all times exist equally and there is no objectively existing present. Therefore, a postulate which embodies change must be added on basic eternalism: the moving spotlight theory adds the objectively existing present, in terms of which change is explained. However, the moving spotlight theory is uneconomical and suffers from other dilemmas.[18] A basic eternalist can also consider change as an illusion. This does not help, for the function of metaphysics is to explain perceptions and not render them illusions; then again, the commitment to change being an illusion is metaphysical; basic eternalism is uneconomical either way, because it fails to embody change or must add a postulate.

Third, in presentism the transition from one present into another is equivalent with the transition from one present *time* into a succeeding present time. All transitions of time are thus in the forward direction. *Intrinsic forward directed* time has thereby been defined in terms of presentism, i.e., time is merely the measure of change. Due to basic eternalism which does not give a direction to time, GR was coupled with *entropy* by Arthur Eddington [54]. The difficulty is that entropy is an uneconomical addition, and an applicable concept of *total entropy* is incompatible with the Relativity Principle. In steps:

(a) The Relativity Principle entails eternalism.

(b) Eternalism leaves the direction of time open.

(c) Therefore GR needs an anchor for the direction of time.

(d) Entropy is now the commonly accepted anchor.
(e) Entropy that is applicable as the anchor is that of total entropy of a TSU).
(f) The concept of total entropy of a TSU whose parts exist simultaneously, entails absolute simultaneity.
(g) Total entropy thus contradicts the Relativity Principle.
(h) Therefore, entropy cannot function as an intelligible anchor for the direction of time in the context of GR.

Entropy could be coupled with cosmic time that is independent of relativistic time, but having two independent times is uneconomical (case 2). Eternalism and the entropy mapping are in any case counted as additions to GR's *P*. DU does not require entropy nor eternalism, for as DU is compatible with presentism, intrinsic time can be defined as a measure of change, and change by definition takes time forward.

CASE 4: EXPANSION HYPOTHESES. In the end of the 1990's, accurate measurements of the magnitudes and red-shifts of distant supernovae were available. In order to make FLRW match these measurements, something repulsive had to be incorporated, which has come to be called *dark energy*. Without dark energy the lowest FLRW curve in figure 4 misses the target, and therefore dark energy had to be added. The hypothesis that the expansion of the Universe is currently accelerating followed as a result of adding dark energy. Today dark energy is supposed to comprise about 70 % of the total energy of the present temporal stage of the Universe (TSU). In addition, early *inflatory expansion* is assumed in FLRW. These are counted as additions to GR's *P*. DU does not stand in the need of dark energy nor inflation, i.e., no hypothetical entities nor exceptional regularities are needed in DU's expansion hypothesis which results from the basic structure.[19]

CASE 5: THE FAINT SUN PARADOX.[20] The predictions of DU and GR differ also in the scale of the Solar System. In GR gravitationally bonded parts such as galaxies and star systems do not expand along with the expansion of space.[21] In DU all gravitationally bonded parts expand equally, including the Solar System, whereas compact objects such as planets and stars do not expand along with the expansion of space (Suntola [37, §6.2.2]). When GR's convention that the Solar System does not expand is coupled with the commonly accepted premises (a-c), the result is that

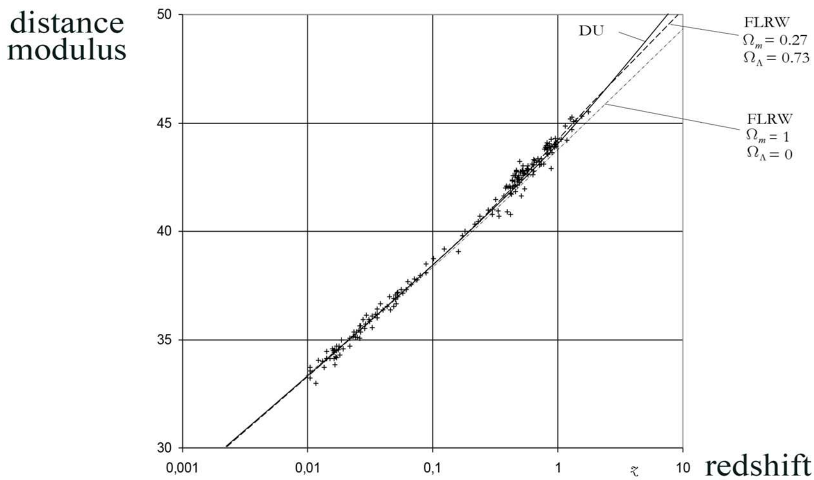

FIGURE 4. The crosses denote observed distance moduli of Ia supernovae as a function of their redshifts (Riess et al. [55]). The lower dashed line denotes the FLRW prediction without dark energy; the higher dashed line denotes the FLRW prediction with dark energy; the solid line denotes the DU prediction. The only actually measured values are the redshift and the apparent magnitude (or the distance modulus). The greater the redshift the greater the distance of the object.

additional parameters are needed in explaining certain discoveries about the Earth and Mars, whereas DU gets by without them.

Commonly accepted premises. Solar luminosity or the radiation efficiency of the Sun increases about 7% in a billion years.[22] Thus, the Sun was about 25 % dimmer 3,85 billion years ago. There were seas on Mars 3,85 billion years ago.[23] Now all water is in the form of ice, concentrated in the poles of Mars. The current mean temperature of Mars is -63 C°. There were seas and life on Earth 3,85 billion years ago and the mean temperature was 30-40 C°.[24]

Circumstances on Mars. Suppose that the Solar System does not expand. This begs the question that how can there have been seas on Mars 3,85 billion years ago, when the temperature was a lot lower than now, as can be deduced from the lower solar luminosity in the past? An additional explanation can be given: there was an atmosphere in Mars which had just the kind of a constitution that the temperature was so high that the seas could have existed. McNally [64, p. 602] notes that *one has to* *assume* that there has been an intensive *greenhouse effect* on Mars 3.8 billion years ago. In contrast, DU predicts that Mars was closer to the Sun in the past, and that the distance was such that the seas were possible even with the smaller Solar luminosity at least around the equator of Mars. As the Solar System expanded, Mars moved so far that the temperature decreased, and the seas turned into ice.

Circumstances on Earth. Suppose that the Solar System does not expand. This supposition leads to the conclusion that the mean temperature on Earth was about -20 C° 3.85 billion years ago,[25] for the solar luminosity was about 25% smaller back then. This begs the question that how can there have been seas on Earth 3.85 billion years ago and why do geological findings indicate that the temperature was 30-40 C° and there was life back then? The heat produced by nuclear reactions in the core of the Earth does not explain why there was water. Lunine [65, p. 162] and McNally [64, p. 602] propose a greenhouse effect. In contrast, DU predicts that the Earth was closer to the Sun in the past, which allows the mean temperature of 30-40 C° and the existence of seas (not ice) back then, even with the smaller Solar luminosity. The greenhouse effects are counted as additions to GR's *P*.[26]

CASE 6: CONVEYING OF INTERACTIONS/FORCES. In GR and standard physics, all interactions are explained in terms of particles/waves moving at the velocity of light at the fastest. Consider an apple hanging from a tree. In GR/quantum field theory, gauge boson particles called gravitons that are emitted by the Earth hit the apple and attract it towards the ground. Also, the apple emits gravitons which hit the Earth. The apple remains in the tree as long as the gravitational force conveyed by the gravitons is weaker than the force due to the chemical bonds of the molecules that keep the stem of the apple attached to a branch.

In DU, interactions are explained in terms of energy conversions. DU shifts from mechanistic conveying of forces via particles into *non-mechanistic recognition of the local gradient of energy* (Suntola et al. [35]). In the case of gravitation, DU shifts from mechanistic conveying of gravitation via graviton particles that move at the velocity of light, into instantaneous recognition of the local gradient of gravitational potential. In DU, the apple recognizes its gravitational energy and it also recognizes the energy of the chemical bonds by which it is attached to the branch. The gravitational energy together with the chemical bonds create a local minimum of potential energy at the bonding distance, i.e., at the location where the apple hangs from the tree. When the apple hangs in location *x*, the apple is in a local minimum, and therefore does not fall to the ground. As the apple ripens, the chemical bonds weaken. In effect, the location of the local minimum of the apple changes: the apple falls to the ground to a new local minimum.

The mechanistic approach as such is equally economical with the energy approach, but it has problems that are resolved by the energy approach. Based on Laplace's[27] calculations, the Solar System is unstable with gravitation that propagates at the velocity of light, which is the case in GR. In DU the Solar System is stable as gravitation is instantaneous. This is not a generally acknowledged problem, but if it will be fixed while sustaining gravitation that propagates at the velocity of light, some postulate is needed in that fix. The failure of explaining the stability of the Solar System or its compensation by additional metaphysics is counted as an addition to GR's *P*. Gravitons reveal another disunified feature of GR: in the scale of individual galaxies and smaller, gravitons are supposed to move with a force towards direction D, but still counter-intuitively *pull* objects which they hit towards a direction opposite to D. In the largest scale the pushing-idea works at least partially, in the sense that dark energy is supposed to push galaxies away from one another.

CASE 7: PRECESSION OF THE PERIHELION OF MERCURY. The precession of the planet Mercury's perihelion within a 0.7 million years period can be explained in terms of DU so that Mercury remains on its orbit. In GR the perihelion shift solved for Schwarzschild space comprises a cumulative term which increases the orbital radius, and Mercury is thrown away from the orbit. This is not a generally acknowledged problem, but if it will be fixed while sustaining Schwarzschild space, some metaphysical postulate is needed in that fix. Therefore, GR's *P* is increased.[28]

SUMMARY. In explaining cases 1-7, the basic structure of GR has the following implications and/or must be complemented by additional postulates, whereas the plain basic structure of DU handles all cases.

(1-3) GR's Relativity Principle implies that atomic clocks and other parts of the Universe have their own relativistic times; either this contradicts cosmic time which is indispensable in cosmology, or requires that relativistic and cosmic times are independent, which is uneconomical. The Relativity Principle entails eternalism, which is uneconomical, which requires an extra postulate to explain the passage of time, and an extra anchor (entropy) for the direction of time. DU commits to absolute simultaneity, cosmic time is the only time, and DU is compatible with presentism in terms of which the passage and direction of time are defined. In FLRW, there are three space dimensions and one time dimension, and three geometrical *options* for the 3D space, i.e., the form of the present stage of the Universe as well as its development are open questions; in DU the geometrical form of space as well as its development are strictly defined as an expanding 3D surface of a 4D sphere.

(4-5) In FLRW, dark energy comprises about 70 % of the total energy, which implies the accelerating expansion hypothesis; also, inflation is assumed. The interpretation that e.g. planetary systems do not expand along with the expansion of space conflicts evidence about Earth and Mars, and the conflict has been fixed by supposing hypothetical greenhouse effects on Earth and Mars in the past. In DU, no parameters are needed in deriving the expansion prediction, which results from the basic structure of DU; the findings on Earth and Mars are compatible with DU without greenhouse effects.

(6-7) Conveying of gravitational interactions at the velocity of light entails an unstable Solar System, and thus requires some additional postulate. Explaining the precession of the perihelion of Mercury requires some additional postulate, in order to prevent Mercury from bouncing out of the Solar System. In DU, the Solar System is stable and the precession of the perihelion of Mercury is explained in a way that Mercury remains on a stable orbit.

Although numeric additions to GR's P are not given, this does not change the fact that the evaluation amounts to just how much greater GR's P is. Eventually, all phenomena of all scales and all postulates and their implications needed in explaining the phenomena should be counted in conclusively. This is not done here, but looking at all scales and all postulates would not change the general picture that the above evaluation revealed.

6. Conclusions

The role of the principle of economy as an evaluation criterion of theories was opened up and economy was applied in evaluating the Dynamic Universe model (DU) vs. physics and cosmology based on the General Theory of Relativity (GR). The conclusion was that the predictions of DU match observations at least as accurately as those of GR, and that DU builds on unified metaphysics whose weight is clearly smaller than that of GR. Economy thus favours DU. The path should be open for a paradigm shift, but this is not likely to happen in the near future, due to stagnation in the GR paradigm. This underlines the need for economy and reminds that Paul Feyerabend's central notions about stagnation are very clearly implemented in 21st century science, and his requirements of theory proliferation need to be taken seriously:

> The weaknesses of a theory often do not appear if the theory confronted with the facts as seen from its own perspective, but may only appear if facts as seen from the perspective of an alternative theory are allowed. Hoyningen-Huene [64, p. 10]

The acknowledgement and open explication of metaphysics in physics and the acceptance of the degree of virtuousness as judge in theory choice on par with the accuracy of predictions, paves the way to an enlightened state of science where proposed changes to paradigms are no longer seen as rebellions which are opposed until a revolution, but as suggestions whose fitness can be objectively evaluated. But this enlightened state of science is merely a dream of a better future. Perhaps the only long-term solution to the problem of unconditional stagnation is to teach philosophy of science to all students.

Notes

1 For congenial formulations, see Quine [1, p. 11] and Cameron [2, p. 250].

2 Economy has also been called Ockham's razor and the principle of parsimony.

3 The weight of metaphysical commitments of a theory is determined by the number of different types (or kinds) of metaphysical entities, and quantities of each type. Both the number of kinds of entities and the quantity of entities of each kind need to be counted, for one can compensate the other (cf. Nolan [4]).

4 According to Sider [31, p. 230], Quine's [1] ideological commitments are "as much commitments to metaphysics as are ontological commitments."

5 E.g. Planck [16, pp. 33-4] and Feyerabend [17, pp. 193-4] [18] warn about the dangers of dogmatism. See also Narlikar, this volume.

6 Aliseda and Gilles [21, pp. 466-7] propose "that philosophers of science have to develop not only a theory of the growth of science, but also a theory of the appraisal of scientific hypotheses. ...we need a theory of the appraisal of scientific hypotheses which does not involve detailed considerations of how those hypotheses are discovered." Economy is a suggestion of exactly this kind of a 'theory' or a criterion of fitness.

7 Niiniluoto (personal communication, 21.5.2016) confirms that he accepts the idea that the similarity approach is first applied in picking out theories with the most accurate predictions, and after this the aesthetic features such as simplicity are evaluated.

8 These remarks conform to Snyder [32] and Whewell [33, pp. 83-96].

9 For the basic structure of DU, see Suntola [34] and this volume, and Suntola et al. [35]. See Suntola [36, p. 125] for comparison of the postulates.

10 This test is analogous to Chou et al. [37], where the difference in heights of the clocks was less than 1 meter, and the resulting difference in their velocities less than 10 meters per second.

11 See Suntola [38, pp. 12, 55-7, 283-4, 301, 313] and this volume, §4.

12 As in this test we are dealing with differences in the state of gravitation, Schwarzschildian metrics is applied. If we were dealing only with differences in velocity in a fixed state of gravitation, Lorentz transformations would suffice.

13 See Suntola [38, pp. 36-9, 73-4] and this volume, §4.

14 Lehti [38] notes that Einstein [41, pp. 98-9] in no way indicates that he has given a suggestion about the structure of the Universe which is incompatible with his own Relativity Principle.

15 See e.g. Rietdijk [43], Putnam [44], Peterson and Silberstein [45] and Saunders [46] for proofs. The fusion of eternalism and partial determinism —or indeterminism— implies some version of branching space-time (Belnap [47]). If branching space-time is evaded by selecting total determinism —also called causal determinism— the question boils down to whether total determinism is plausible after all, as it is e.g. incompatible with free will.

16 This definition is congenial with e.g. Dummett [49, p. 73-4] and Putnam [44, p. 240].

17 See e.g. Broad [50, pp. 59-60] and Deasy [51, p. 2075].

18 See Sider [52, p. 261]. Merricks' [53, p. 105] critique of the growing-block theory applies also to the moving spotlight theory.

19 See Suntola [38, §§1.2.5, 3.3.1, pp. 254-6], [36, pp 186-7], this volume, §4.

20 The following was inspired by Sipilä [56].

21 The standard interpretation since the 1930's has been that galaxies and planetary systems do not expand but the Universe as a whole expands (de Sitter [57]). The expansion is explained by Hubble flow between galaxies or galaxy groups (de Sitter [58]).

22 See e.g. Gough [59] and Bahcall et al. [60].

23 Emiliani [61, p. 543] notes that there was water in Mars more than 3 billion years ago.

24 See e.g. Kusky [62, p. 238] and Le Bihan and Fukuyama [63, p. 344]. In terms of DU, '3.85 billion years ago' is translated as 'when the 4-radius of the Universe was 3.85 billion light years smaller'.

25 Lunine [65, p. 162] notes that the Earth should have been frozen for the first three billion years due to the faint Sun but that geological findings suggest that the temperature of the seas was much higher 3.4 billion years ago than today.

26 See Suntola, [38, §§7.3.3, 7.4.2] and this volume §4, for the effect of the expansion of space on Earth to Moon distance, and the compatibility of DU's predicted expansion with coral fossil data.

27 Pierre-Simon Laplace, Mécanique Céleste 1, 1799-1825.

28 See Suntola [36, pp. 175-6] and this volume, §4.

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Ari Lehto

PERIOD-DOUBLING AS A STRUCTURE CREATING NATURAL PROCESS

[**Abstract**] The period-doubling phenomenon is a common property of nonlinear dynamical systems. The aim of this presentation is to show that this phenomenon may create several natural structures from small to large. Analysis of observational and experimental data shows that the structures have three and four intrinsic degrees of freedom.

1. Introduction

In this presentation 'structure' means such properties of an object that can be described in terms of shape and size, or geometry and magnitude. Professor K.V. Laurikainen, the founder of The Finnish Society for Natural Philosophy, held popular seminars in the cellar auditorium of the Department of High Energy Physics on Thursdays at the end of the 70's. The main topic was quantum mechanics and its implications concerning observations vs. reality. The inspiration for searching a simple structure creating natural process came from these seminars. Chaos was an active field of research then, and it offered an interesting possibility for a search of a simple structure creating natural process.

M. J. Feigenbaum [1, 2] showed that period-doubling is a universal property of nonlinear dynamical systems. The word universal is important, because nothing in nature is truly linear, and so we should be able to discover the period-doubling phenomenon at least in the nonlinear gravitational and Coulombic 1/*r*-potential systems. The aim of this presentation is to illustrate the fundamental role of the period-doubling mechanism behind natural processes in creating the structures of the elementary particles, planetary and galactic systems and others.

2. What is period-doubling or frequency halving?

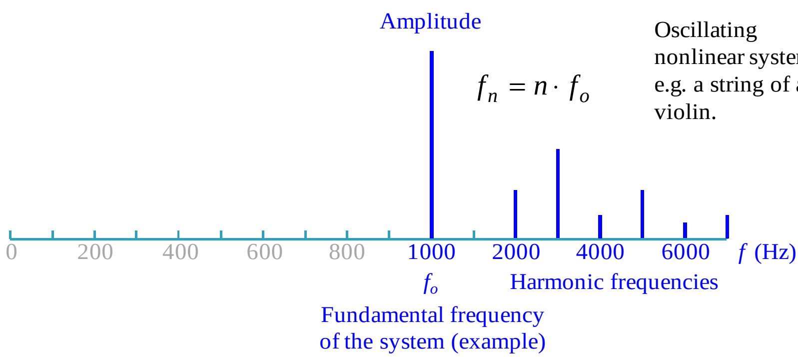


FIGURE 1. Harmonic frequency generation.

An example of harmonic frequency generation in nonlinear systems is shown in Figure 1. If f_o is the fundamental frequency, then the harmonic frequencies are $n \cdot f_o$, where $n = 2, 3, 4, 5, \ldots$ Harmonic generation is instantaneous. Applications can be found for instance in radio- and laser technologies. In a linear system, there are no harmonic frequencies.

It is less widely known that subharmonics, Figure 2, may be generated, too. The process is called period-doubling (=frequency halving). Generation of *subharmonics* is not instantaneous because a long period cannot be generated within a short period. The subharmonics stabilize (or become chaotic) in the course of time.

An attractor is a set of numerical values toward which a system tends to evolve, given enough time, for a wide variety of starting conditions of the system. System values (e.g. period, energy) that get close enough to the attractor values remain close even if slightly disturbed.

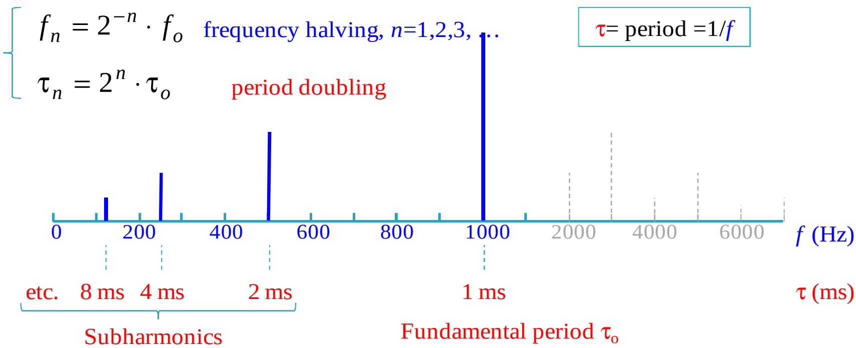
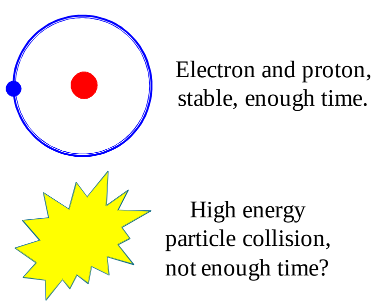


FIGURE 2. Subharmonic periods.

We shall use the period-doubling phenomenon as a tool in analysing experimental and observational data.

3. Is there enough time for the attractors to develop?

The vast majority of the elementary particles have lifetimes on the order of 10^{-20} s or less, whereas the planetary systems have evolved for billions of years (~10^{18} s). The electrons and protons have existed for billions of years, too, and they have well-defined intrinsic physical properties. Our Solar system is likewise very old. Is 10^{-20} s long enough for the attractors of the artificial elementary particles to fully develop? An answer will be given later in this presentation.



If the shortest, or the fundamental period of the system is τ_o, then the *n*'th period is

1. $$\tau_n = 2^n \cdot \tau_o$$

where $n>0$ is an integer, and *n* is called the number of period-doublings,

$n=$ **1** **2** 3 **4** 5 6 7 **8** 9 10 11 12 13 14 15 **16** 17 18

2^0 2^1 2^2 2^3 2^4

and the subharmonic periods are $2\tau_o$, $4\tau_o$, $8\tau_o$, $16\tau_o$, $32\tau_o$, $64\tau_o$ etc., respectively. Some *n*'s are integer powers of two themselves, i.e. $n = 1, 2, 4, 8, 16, 32, 64, 128$ …. These periods are superstable, and they are related to the naturally occurring structures we will analyse later in this article.

2. $$\tau_n = 2^n = 2^{2^i} \cdot \tau_o$$

Period-doubling is not a mathematical curiosity but a real physical phenomenon, which has been observed e.g. in pulsating stars and demonstrated in many experiments.

4. Connection to physics

Different physical quantities *q* can be written in terms of period:

3. $$q \begin{cases} \text{Energy: } E=hf=h/\tau \\ \text{Wavelength: } l=c\tau \text{ (also circumference of an orbit)} \\ \text{Temperature } T=h/k\tau \\ \text{Magnetic moment: } \mu=ec^2\tau/4\pi \text{ (classical current loop)} \end{cases}$$

These relations indicate that period-doubling will manifest itself as a halving/doubling behaviour in these quantities, too.

For the fundamental (=shortest) period we choose the Planck time τ_o defined by natural constants *h*, *c* and *G*. The process independent Planck scale reference values are:

τ_o = 1.35·10^{-43} s l_o= 4.05·10^{-35} m T_o=3.55·10^{32} K

E_o =3.06·10^{22} MeV μ_o = 1.55·10^{-46} Am^2 c = 299792458 m/s

It is now possible to compare the measured values of different quantities *q* (e.g. energies) to the corresponding Planck references using (4). If the number of period-doublings is an integer (n≠0), then period-doubling may be taking place.

4. $$\frac{q}{Planck\ reference} = 2^{\pm n}$$

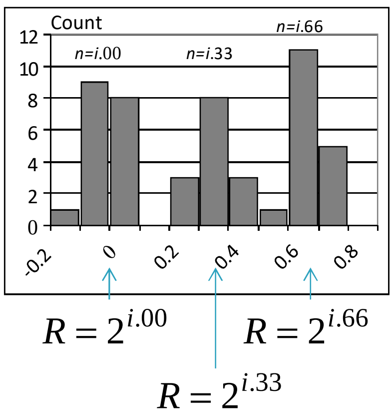


FIGURE 3. Distribution of the decimal parts of *n*.

Figure 3 shows ratios *R* of 49 arbitrarily chosen commensurate quantities including rest energies of the elementary particles, semimajor axes of the orbits of the planets etc. [3] [4]. Of course, the magnitude of the ratio depends on what is compared. It turned out that the majority of the ratios were something else than integer powers of two. However, the decimal part of *n* tells how close the exponent is an integer value (e.g. exponents n=63.98 and n=64.01 are close to integer n=64). The decimal parts seem to form three groups (*i* is the integer part of the exponent, and its value depends on the magnitude of *R* in question):

5. $$R = 2^n = 2^{\frac{integer}{3}} = 2^{\frac{N}{3}} \qquad (N \neq 0)$$

$n=N/3$ means that the 49 calculated ratios are cube roots of an integer power of 2! For the periods, our finding means that

6. $$\tau_N = 2^{\frac{N}{3}} \cdot \tau_o$$

and

7. $$\tau_N{}^3 = 2^N \cdot \tau_o{}^3$$

which means that the *period-space volume* doubles.

Volume means that the 49 systems we analysed have three internal periods or *degrees of freedom* (or dimensions of the period-space).

The degree of freedom means that the three periods are independent and that the number of doublings can be different for each period. The total number of period-doublings is $N=i+j+k$:

8. $$\tau_N{}^3 = \tau_{ijk}{}^3 = 2^N \cdot \tau_o{}^3 = 2^{i+j+k} \cdot \tau_o{}^3$$

The perceived period (9) is given by the cube root of (8)

9. $$\tau_N = \tau_{ijk} = 2^{\frac{i+j+k}{3}} \cdot \tau_o$$

Equation (9) can be converted into other quantities, e.g. energy, as mentioned before. In terms of the perceived energy, equation (9) becomes:

10. $$E_N = E_{ijk} = 2^{-\frac{i+j+k}{3}} \cdot E_o$$

5. Rotation and vibration

Rotation and vibration are well-established phenomena in nuclear, atomic and molecular physics. Even the Earth vibrates, in addition to the rotation, after an earthquake. We assume that rotation and vibration are ubiquitous phenomena and that rotation and vibration can be taken as internal degrees freedom of the system. It was Niels Bohr's idea that a wave can close (or localize) itself into a circle such that the circumference of the circle is an integer multiple of half a wavelength. The structure is called a ring resonator, and the energy levels of a hydrogen atom were explained for the first time. A ring resonator describes energy in rotational motion. The Fabry-Perot interferometer is a linear resonator, where an integer number of half waves are 'trapped' between two parallel mirrors. This type of an interferometer describes energy in linear, or vibrational, motion. It is plausible to assume that the elementary particles have rotational and vibrational energy levels, too. To find out whether this is so, we include a factor of *pi* in our equation (10) for particle rest energy analysis, because the ratio of the circumference of a circle to the diameter is *pi*.

We obtain for one degree of freedom:

11. $$E_n = \underset{\substack{\uparrow \\ \text{rot-vib} \\ \text{indicator}}}{\pi^a} \cdot \underbrace{2^{-n} \cdot E_o}_{\substack{\text{energy defined} \\ \text{by period}}}$$

The possible values of a are: a = -1, 0, 1

The 3d form of (11) becomes:

12. $$E_{ijk}{}^3 = (\pi^{a_i} \cdot 2^{-i}) \cdot (\pi^{a_j} \cdot 2^{-j}) \cdot (\pi^{a_k} \cdot 2^{-k}) \cdot E_o{}^3$$

and the perceived energy is:

13. $$E_{a,N} = \pi^{\frac{a}{3}} \cdot 2^{-\frac{N}{3}} \cdot E_o$$

where $a=a_i+a_j+a_k$ and $N=i+j+k$.

A system with 4-degrees of freedom can be described using the same formalism:

14. $$E_{b,M} = \pi^{\frac{b}{4}} \cdot 2^{-\frac{M}{4}} \cdot E_o$$

6. Why four degrees of freedom?

The natural reference for the elementary charge *e* is the Planck charge q_o:

15. $$q_o = \sqrt{4\pi\varepsilon_o hc}$$

The ratio of the Coulomb energies (proportional to the square of the charges) is

16. $$R = \frac{e^2}{q_o{}^2} = \left(\frac{1.602 \cdot 10^{-19}}{4.701 \cdot 10^{-18}}\right)^2 = 2^{-9.7499} \cong 2^{-\frac{39}{4}} = 2^{-\frac{2^0+2^1+2^2+2^5}{4}}$$

The intrinsic Coulomb energy system of the elementary charge has four degrees of freedom! The fourth root also brings about the +/- polarity for electricity. The system is superstable because *M*=39 is the sum of integer powers of 2 according to the stability rule (2). In the course of time, the Planckian Coulomb energy has halved 39 times in four degrees of freedom before obtaining the present value. The numerical value with *M*=39, given by (16) for the elementary electric charge, deviates from the NIST value by 0.003 % [5].

7. Enough time for the attractors to develop

Suppose an initially 3d+4d=7d system (i.e. mass with charge) has enough time to evolve. The corresponding 3d (mass) and 4d (EM) subharmonics become fully developed independently and the system becomes a combination of the 3d and 4d parts:

17. $$E_{NM} = \underbrace{\pi^{a/3} 2^{-\frac{i+j+k}{3}}}_{\text{3d energy (rot-vib mode and period-doublings)}} \cdot \underbrace{\pi^{b/4} 2^{-\frac{l+m+n+p}{4}} \cdot E_{oo}}_{\text{4d energy (rot-vib mode and period-doublings)}}$$

E_{oo} = 2.64·10^{25} MeV is the generalized Planck energy which takes into account the Planck scale Coulomb energy, and not only the conventional Planck mass-energy E_o=3.05·10^{22} MeV. Therefore, E_{oo} is larger than E_o by q_o^2/e^2.

8. Not enough time for the attractors to develop

For the short-lived elementary particles, there may not be enough time for the attractors of the 3d and 4d parts of the particle structure to fully develop. The period-space volume of the structure can be described by a nonlinear system with 7 degrees of freedom. The energy levels are

18. $$E_N = \pi^{\frac{a}{3}} \cdot \pi^{\frac{b}{4}} \cdot 2^{-\frac{N}{7}} \cdot E_{oo}$$

Equation (18) describes a system, where the 3d and 4d subharmonic periods have not yet developed separately.

The system can be described with three independent phase-spaces, namely:

1. Period-space with 3+4=7 degrees of freedom (mixed mass and EM), observed as $2^{N/7}$
2. 3d rot-vib space observed as $\pi^{a/3}$ (mass-energy system)
3. 4d rot-vib space observed as $\pi^{b/4}$ (EM-energy system)

Reminder: The roots are required to return the phase-space *volume* to the observed scalar values.

9. Analysis of the short-lived particles

Most artificially created elementary particles are extremely short-lived. Their lifetime is on the order of 10^{-23} s to 10^{-19} s. This may be too short a time for the particles to obtain stable 3d and 4d parts (manifested by the wide Breit-Wigner distributions). We, therefore, consider these particles as 3d (mass)+4d (EM)=7 degree of freedom 'flashes' of energy and apply (18) to their rest energies.

The total number N of period-doublings can be solved for from (18) if the particle rest energy E_N is known:

19. $$N = -7 \cdot \frac{\log(E_N / (\pi^n \cdot E_{oo}))}{\log(2)}$$

$n = a/3 + b/4$ is the combined rotation-vibration indicator (or mode).

reference	2,64E+25	MeV	dim.	7	base	2,0	
			(-3,-4)	(-3,-3)	(-2,-4)	(-3,-2)	(-2,-3)
particle	**energy**	**N**	**-2,000**	**-1,750**	**-1,667**	**-1,500**	**-1,417**
Y(11020)	**11019,00**	474	474,02				
Y(2S)	**10023,26**	475	474,98				
	9057,20	476					
	10921,0	477					
Khi b1(1P)	**9892,78**	478		478,00			
Khi b2(1P)	**9912,21**	478		477,98			
Y(10860)	**10865,00**	478			478,02		
Khi bo(1P)	**9859,44**	479			479,00		

Because the rot-vib mode (a,b) is not known a priori, we calculate the N-values for all different modes from n =-2 (a=-3, b=-4) to n=+2 (a=3, b=4) for each particle. Integer N's are coloured and written in a column in downwards growing order.

The following tables show the results of the particle rest energy analyses using (19). Particle rest energies are taken from the Particle Data Group 2014 particle listings.

The period-doubling process organizes the baryons into three groups according to their rotation-vibration mode and the number of period-doublings. The nucleons are at (a,b)=(0,0).

The group names are taken from the Standard Model (SM) of the elementary particles. Otherwise, the concepts and ideas used in the SM do not have any meaning in the period-doubling scenario.

Table 1. Integer N-values for the baryons. The table can be zoomed in for details.

Bottom			Charmed				Strange				Nucleons																					
reference=	2,6E+25	MeV	dim.	7	base	2	(a,b)			(-3,0)			(-3,1)	(1,-4)		(-3,2)	(1,-3)	(2,-4)	(-3,3)	(1,-2)	(2,-3)	(3,-4)	(-2,3)	(-1,2)	(3,-3)	(-2,4)	(-1,3)	(0,2)		(-1,4)	(3,-1)	
			(-2,-4)	(-3,-2)	(-2,-3)	(-1,-4)	(-3,-1)	(-2,-2)	(-1,-3)	(0,-4)	(-2,-1)	(-1,-2)	(0,-3)	(-2,0)	(-1,-1)	(0,-2)	(-2,1)	(-1,0)	(0,-1)	(-2,2)	(-1,1)	(-3,4)	(1,-1)	(2,-2)	(0,1)	(1,0)	(2,-1)	(3,-2)	(1,1)	(2,0)	(0,3)	(1,2)
Particle	E (MeV)	N	-1,667	-1,500	-1,417	-1,333	-1,250	-1,167	-1,083	-1,000	-0,917	-0,833	-0,750	-0,667	-0,583	-0,500	-0,417	-0,333	-0,250	-0,167	-0,083	0,000	0,083	0,167	0,250	0,333	0,417	0,500	0,583	0,667	0,750	0,833
Xi b*	5945,50	487			487,00																											
		488																														
		489																														
		490																														
		491																														
Sigma b*+	5829,00	492								492,01																						
Sigma b*-	5836,40	492								492,00																						
Sigma b+	5807,80	493									493,01																					
Sigmab-	5815,20	493									493,00																					
Xi co	2968,00	494			494,01																											
Xi c+	2971,40	494			494,00																											
Xi b-	5790,50	494										494,01																				
		495																														
		496																														
Lam c+	2939,30	497						497,00																								
		498																														
		499																														
Delta	1232,00	500	500,00																													
Xi c	2645,90	501								499,99																						
Lam	1115,68	501	501,00																													
Lam c+	2628,10	501									501,02	501,98																				
Lam c+	2881,53	502											502,02	502,98																		
Lambda bo	5620,20	502																		502,01												
		503																														
		504																														
Lam c+	2595,40	505													505,00																	
		506																														
Xi -	1321,71	507								507,00																						
Xi c'+	2575,60	507															507,00															
Xi c'o	2577,90	507															507,00															
Sigma-	1197,45	508								508,00																						
Xi o	1314,86	508									508,01																					
Xi co	2819,60	508																	508,02	508,98												
Sigma o	1192,64	509									509,00																					
Xi c+	2816,60	509																		508,99												
Sigma+	1189,37	510										509,99																				
Xi co	3079,90	510																				510,02										
Xi c+	2789,10	511																				511,02										
Xi co	2791,80	511																				511,01										
Xi c+	3077,00	511																					510,99									
		512																														
Omega co	3695,20	513																									512,99					
Sigma c+	2517,50	513																					513,02									
Sigmaco	2518,00	513																					513,01									
Sigma c++	2518,40	513																					513,01									
Lam c+	2286,46	514																					513,99									
Omega co	2765,90	514																							513,99							
		515																														
Lam	1405,10	516																		516,01												
		517																														
Xi -	1535,00	518																					518,01									
Xi co	2470,88	518																										518,02	518,98			
Xi o	1531,80	519																						519,00								
Xi c+	2467,80	519																											519,00			
Sigma -	1387,20	520																						520,00								
Sigma c+	2452,90	520																												520,02	520,98	
Sigmaco	2453,76	520																												520,02	520,98	
Sigma c++	2454,20	520																												520,02	520,98	
Lam	1519,50	521																								521,00						
Omega-	1672,45	521																									521,00					
Omega co	2695,20	521																														521,00
Sigma +	1382,80	521																							520,99							
Sigma o	1383,70	521																							520,99							
Proton	938,27	522																				522,02										
Neutron	939,58	522																				522,01										

10. Experimental baryon rest energies

Table 2. Baryon rest energies (MeV).

	Ome	Xi	Sig	Del	Lam	Nucl
1	1672,5	1314,9	1189,4	1232,0	1115,7	938,3
2	2695,2	1321,7	1192,6		1405,1	939,6
3	2765,9	1531,8	1197,5		1519,5	
4	3695,2	1535,0	1382,8		2286,5	
5		2467,8	1383,7		2595,4	
6		2470,9	1387,2		2628,1	
7		2575,6	2452,9		2881,5	
8		2577,9	2453,8		2939,3	
9		2645,9	2454,2		5620,2	
10		2789,1	2517,5			
11		2791,8	2518,0			
12		2816,6	2518,4			
13		2819,6	5807,8			
14		2968,0	5815,2			
15		2971,4	5829,0			
16		3077,0	5836,4			
17		3079,9				
18		5790,5				
19		5945,5				

Table 2 shows the experimental baryon rest energies. Figure 4 is a scatterplot of Table 2. There seem to be three particle groups, one group little below 6000 MeV, another little below 3000 MeV and the third at around 1500 MeV.

Period-doubling or energy halving can be clearly seen. The energy steps in the doubling/halving process explain why the 'charm' and 'bottom' quarks had to be introduced in the Standard Model.

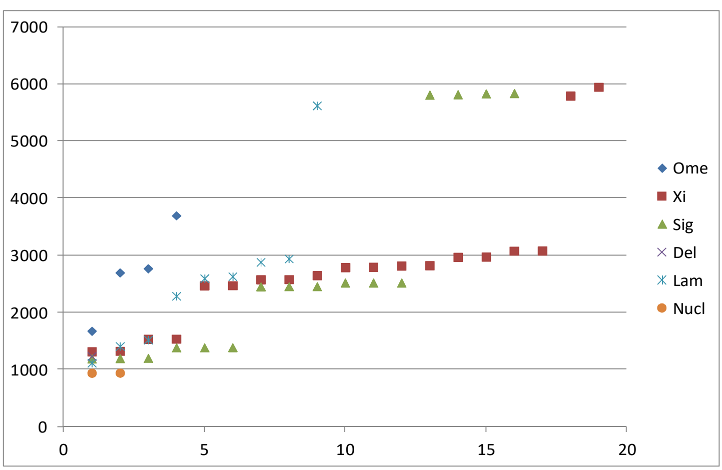


Figure 4. Doubling /halving of the measured rest energy. N can change by ±1 for any degree of freedom, but the mode (a,b) changes correspondingly in such a way that E_N (the total rest energy) obeys the doubling/halving process.

TABLE 3. Integer N-values for the mesons.

Higgs: H — Gauge boson: gb
Charmed: cc, cs, c — Confirmed, not listed yet
Bottom mesons: bb, bc, bs, mix, b
Strange: s
Light unflavoured: ud

particle	energy	N			(-3,-4) -2,000	(-3,-3) -1,750	(-2,-4) -1,667	(-3,-2) -1,500	(-2,-3) -1,417	(-1,-4) -1,333	(-3,-1) -1,250	(-2,-2) -1,167	(-1,-3) -1,083	(0,-4) -1,000	(-2,-1) -0,917	(-1,-2) -0,833	(0,-3) -0,750	(-2,0) -0,667	(-1,-1) -0,583	(0,-2) -0,500	(-2,1) -0,417	(-1,0) -0,333	(0,-1) -0,250	(-2,2) -0,167	(-1,1) -0,083	(0,0) 0,000	(1,-1) 0,083	(2,-2) 0,167	(0,1) 0,250	(1,0) 0,333	(2,-1) 0,417	(3,-2) 0,500	(1,1) 0,583	(2,0) 0,667	(0,3) 0,750	(1,2) 0,833	(2,1) 0,917	(3,0) 1,000	(1,3) 1,083	(2,2) 1,167	(3,1) 1,250	(1,4) 1,333	(2,3) 1,417	(3,2) 1,500	(2,4) 1,667	(3,3) 1,750	(3,4) 2,000
reference	2,64E+25	MeV	dim.	7	base	2,0																																									
Higgs	126600,0	459	H									459,00																																			
Zo	91188,00	471	GB																	470,02	470,98																										
		472																																														
		473																																														
Y(11020)	11019,00	474	BB		474,02																																										
Y(2S)	10023,26	475	BB		474,98																																										
	9057,20	476																																														
	10921,0	477																																														
Khi b1(1P)	9892,78	478	BB			478,00																																									
Khi b2(1P)	9912,21	478	BB			477,98																																									
Y(10860)	10865,00	478	BB				478,02																																								
Khi bo(1P)	9859,44	479	BB				479,00																																								
W+	80399,00	479	GB																										479,00																			
		480																																														
		481																																														
		482																																														
		483																																														
X(10650)	10650,00	484	BB									484,00																																			
X(10610)	10610,00	485	BB										485,00																																		
Y(4S)	10579,40	486	BB											485,99																																	
Khi bo	10539,00	487	BB												487,00																																
B*s	5415,40	487	BS	V				486,98																																							
		488																																														
Z	4430,00	489						489,00																																							
Bos	5366,30	489	BS	PS						488,99																																					
Y(1S)	9460,30	490	BB	V													490,01																														
B*	5325,10	491	B	V								491,00																																			
Y(3S)	10355,20	492	BB																	491,99																											
B*s2(5840)	5839,70	492	BS											491,99																																	
Bs1(5830)	5829,40	492	BS											492,01																																	
Bo	5279,50	493	B	PS										493,01																																	
B+	5279,17	493	B	PS										493,01																																	
X	4361,00	493										493,02	493,98																																		
Khi b2(2P)	10268,65	494	BB																				494,00																									
Khi b1(2P)	10255,46	494	BB																				494,01	494,98																								
Khi bo(2P)	10232,50	495	BB																					495,00																								
B2*(5747)	5743,00	496	B																496,02	496,98																												
B1(5721)	5723,40	497	B																	497,01																												
Bc	6277,00	498	BC	PS																		498,01																										
hc(1P)	3525,42	499	CC														499,02	499,98																													
X(3872)	3871,56	500	CC																500,00																												
X(4260)	4263,00	500	CC																	499,99																											
Ypsilon	4260,00	500																		500,00																											
Ypsilon	4664,00	501																				501,01																										
Khi c1(1P)	3510,66	501	CC																500,99																												
X	4664,00	501	CC																			501,01																										
		502																																														
		503																																														
Khi cx	3467,00	504	CC																			504,00																										
		505																																														
		506																				506																										
f2(2340)	2339,00	507	LU																		507,01	507,98																										
D*s2(2573)	2572,60	507	CS																			507,02	507,98																									
Psi(3770)	3772,92	507	CC																							507,00																						
Psi(4160)	4153,00	507	CC																								507,00																					
Khi co(1P)	3414,75	508	CC																							508,01																						
D*s+	2112,30	509	CS	V																		509,01																										
J/Psi(1S)	3096,92	509	CC	V																						509,00																						
D*so(2317)	2317,80	510	CS																					510,00																								
Do*(2400)	2318,00	510	C																					510,00																								
Ds1(2536)	2535,29	511	CS																							511,02																						
f2(2300)	2297,00	512	LU																							512,01																						
Phio(1710)	1720,00	513	LU																					513,01																								
Rho(1700)	1720,00	513	LU																					513,01																								
Pi2(1880)	1895,00	513	LU																						512,99																							
Psi(2S)	3686,09	513	CC																													513,02	513,98															
K*(1680)	1717,00	514	S																						513,99																							
Psi(4040)	4039,00	515	CC																															514,02	514,98													
K1(1410)	1414,00	515	S																					514,99																								
f1(1285)	1281,80	515	LU																				515,02																									
Psi(4415)	4421,00	516	CC																																		516,00											
Eta'(958)	957,78	517	LU	PS																		516,99																										
Eta c(2S)	3637,00	517	CC																																	517,01												
f2(1270)	1275,10	517	LU																						516,99																							
K1(1270)	1272,00	517	S																						517,02	517,98																						
K1(1400)	1403,00	517	S																							516,99																						
D+	1869,60	517	C																									516,02	516,98																			
Do	1864,80	517	C																										517,01																			
Rho3(1690)	1688,80	518	LU																										518,01																			
K4*(2045)	2045,00	518	S																												518,00																	
Eta c(1S)	2980,30	519	CC	PS																																519,02	519,98											
Phi3(1850)	1854,00	519	LU																												518,99																	
Ds1(2460)	2459,50	520	CS																																519,99													
D2*o(2460)	2462,80	520	C																															519,02	519,98													
D2*+(2460)	2460,10	520	C																																519,99													
Ome(782)	782,65	520	LU	V																			520,00																									
f2'(1525)	1525,00	520	LU																											520,00																		
Phi(1680)	1680,00	520	LU																												519,99																	
Pi2(1670)	1672,40	521	LU																													521,00																
Ome(1650)	1670,00	521	LU																													521,01																
Ome3(1670)	1667,00	522	LU																														522,00															
f4(2050)	2018,00	522	LU																																521,99													
Rho(770)	775,49	522	LU	V																					522,02	522,98																						
Khi c2(1P)	3556,20	523	CC																																							523,01						
D*+(2010)	2010,25	523	C																																	522,99												
Pi1(1600)	1662,00	523	LU																															522,99														
f2(2010)	2011,00	523	LU																																	522,99												
D*o(2007)	2006,96	523	C																																	523,01												
fo(1500)	1505,00	524	LU																															523,99														
a4(2040)	2001,00	524	LU																																		524,00											
D1(2420)	2422,00	524	C																																				524,00									
K2(1820)	1816,00	525	S																																	524,02	524,98											
Pi(1800)	1816,00	525	LU																																		524,98											
Phi(1020)	1019,46	526	LU	V																												526,00																
b1(1235)	1229,50	527	LU																																527,00													
Pi1(1400)	1354,00	527	LU																																	526,99												
Phi(2170)	2175,00	527	LU																																						527,02	527,98						
		528																																						528								
Eta(1475)	1476,00	529	LU																																				529,00									
ao(1450)	1474,00	529	LU																																				529,02									
D+s	1968,47	529	CS	PS																																						528,99						
Eta2(1645)	1617,00	530	LU																																						530,01							
K3*(1780)	1776,00	531	S																																								530,99					
K2(1770)	1773,00	531	S																																								531,01					
Rho(1450)	1465,00	531	LU																																						531,01							
f2(1950)	1944,00	532	LU																																										532,00			
		533																																								533						
a2(1320)	1318,30	534	LU																																								534,00					
K*(892)o	895,94	535	S	V																																				535,01								
K*(892)+	891,66	536	S	V																																					536,02	536,98						
fo (980)	980,00	537	LU																																								536,99					
K2*+(1430)	1425,60	538	S																																													538,03	
K2*o(1430)	1432,40	538	S																																													537,98	
f1(1420)	1426,40	538	LU																																													538,02	
Ko*(1430)	1425,00	538																																														538,03	
Ko	497,61	539	S	PS																																		539,02	539,98									
Eta_o	547,85	539	LU	PS																																			539,01									
Eta(1295)	1294,00	539	LU																																													539,00	
		540																																												540		
K*(1410)	1414,00	541																																															541,00
Eta(1405)	1409,80	541	LU																																														541,03
K+-	493,68	542	S	PS																																					541,99							
		543																																							543							
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		547																																							547							
Pion+	139,57	548	LU	PS																														548,01														
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Pion o	134,98	557	LU	PS																																							557,01					

Period-doubling process organizes the mesons into groups. The W and Z bosons seem to form a group of their own. The Higgs (group?) is in between the Bottom meson group and the W-Z-group.

11. Electron-positron pair

Electron-positron (ep) pair creation is the fundamental process for converting energy into matter. According to the present understanding, these particles are stable over billions of years, which suggests superstability according to the theory of nonlinear dynamical systems. The rest energy of the pair is E_{ep}=1.022 MeV and the Planck (mass) energy E_o =3.060·10^{22} MeV. Taking E_o as the reference energy one finds that the ratio of the energies is

20. $$R = \frac{1.022\ MeV}{3.060 \cdot 10^{22}\ MeV} = 2^{-\frac{N}{3}} = 2^{-74.667} \cong 2^{-\frac{224}{3}}$$

The total number N of period-doublings is very close to 224 divided by 3. $N=i+j+k$ and according to the superstability rule i, j and k should be integer powers of 2. We find that

21. $$224 = i + j + k = 32 + 64 + 128 = 2^5 + 2^6 + 2^7$$

which means that the structure of the electron-positron pair is superstable (otherwise we would not exist as we are).

The superstability of the pair structure means that the electrons and positrons always co-exist. If so, where are the positrons (… the positive elementary charge e.g. in Hydrogen …)?

With N exactly 224 we get:

22. $$E_{ep} = 2^{-\frac{2^5+2^6+2^7}{3}} \cdot E_o = 1.021\, MeV$$

Equation (22) yields the ep-pair rest energy with an inaccuracy of one keV. We can now write down the combined superstable structure of the electron-positron pair:

23. $$E_{ep} = 2^{-\frac{2^5+2^6+2^7}{3}} \cdot 2^{-\frac{2^0+2^1+2^2+2^5}{4}} \cdot E_{oo}$$

Electron magnetic moment

The electron has a very large magnetic moment, and we take a look at that, too. Magnetic moment μ is defined as a current loop $\mu = iA$, where i is the current and A the area. The Planck loop serves as the natural reference, where the loop circumference is the Planck length $l_o = c\tau_o$, and current the elementary charge divided by the Planck time (period). The Planck scale reference magnetic moment $\mu_{o\text{-}orb}$ becomes (proportional to period)

24. $$\mu_{o-orb} = \frac{ec^2\tau_o}{4\pi} = 1.549 \cdot 10^{-46}\ Am^2$$

The ep-pair magnetic moment is $4.643.10^{-24}$ Am^2 (half of electron's μ), and the magnetic moment becomes

25. $$\mu_{ep} = 2^{+\frac{2^5+2^6+2^7}{3}} \cdot \mu_{o-orb}$$

Note the same number of period-doublings as in the ep-pair rest energy! Equations (24) and (25) yield a practically accurate value for the electron magnetic moment (the difference is 0.016 % compared to the NIST value, details in [4]). For the ep-pair every process step halves the energy and doubles the magnetic moment.

12. Proton

For the analysis, we use the previous equation (17), which separates the mass- and EM-energies:

$$E_{NM} = \pi^{a/3} 2^{-\frac{i+j+k}{3}} \cdot \pi^{b/4} 2^{-\frac{l+m+n+p}{4}} \cdot E_{oo}$$

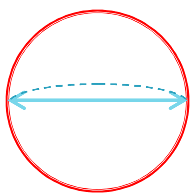
For the ratio R of the energies, one obtains

26. $$R = \frac{938.3\ MeV}{2.64 \cdot 10^{25}\ MeV} = \pi^{-0.5} \cdot 2^{-73.748} \cong \pi^{0/3} 2^{-\frac{192}{3}} \cdot \pi^{-2/4} 2^{-\frac{39}{4}}$$

which can be written in a more illustrative form

27. $$p = 2^{-\frac{192}{3}} \cdot \pi^{-2/4} 2^{-\frac{39}{4}} = \underbrace{2^{-\frac{2^6+2^6+2^6}{3}}}_{\text{3d energy (rot-vib mode and period doublings)}} \cdot \underbrace{\pi^{-2/4}}_{\text{2 vib. modes}} \underbrace{2^{-\frac{2^0+2^1+2^2+2^5}{4}}}_{\text{4d energy (rot-vib mode and period doublings)}} \cdot E_{oo}$$

Proton magnetic moment



$$r_o = \frac{l_o}{4}$$

$$i_o = \frac{e}{\tau_o}$$

The proton has a magnetic moment, too. Because of the two vibrational (or linear) modes in the 4d EM-part we define the reference loop such that the loop diameter is half of the Planck length corresponding to the ground state of a particle in a box. The electric current is the elementary charge divided by the Planck time. The Planck scale reference $\mu_{o\text{-}rad}$ becomes

28. $$\mu_{o-rad} = \frac{\pi}{16} ec^2 \tau_o = 3.8207 \cdot 10^{-46} \ Am^2$$

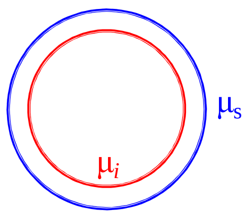
For the nucleon pair, one obtains

29. $$\frac{½\mu_p}{\mu_{o-rad}} = 2^{+64.00} = 2^{2^6}$$

One more period-doubling (N=65) doubles the magnetic moment of the pair for each particle. For the proton, the calculated value of μ_p becomes $1.4096 \cdot 10^{-26}$ Am^2, which differs from the NIST value ($1.4106 \cdot 10^{-26}$ Am^2) by 0.07%.

13. Neutron

Scattering experiments show that the neutron, although neutral, has a charge distribution. The surface is negative, followed by a positive region. The distribution suggests that the magnetic moment μ_n of the neutron can be modelled by two current loops. In the figure μ_s is the magnetic moment of the negative surface current loop and μ_i of the positive inner loop. The measured magnetic moment of the neutron is μ_n= -9.6624·10^{-27} Am^2.



The proton and the neutron sizes are essentially equal, and we simply assume that the magnitude of the magnetic moment caused by the negative surface is the same as the proton's magnetic moment, but of opposite sign. The magnetic moment μ_i of the inner loop is obviously smaller and positive. With these assumptions, we can write

30. $$\mu_n = -\mu_p + \mu_i$$

Equation (30) yields μ_i = 4.438·10^{-27} Am^2, and it belongs to the period-doubling system:

31. $$\frac{\mu_i}{\mu_{o-rad}} = 2^{+63.333}$$

Inserting the calculated μ_i into (30) yields μ_n = -9.662·10^{-27} Am^2 for the neutron, which is practically the same as the measured value. Antiprotons can be artificially manufactured but they are not found in nature. Therefore, some property of the neutron must possess the nucleon 'anti'- property. This analysis suggests that the negative surface magnetic moment of the neutron is the required 'anti'-property fully cancelling the proton magnetic moment. Magnetic binding follows, too.

14. Cosmic microwave background radiation CMBR

For the reference, we take the Planck temperature T_o=3.55·10^{32} K, and we find that

32. $$R = \frac{2.73\,K}{3.55\cdot 10^{32}\ K} = 2^{-106.68} \cong 2^{-\frac{64+128+128}{3}} = 2^{-\frac{2^6+2^7+2^7}{3}}$$

which represents a superstable energy structure (related to the ep-pair by 2^{-32}).

15. Hydrogen 21 cm wavelength radiation

The Hydrogen atom is quite a marvellous thing. Its radius is $5.29\cdot10^{-11}$ m, yet it can radiate 0.211 m wavelength radiation. The atom is far too small to be able to radiate 21 cm wavelength. Tuomo Suntola's Dynamic Universe theory explains this in a natural and simple way [7].

How does 21 cm relate to the Planck length l_o=$4.05\cdot10^{-35}$ m?

33. $$R = \frac{0.211\,m}{4.05\cdot 10^{-35}\ m} = 2^{112.01} \cong 2^{\frac{16+64+256}{3}} = 2^{\frac{2^4+2^6+2^8}{3}}$$

This is again a superstable structure. The 21.1 cm wavelength corresponds to 5.87 μeV, and the relation to the ep-pair is

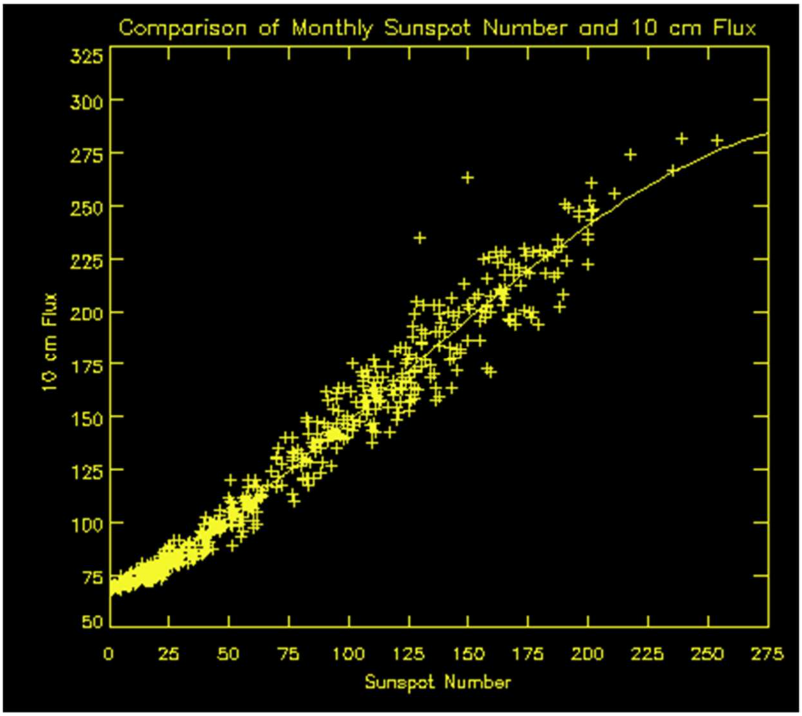
34. $$R = \frac{5.87\,\mu eV}{1.022\ MeV} \cong 2^{-\frac{112}{3}} = 2^{-\frac{16+32+64}{3}} = 2^{-\frac{2^4+2^5+2^6}{3}}$$

which shows that the 21 cm radiation is directly related to the electron-positron pair.

16. The 11-year sunspot cycle

The radio emission from the Sun at a wavelength of 10.7 centimeters (often called "the 10 cm flux") has been found to correlate well with the sunspot number. The radio flux at 10.7 cm can be measured relatively easily and quickly and has replaced the sunspot number as an index of solar activity for many purposes.

Please note that 10.7 cm is half of Hydrogen's 21.1 cm wavelength, suggesting that the sunspot cycle, Hydrogen, and ep-pair are connected.



Picture: http://www.ips.gov.au/Educational/2/2/5

FIGURE 5. The 10 cm solar flux.

17. The Solar system

Equations for the circumference of the orbit and orbital velocity are [3]:

35. $$l_N = 2^{\frac{N}{3}} \cdot l_o$$

36. $$v_M = 2^{-\frac{M}{3}} \cdot c$$

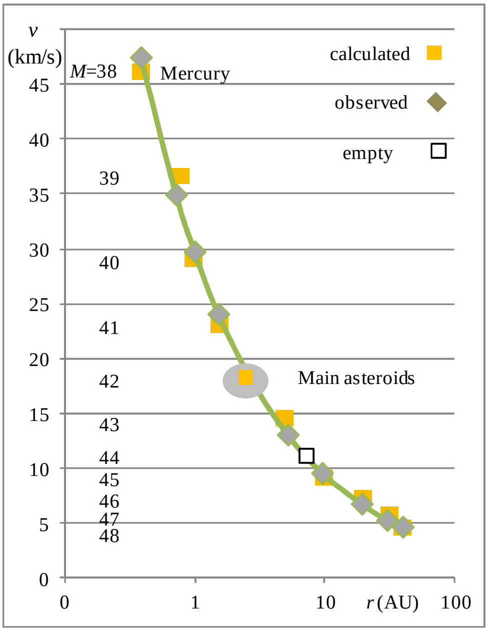


FIGURE 6. The Solar system.

Equations (35) and (36) are universal, since there is no reference to the Sun.

Given enough time, the initial dust and gas accumulate into orbits (=attractors) determined by the period-doubling process.

The orbital velocities of the planets are given by consequent integers M in (36).

'Empty' means an unoccupied allowed orbit. A more detailed analysis has been carried out [4] [6].

18. Quantized galaxy redshifts

W.G. Tifft of the University of Arizona discovered that the redshift difference of galaxy pairs grouped near v=72.5 km/s and v=36.2 km/s if redshift is interpreted as velocity [5,10]. He further noticed that the redshifts of individual galaxies grouped in the same way.

Equation (36) yields

37. $$R = \frac{72.5\ km/s}{3\cdot 10^5\ km/s} = 2^{-12.02} \cong 2^{-\frac{36}{3}}$$

and 36.2 km/s is half of that, which means that galaxies are mass-energy systems with three internal degrees of freedom. The velocity is obtained from the same equation (36), which was used in the analysis of the Solar system pointing to a common (universal) mechanism. In professor

Tifft's opinion, the quantized redshift does not mean quantized recessional velocity [8, 9, 10].

> "How complete and unique is the periodicity pattern? Are there other decay processes and redshift patterns hidden in known data? Three studies have been made to look for power inconsistent with the Lehto-Tifft equations. No deviations have been detected". https://williamtifft.wordpress.com/.

19. Theory for 1/*r* potentials

Both gravitational and Coulomb potentials are 1/*r* nonlinear. It is possible to derive a differential equation in the period-space (τ,r) (not space-time) [4]:

38. $$\frac{d^2r}{d\tau^2} = -\frac{a}{\tau^2}r$$

the solutions of which give the 3d and 4d period-doubling behaviour depending on the value of a (for 3d doubling *a*=46.5 and 4d *a*=82.4).

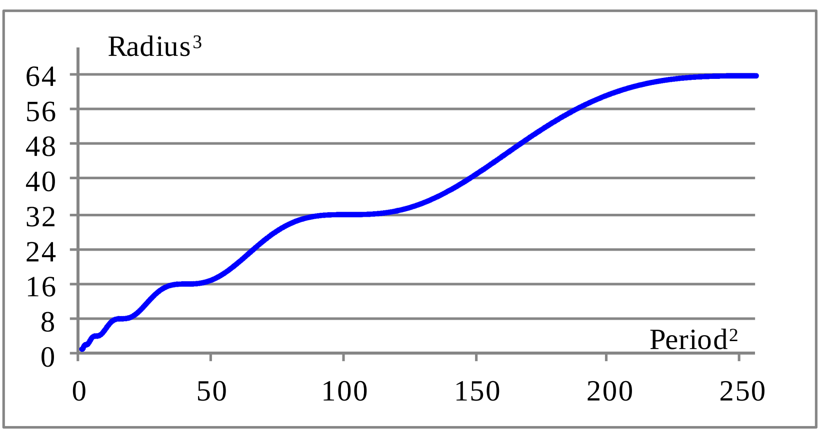
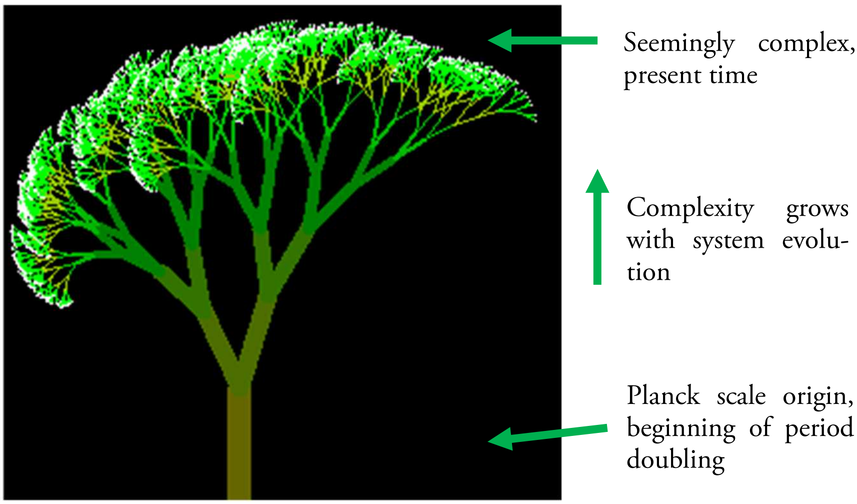


FIGURE 7. Volumetric doubling.



Picture: http://www.learningclojure.com/2010/09/clojure-13-first-impression.html

FIGURE 8. Fractal tree.

20. Complex world – an illusion?

A fractal tree is an example of an object, which seems to be very complex at the top. This is an illusion, however, because the structure of the tree results from repeating the same simple principle. A closer look reveals that the stem and the branches are continuously split into two when going upwards. This phenomenon is called bifurcation, which eventually leads to an apparent chaos. Bifurcation means period-doubling in nonlinear dynamical systems.

21. Discussion

Period-doubling is a general property of nonlinear dynamical systems. It can be rather safely stated that nothing in nature is truly linear, and therefore, it is tempting to analyse different physical systems for discovering the possibly hidden occurrence of the period-doubling phenomenon.

The early study [5] already gave some results pointing to the intrinsic degrees of freedom and related period doubling. However, it was not understood at that time that the mass-energy and electromagnetic energy systems are different and independent. It became later evident that the mass-systems have three intrinsic degrees of freedom (3d), whereas the Coulombic systems possess four degrees of freedom (4d). This explains the unipolar mass and bipolar electricity in a natural way [3] [4].

In the particle analysis, it is convenient to combine the 3d and 4d systems into one equation (17, 18), which also takes the rotational and vibrational modes into account.

The existence of the intrinsic degrees of freedom cannot be directly seen from the observational or experimental data because a measurement returns the geometric mean of e.g. the energy content of each degree of freedom. The great accuracy of the calculated values of the rest mass, elementary charge and the magnetic moments of the electron, proton, and neutron indicates that the period-doubling process is precise even after a large number of period doublings.

The Planck scale values of different physical quantities can be used as reference values. It means that there is a direct connection between the natural constants and the properties of matter.

We can also say that we would not exist without the long term stability of the basic constituents of matter, i.e. electrons and protons. It is not much of a surprise then that the number of period-doublings for the basic constituents and the related phenomena are in accordance with the theoretical stability condition (2).

Our analysis suggests that the proton alone is superstable, not the nucleon pair. It is, therefore, tempting to think that a proton is actually a positron in disguise because the electron-positron pair is superstable. If so, we do not need to search for the possible anti-universes.

What may be surprising is the close relation between the electron-positron pair, the CMBR, the 21 cm Hydrogen line and the sunspot cycle. All belong to the period doubling scheme.

In our scenario, the CMBR is related to the superstable electronic system - not to the 'Big Bang' and the cooling afterglow.

The initial gas and dust cloud around the Sun seems to have undergone period-doubling since the material has accumulated in the corresponding orbits. The orbital velocities of the planets are determined by consequent integers with one exception. There is an allowed unoccupied orbit next to and outside Jupiter's orbit. Figure 6 shows that Jupiter has moved towards the empty orbit as if the missing planet had pulled it there.

If the local group of galaxies is considered as a local energy system, like the Solar system, one would expect to find an energy related period-doubling phenomenon. The redshift quantization seems to be one.

The behaviour of nonlinear dynamical systems is normally analysed using *space-time* coordinates. In this study *space-period* is used instead because we are interested in the structure creation by the period-doubling phenomenon.

A second order differential equation can be derived for $1/r$-nonlinear systems. The solution shows that 3d and 4d period-doubling takes place given proper parameter values in (38).

Finally, we would like to point out that there may be a simple connection between the quark concept in the Standard Model of the elementary particles and the intrinsic degrees of freedom of the particles. Quark = intrinsic degree of freedom, which cannot be taken out of the system.

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NIINILUOTO ILKKA

SCIENCE APPROXIMATES REALITY

[**Abstract**] According to critical scientific realism, an important aim of science is to find true and informative theories which postulate non-observable entities and laws to describe and explain observable phenomena. When such theories are successful, they are truthlike in the sense that they approximate reality. In the case of scientific laws, this notion of truthlikeness or verisimilitude is called legisimilitude. This paper discusses the idea of approximation by showing how the distance of a law statement from the true law can be defined.

ATOCHA ALISEDA

WHAT COUNTS AS A LOGICAL SYSTEM?

[Abstract] As is well known, there are several logical systems as well as cosmological models around, but there is no apparent general framework in either discipline serving as a platform in which to represent and compare existing proposals.
In Logic, the key concept is that of inference, a relationship between a set of premises and a conclusion. But this relation manifests itself in many different ways leaving ample room for a plurality of logical systems, each of which may be characterized by a set of structural rules. These rules state properties of the underlying consequence relationship, but there is no particular set of specific structural rules valid throughout the universe of logical systems. We argue for a schema set of structural rules, with particular instantiations in each logical system. Indeed, we propose this schema set as a demarcation criterion to distinguish those formal systems which are logical from those which are not.
The search of a set of minimal properties for a system to be considered logical may be exported to other areas, such as Cosmology, in which coordinate quantities, such as time and space have several ways of relating to each other depending on the model of the Universe under consideration.
Our view allows to argue for a comprehensive picture of reality, while giving place to a plurality of systems.

1.Introduction

In agreement with the topic of the workshop, our question then was the following one: what makes logical and physical systems comprehensive pictures of reality? We already acknowledged this question is far too ambitious to be fully answered. In this paper, we are rather concerned with an antecedent question, the one giving its title: What counts as a logical system? Once our question is accounted for, we will briefly sketch a transfer to the case of Physics, in particular to Cosmology. Our strategy to address our target question will be as follows.

§2. In this section we shall describe *the problem of demarcation in Logic*, that is, the problem of coming up with criteria to distinguish between logical and non-logical systems. We will first introduce a standard approach in philosophy of logic based on the relationship between informal arguments and their counterparts in formal logic, namely the view endorsed by Susan Haack. Her classification of kinds of logics will be presented, that is, the well-known distinction in the field, amongst extensions and deviations of classical logics, and inductive logics. Moreover, we take up on Haack's discussion on the several positions with respect to the legitimization (and proliferation) of logics, namely *Instrumentalism*, *Monism* and *Pluralism*.

§3. In this section we will introduce a much less-known approach – but still standard – coming from artificial intelligence, namely the logical structural approach devised for the study of non-monotonic logics[1], and in particular for characterizing a notion of inference via its basic repertoire for handling arguments. As we shall see, the structural analysis of a logical inference is a metalevel explication based on structural rules and not on language.

§4. Previous sections set the necessary ground to address our main question: What counts as a logical system? Our answer is given within the structural approach and we identify ourselves with Pluralism. We put forward a demarcation criterion based on a minimal list of structural schema rules that characterize what is to be a logical system.

§5. In this section we shall only sketch a transfer of the motivating question to Physics, in particular as the following one: What counts as a cosmological system?

2. Logic: The Problem of Demarcation

One of the main questions in Logic is the problem of demarcation. This question is at the core of the philosophy of logic, and has a central place in the philosophy of mathematics, in the philosophy of science as well as in the foundations of artificial intelligence.

Some questions in need of an answer for this problem concern the following ones: What counts as a logic?, which is the scope of logic?, which formal systems qualify as logics?, all of these leading to metaphysical questions concerning the notion of correctness of a logical system: Does it make sense to speak of a logical system as correct or incorrect?, could there be several logical systems which are equally correct?, is there just one correct logical system? These questions in turn lead to epistemological questions of the following kind: how does one recognize a truth of logic? could one be mistaken in what one takes to be such truths?

There are however, several proposals and positions in the literature in regard to all these questions. Our overall discussion in this section will serve two purposes. On the one hand, it aims to show that even under a broad view of Logic, there is neither a unique nor a definite answer to the problem of demarcation, not to mention to each of the former questions.

From a logical perspective, mathematical reasoning may be identified with classical, deductive inference. Two aspects are characteristic of this type of reasoning, namely its *certainty* and its *monotonicity*. The first of these is exemplified by the fact that the relationship between premises and conclusion is that of necessity; a conclusion drawn from a set of premises, necessarily follows from them. The second aspect states that conclusions reached via deductive reasoning are non-defeasible. That is, once a theorem has been proved, there is no doubt of its validity regardless of further addition of axioms and theorems to the system. Deductive reasoning has been the paradigm of mathematical reasoning, and its logic is clearly identified with Tarski's notion of logical inference.

In contrast, inductive and abductive types of reasoning are paradigmatic types of reasoning in areas like philosophy of science, and more recently, artificial intelligence. Regarding the former, contemporary research indicates that many questions regarding their logic remain controversial. As is well known, Carnap's proposal for an inductive logic [1] found ample criticisms. As for abduction, while some scholars argue that the process of forming an explanatory hypothesis cannot be logically reconstructed [2,3], and have instead each proposed a logical characterization of explanation[2]; others have tried to formally characterize 'retroduction' (another term for abduction), as a form of inversed deduction [5], but no unique acceptable formulation has been found (See [6] for an overview of research on logical approaches to abductive reasoning). Regarding the latter, recent logico-computational oriented research has focused on studying non-standard forms of reasoning, in order to build computer programs modelling human reasoning, which being subject to revision, is uncertain and exhibits non-standard non-monotonic features. Several contemporary authors propose a more finely structured algorithmic description of logics. This concern is found both in the logical tradition [7,8,9], as well as in work in philosophy (10).

Logics: Extensions, Deviations, Inductive

Haack [11] takes as primitive an intuitive notion of a formal system, and from there it hints at the characterization of what is to be a logical system, as follows:

> "The claim for a formal system to be a logic depends, I think, upon its having an interpretation according to which it can be seen as aspiring to embody canons of valid argument." [11, page 3].

The next problem to face is that of deciding what counts as valid argumentation. But before we get into her own answer to this question, here are other criteria aiming to characterize what counts as a logical system[3]. On the one hand, according to Kneale, logical systems are those that are purely formal, for him, those that are *complete*. According to Dummet, on the other hand, logical systems are those which characterize precise notions. Following the first characterization, many formal systems are left out, such as second order logic. If we follow the second one, then proposals such as Hintikka's system of epistemic logic is left out as well, for the notions of knowledge and belief characterize pretty vague epistemic concepts [11, page 7]. Both these characterizations provide purely formal criteria for logical demarcation. For Haack, however 'the prospects for a well-motivated formal criterion are not very promising'[11, page 7], for it has the drawback of limiting the scope of logic to the point of even discarding well accepted formal systems (e.g. predicate logic) on the basis of being in absence of other metalogical properties (e.g. decidability). Moreover, many logical systems are indeed undecidable, incomplete, but nevertheless have interesting applications and have proved useful in areas like computer science and linguistics.

Haack takes a broad view of Logic, considering that 'the demarcation is not based on any very profound ideas about 'the essential nature of logic'' [11, page 4], and follows 'the benefit of the doubt policy', according to which, arguments may be assessed by different standards of validity, and thus accepts several formal systems as logical. For her, the question we should be asking is whether a system is good and useful rather than 'logical', which after all is not a well-defined concept. Her approach however, is not wholly arbitrary, for it does not give up the requirement of being rigorous, and takes classical logic as its reference point, building up a classification of systems of logic based on analogies to the classical system, as follows:

Extensions (**e**):	Modal, Epistemic, Erotetic, . . .
Deviations (**d**):	Intuitionistic, Quantum, Many-valued, . . .
Inductive (**i**):	Inductive probability logic

Extensions (**e**) are formal logical systems, which extend the system of classical logic (**c**) in three respects: their language (L_c, L_e), axioms (A_c, A_e) and rules (R_c, R_e) of inference ($L_c \subseteq L_e$, $A_c \subseteq A_e$, $R_c \subseteq R_e$). These systems preserve all valid formulas of the classical system, and therefore all previous valid formulas (φ) remain valid as well (For all φ ($\boldsymbol{\Sigma} \models_c \varphi \Rightarrow \boldsymbol{\Sigma} \models_e \varphi$); $\varphi \in L_c$). So, for instance, modal logic extends the classical system by the modal operators of necessity and possibility together with axioms and rules for them.

Deviations (**d**) are formal systems that share the language (L_d) with the language of the system of classical logic (L_c), but that deviate in axioms and rules ($L_c = L_d$, $A_c \neq A_d$, $R_c \neq R_d$). Therefore, some formulae, which are valid in the classical system, are no longer valid in the deviant one (There is a φ such that $(\Sigma \models_c \varphi \wedge \neg (\Sigma \models_d \varphi)$; $\varphi \in L_c$). Such is the case of intuitionistic logic, in which the classical axiom of the excluded middle: $A \vee \neg A$ is no longer valid.

Inductive systems (i) are formal systems that share the language with the system of classical logic ($L_c = L_i$), but in which no formula which is valid by means of the inductive system is valid in the classical one (For all φ, $(\Sigma \models_i \varphi \Rightarrow \neg (\Sigma \models_c \varphi))$; $\varphi \in L_i$). Here the basis is the notion of 'inductive strength', and the idea is that 'an argument is inductively strong if its premises give a certain degree of support, even if less than conclusive support, to its conclusion: if, that is, it is *improbable* that its premises (Σ) should be true and its conclusion (φ) false' (NOT PROB $(\Sigma \wedge \neg \varphi)$) [11, page 17].

In each of these logical systems there is an underlying notion of logical consequence (or of derivability), which settles the validity of an argument within the system. While the first two categories pertain to formal systems that are deductive in nature, the third one concerns inductive ones. But still there may be several characterizations for both deductive and inductive kinds. For example, one deviant system, that of *relevance logic* renders the notion of classical consequence insufficient and asks for more: an argument in relevance logic must meet the requirement that the premises be 'relevant' to its conclusion. As for inductive systems, another way of characterizing them is that for which 'it is improbable, given that the premises (Σ) are true, that the conclusion is false ($\neg\varphi$)' [11, page 17]. We may interpret this statement in terms of conditional probability as follows: (NOT PROB $(\Sigma / \neg\varphi)$). Notice that deductive validity is a limiting case of inductive strength, where the probability of the premises being true and the conclusion false is zero, for the first characterization, and where it is certain that the conclusion is true when the premises are, for this second one.

Overall, under this approach, arguments may be assessed by deductive or inductive standards, and thus there may be deductively valid, inductively strong or neither.

Positions: Instrumentalism, Monism, Pluralism

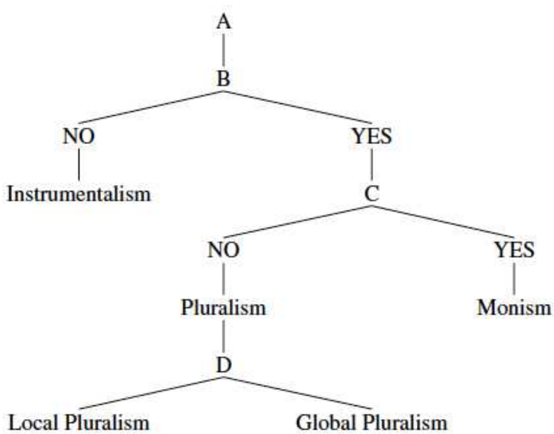
The position taken with respect to the demarcation of logic largely depends upon the answers given to metaphysical questions concerning the notion of correctness of a logical system, which in turn depend on the distinction between system-relative and extra-systematic validity/logical truth. Roughly speaking, a logical system is correct if the formal arguments (and formulae) which are valid (logically true) in that system correspond to informal arguments (statements), which are valid (logically true) in the extra-systematic sense ([11, page 222]). Three positions are characterized by Haack, each of which is characterized by the answers (affirmative or negative) given to the following questions:

A: Does it make sense to speak of a logical system as correct or incorrect?

B: Are there extra-systematic conceptions of validity/logical truth by means of which to characterize what it is for a logic to be correct?

C: Is there one correct system?

D: Must a logical system aspire to global application, i.e. to represent reasoning irrespective of subject-matter, or may a logic be locally correct. i.e. correct within a limited area of discourse?



Thus, on the one hand, the instrumentalist position answers the first two questions negatively. It is based on the idea that the notion of 'correctness' for a system is inappropriate, and that one should rather be asking for its being more fruitful, useful, convenient... etc. than another one. 'An instrumentalist will only allow the 'internal' question, whether a logical system is sound, whether, that is, all and only the theorems/syntactically valid arguments of the system are logically true/valid in the system' [11, page 224]. On the other hand, both the monist and the pluralist answer these questions in the affirmative, the difference being that while the monist recognizes one and only one system of logic, the pluralist accepts a variety of them. Thus, they answer the third question opposite. Note that the distinction in these questions is only relevant for the classical logic vs. deviant logic dichotomy. The reason being that for a monist classical logic and its extensions are fragments of a 'correct system', and for a pluralist classical logic and its extensions are both 'correct'.

Likewise, while for an instrumentalist there are not extra-systematic conceptions of validity/logical truth by means of which to characterize what is to be a logic to be correct, for the monist as well as for the pluralist there are, either in the unitary fashion or in the pluralistic one. A further distinction made by the pluralist concerns the scope of application for a certain logical system. While a global pluralist endorses the view that a logical system must aspire to represent reasoning irrespective of subject-matter, a local pluralist supports the view that a logical system is only locally correct within a limited area of discourse.

The next question to analyse is the position taken by each of these stances with regard to whether deviant logics rival classical logic. In order to answer this question, we have the following diagram:

(i) Formal argument which represents (iii) informal argument	(ii) Valid in L corresponding to (iii)'s being (iv) extra-systematically valid

On the one hand, the monist answers this question in the affirmative and supports the view that (i) aspires to represent (iii) in such a way that (ii) and (iv) do correspond in the 'correct logic'. On the other hand, the local pluralist answers this question in the negative by relativizing (iv) to specific areas of discourse and the global pluralist either fragments the relation between (i) and (iii) (that is, denies that the formal arguments of a deviant system represent the same informal arguments as those of classical logic) or fragments the relationship between (ii) and (iv) (denies that validity in the deviant logic is intended to correspond to extra-systematic validity as that to which validity in classical logic is intended to correspond). Finally, the instrumentalist rejects (iv) altogether.

3. Structural Logical Approach

This type of analysis (started in [12]) was inspired in the works of logical consequence by Tarski [13] and those of natural deduction by Gentzen [14,9]. It describes a style of inference at a very abstract structural level, giving its pure combinatorics beyond its semantics and proof theory. It has proved very successful in artificial intelligence for studying different types of plausible reasoning ([15]), and indeed as a general framework for non-monotonic consequence relations ([16]). The basic idea of logical structural analysis is the following:

> A notion of logical inference can be completely characterized by its basic combinatorial properties, expressed by structural rules.

Structural rules are instructions which tell us, e.g., that a valid inference remains valid when we insert additional premises ('monotonicity'), or that we may safely chain valid inferences ('transitivity' or 'cut'). To understand this perspective in more detail, one must understand how it characterizes classical inference, our point of departure and of reference with respect to other logical systems.

Classical Inference

In what follows we use logical sequents $\Sigma \Rightarrow C$, with a finite sequence of premises to the left (Σ), and one conclusion (C) to the right of the sequent arrow ($\Rightarrow$). While X, Y and Z are finite sets of formulae, A, B and C are a single formula. Each structural rule (except for reflexivity) states one or two sequents above the line and another one below. The former represent the antecedent of the structural rule and the latter the consequent, its conclusion.

The structural rules for classical inference are the following:

Reflexivity: $C \Rightarrow C$

Contraction: $$\frac{X, A, Y, A, Z \Rightarrow C}{X, A, Y, Z \Rightarrow C}$$

Permutation: $$\frac{X, A, B, Y \Rightarrow C}{X, B, A, Y \Rightarrow C}$$

Monotonicity: $$\frac{X, Y \Rightarrow C}{X, A, Y \Rightarrow C}$$

Cut Rule: $$\frac{X, A, Y \Rightarrow C \qquad Z \Rightarrow A}{X, Z, Y \Rightarrow C}$$

These rules state the following properties of classical consequence. Any premise implies itself (reflexivity), deleting repeated premises causes no trouble (contraction); premises may be permuted without altering validity (permutation), adding new information does not invalidate previous conclusions (monotonicity), and premises may be replaced by sequences of premises implying them (cut).

In all, these rules allow us to treat the premises as a mere set of data without further relevant structure. They play an important role in classical logic, and are often referred to as "simple properties of the notion of consequence" in introductory textbooks (17, Page 30). Structural rules are also used extensively in completeness proofs[4].

These rules are structural in that they mention no specific symbols of the logical language. In particular, no connectives or quantifiers are involved. This makes the structural rules different from inference rules like, say, Conjunction of Consequents or Disjunction of Antecedents[5]. Under this approach, Haack's previous classification of extensions of logics is subsumed, for one rule may fit classical logic as well as extensions: propositional, first-order, modal, type-theoretic, etc.

Each rule in the above list reflects a property of the set-theoretic definition of classical consequence [18], which – with some abuse of notation – calls for inclusion of the intersection of the (models for the) premises in the (models for the) conclusion:

$P1, \ldots, Pn \Rightarrow C$ if and only if $P1 \cap \ldots \cap Pn \subseteq C$

Now, in order to prove that a set of structural rules completely characterizes a style of reasoning, representation theorems exist. For classical logic, one version was proved by van Johan Benthem in [19]: *Monotonicity, Contraction, Reflexivity and Cut completely determine the structural properties of classical consequence.* We omit the proof. Note that permutation is not in here, it is a derived rule from monotonicity and contraction.

Non - Classical Inference

For non-classical consequences, classical structural rules may fail. Well-known examples are the ubiquitous 'non-monotonic logics'. These are logics in which the classical monotonicity rule fails, that is, a conclusion may not remain valid when additional premises are added. However, this is not to say that no structural rules hold for them. The point is rather to find appropriate reformulations of classical principles (or even entirely new structural rules) that fit other styles of consequence. For example, many non-monotonic types of inference do satisfy a weaker form of monotonicity. Additions to the premises are allowed only when these premises imply them:

Cautious Monotonicity: $$\frac{X \Rightarrow C \quad X \Rightarrow A}{X, A \Rightarrow C}$$

Examples of non-monotonic inference styles observing weaker forms of classical structural rules are to be found in the area of *dynamic semantics*, where not one but many new notions of dynamic consequences are to be analysed ([20, 21]). They find applications in the modelling of natural language processing, in which the order of premises is essential. But dynamic inference also quarrels with other classical structural rules, such as Cut. But again, representation theorems exist. One dynamic is characterized by the following restricted forms of monotonicity and cut, in which additions and omissions are licensed only to the left side:

Left Monotonicity:
$$\frac{X \Rightarrow C}{A, X \Rightarrow C}$$

Left Cut:
$$\frac{X \Rightarrow C \qquad X, C, Y \Rightarrow D}{X, Y \Rightarrow D}$$

For a broader survey and analysis of dynamic styles, see [18,20]. For sophisticated representation theorems in the broader field of non-classical inference in artificial intelligence see [22,15]. Yet other uses of nonclassical structural rules occur in relevance logic, linear logic, and categorical logics (cf. [21,23]).

Another example of a non-monotonic inference style is enumerative induction, a type of inference that explains a set of observations, and makes a prediction for further ones:

$$\frac{\alpha \Rightarrow \varphi 1 \qquad \alpha \Rightarrow \varphi 2}{\alpha \Rightarrow \varphi 1, \varphi 2}$$

That is, an inductive explanation α for $\varphi 1$ remains an explanation when a formula $\varphi 2$ is added, provided that α also accounts for it separately. Note that this rule is a kind of monotonicity, but this time the increase is on the conclusion set rather than on the premise set. More generally, an inductive explanation α for a set of formulae remains valid for more input data ψ when it explains it (Θ represents the background theory):

(Inductive) Monotonicity on Observations

$$\frac{\Theta \mid \alpha \Rightarrow \varphi 1, \ldots, \varphi n \qquad \Theta \mid \alpha \Rightarrow \psi}{\Theta \mid \alpha \Rightarrow \varphi 1, \ldots, \varphi n, \psi}$$

In order to put forward a set of rules characterizing inductive explanation, a further analysis of its properties should be made, and this falls beyond the scope of this paper. What we anticipate however, is that a study of enumerative induction from a structural point of view will bring yet another twist to the standard structural analysis, that of giving an account of changes in conclusions (for a structural characterization of abductive inference, see [24]).

Characterizing a notion of inference such as dynamic or inductive, determines its basic repertoire for handling arguments. Although this does not provide a more ambitious semantics, or even a full proof theory, it can at least provide valuable hints. The suggestive Gentzen style format of the structural rules turns into a sequent calculus, if appropriately extended with introduction rules for connectives[6].

The structural analysis of a logical inference is a metalevel explication based on structural rules and not on language, as it does not take into account logical connectives or constants, and in this respect differs from Haack's approach. But we are with Haack in the search for an answer to our main motivational question, namely: What counts as a logical system? And this is the subject of the following section.

4. What counts as a Logical System?

In this section we tackle the question of its title: what counts as a logical system? We anticipate that our answer will be given within the structural approach and that our position is that of a global pluralist. But we shall start by addressing the following question: are non-classical inferences, really l*ogical*?

In spite of the structural approach we have presented, some readers may still doubt whether non-standard inference types, such as dynamic or inductive, can be considered really *logical*, perhaps it is more appropriate to render them as a special types of reasoning. After all, by accepting them as logical we are accepting systems that only produce tentative conclusions and not certainties as is the case for classical reasoning.

The answer to the question of whether non-classical inferences are really logical concerns a terminological question of what we want to denote by the term *Logic*. Although structural analysis of consequence has proved very fruitful and has even been proposed as a distinguished enterprise of *Substructural Logics* [14,9,25], many logicians remain doubtful, and withhold the status of bona fide 'logical inference' to the products of non-standard styles.

This situation is somewhat reminiscent of the emergence of non-euclidean geometries in the nineteenth century. Euclidean geometry was thought of as the one and only geometry until the fifth postulate (the parallel axiom) was rejected, giving rise to new geometries. Most prominently, the one by Lobachevsky, which admits of more than one parallel, and the one by Riemann admitting none. The legitimacy of these geometries was initially doubted but their impact gradually emerged. Indeed, the analogy with Logic can be carried even further, as these new geometries were sometimes labeled 'meta-geometries'.

Whether non-classical modes of reasoning are really logical is like asking if non-euclidean geometries are really geometries. The issue is largely terminological, and we might decide – as Quine did on another occasion (cf. [26])– to *just* give conservatives the word 'logic' for the more narrowly described variety, using the word 'reasoning' or some other suitable substitute for the wider brands.

In any case, an analysis in terms of structural rules does help us to bring into light interesting features of many styles of logical inferences, logical or not. Indeed, our proposal is to use this approach to come up with a demarcation criterion, one to help us distinguish those systems that are to be considered as logical from those which have no place in our pluralistic universe. After all, we do not want to call any formal system, *logical*. In the first place, we require a logical system to be useful, which we interpret as reflecting some mode of "human reasoning", but at the same time, we require a logical structure, that is, some set of logical properties.

To be sure, we answer Haack's question: does it make sense to speak of a logical system as correct or incorrect? In the affirmative and look for a defining logical structure – in terms of structural rules – of what the correctness of a system is.

Going back to our analogy in Geometry, in our context, it is not geometry but styles of reasoning that occupy the space, and there is not one postulate under critical scrutiny, but several. Rejecting monotonicity gives rise to the family of non-monotonic logics, and rejecting permutation leads to styles of dynamic inference. Linear logics, on the other hand, emerge by rejecting contraction. All these alternative logics might get their empirical vindication, too – as reflecting different *modes* of human reasoning.

In this respect, we are answering in the negative one of Haack's questions, namely, Is there one correct system? And by so doing, we are embracing Pluralism. Let's now state our position within the structural approach.

While it is clear there is no set of structural rules that apply throughout all logical systems[7], we put forward a criterion of demarcation based on a minimal list of structural schema rules which characterize logical formal systems. Elsewhere (in [27]) I have suggested that for a formal system to be considered as a logical one, it must have a safe way to preserve inference validity when we insert additional premises, it must somehow allow to safely chain inferences and it must also have the capacity of auto-reflection. In our language of structural rules, it must have some forms of monotonicity, cut and reflexivity. Of course, these forms need not be the same ones as those for classical logic.

This view allows to argue for a pluralistic picture, reflecting there are indeed several modes of reasoning, giving place to a plurality of logical systems.

5. What counts as a Cosmological System?

In this section I shall briefly explore the translation into Physics of the motivating question of this paper, that is, what counts as a cosmological system? I shall spell out this question pointing out some of its essential elements, but then I leave the search for a framework in which to an answer this question to philosophers of Cosmology and to physicists themselves. Before I tackle the question, however, I shall state those assumptions and guiding principles to follow in the making of our proposal, as well as the antecedent of this discussion, the one that took place at the Workshop.

The first one of these concerns is our commitment to Pluralism. Just as in the case of Logic, we acknowledge there is a diversity of cosmological models, each one serving its own purpose, and altogether offering a multiplicity of views on certain phenomena. Questions such as the origin of the universe and of its very geometry and dynamics are examples of these phenomena[8]. Answers to these cosmological questions, are to a large extent, speculative, in which no empirical test can be performed. In Prof. Narlikar´s own words: "*The studies of the very early universe are highly speculative both in terms of astronomy and particle physics*" ([28], page 29). Prof. Narlikar goes even further as to question the scientific status of Cosmology:

> Although remarkable strides have been made both in theory and experiment in physics, and telescopes of various kinds have enlarged man's capacity to observe the universe, by the normal criteria of close interaction between theory and observation, cosmology, as it is practised today, has far too large a speculative element to qualify for the title of a scientific discipline. ([28], page 9).

In other interpretations, the lack of empirical facts calls for the anticipation of "*some prior knowledge on the global structure of space time, which may be validated subsequently*" ([29], page 254).

This claim resembles our own for the case of Logic, in which we argued for a multiplicity of logical systems, each one corresponding to a style of reasoning. The difference however, is that presumably, there is a single cosmological *true* model, we just do not know which one it is. An evaluation criterion, the economy principle, is used to single out the best theory, as applied to the case of the dynamic universe vs. general relativity (see article by Avril Styrman [30], page 65 this volume).

To be sure, we are committed to Pluralism – as far as the *explanatory* aspect of cosmological models is concerned. We acknowledge there are several cosmological models that account for phenomena of the universe. However, on the one hand, perhaps not all of them should count as cosmological proper systems and on the other hand, amongst those that pass commonly accepted tests, there is in principle no privileged one, but all should enjoy the same epistemological status until some novel test comes in favouring (or refuting) any one of them[9].

Let's now move into the discussion that took place at the Workshop. The approach of what counts as a logical system was given along the lines of sections 3 and 4 of this paper, and then we went directly into the question of whether there are universally valid principles in Physics and analysed it for the principle of energy conservation. As it turns out, this principle appears not to be valid in an infinite system, which draws the unwanted conclusion that the laws of classical mechanics entail neither energy conservation nor determinism. We followed the view of Atkinson and Johnson [31], one in which rather than drawing the above conclusion, one should state the following: "mechanics does not make sense in (actual) infinite environments". In other words, the point is rather to describe under what conditions and settings does classical mechanics make sense, and this is found in the finite or with potential infinites, a theoretical condition that allows the study of the behaviour of a system when it grows unbounded, but that does not commit to the view that the system is indeed infinite. This is analogous to our discussion in the case of Logic, which we now rephrase as follows: the issue is not so much to speak of nonmonotonic logics, but rather to characterize logical systems according to the particular form of mononicity they observe, that is, to their own way of validating conclusions when information is added.

We are concerned with the question of what counts as a cosmological system; an answer involves a demarcation criterion. In order to better appreciate this question, let us first recapitulate what we did for Logic, and only then transfer the analysis into Cosmology. First of all, we singled out an essential concept of what is Logic about, and this was, without doubt, the very notion of inference, an argument representing the relationship between premises and a conclusion, telling "what follows from what else", and then presented properties of the notion of inference from a structural approach, together with the suggestion that for an inferential notion to be counted as a logical system, it must exhibit valid ways to guarantee the validity of the conclusion when information is added (monotonicity), a way to chain arguments, in order to help build "what follows from what", that is, a form of transitivity or cut and finally, a mathematical property present in many structures, the capacity of auto-reflection, of stating explicitly under what conditions some information implies itself.

In the case of Cosmology, and indeed in Physics in general, some essential concepts are the following: time, space, matter, energy and radiation, together with laws, principles and constants relating them. As for a distinctive physical notion, any cosmological system has to account for the structure and dynamics of time and space as well as with a defined relationship between mass and energy. Once the characterizing relationship has been singled out (the one analogous to inference), the next thing would be to identify the reference system (the one analogous to classical logic), and then discuss whether it makes sense to speak of extensions or deviations from the reference system. Additionally, some analogue to structural rules may be put forward and ideally, a suggestion in terms of a set of schema rules (or laws, principles, constants), each one being a particular instantiation in a system and part of a demarcation criterion distinguishing appropriate models for Cosmology.

Of course, we cannot expect that what we did for Logic will work for Cosmology in a straightforward way, but hopefully, an analysis of the kind we have carried out, will prove useful as a point of departure to design a general framework in which to analyse and compare cosmological models. At the very least, it would allow scientists from opposing theories to interact with each other.

NOTES

1 Roughly speaking, a consequence relation is monotonic if the conclusion remains valid when additional premises are added. Such is the case of classical logic. Non-monotonic logics fail this rule; their valid consequences are no longer guaranteed when additional premises are added. (Cf. section 3 for a formal definition and further details)

2 As for the roots and similarities of these two models of explanation, Niiniluoto [4, page. 140] rightly observes: "After Hempel's (1942) paper about the deductive–nomological pattern of historical explanation, Karl Popper complained that Hempel had only reproduced his theory of causal explanation, originally presented in 'Logik der Forschung' (1935, see Popper 1945, chap 25, n. 7; Popper 1957, p. 144). With his charming politeness, Hempel pointed out that his account of D–N explanation is 'by no means novel' but 'merely summarizes and states explicitly some fundamental points which have been recognized by many scientists and methodologists".

3 Under a standard approach in Logic, a logical system L is characterized by a semantics and a proof theory. The latter characterizes what is a proof, via the notion of derivation, as follows: "If $\Sigma \cup\{\varphi\}$is a set of formulas in L, we say that φ is deduced from Σ, denoted by $\Sigma \vdash S\ \varphi$, if and only if there is a formal derivation of the conclusion (φ) from its premisses (Σ), that is, a list of n formulae $\varphi 1,\ldots,\varphi n$ such that $\varphi n = \varphi$ and for every i, ($1 \leq i \leq n$), either φi is an axiom or a premise of L or it is obtained by an application of an inference rule of the axiomatic system L".

A semantics for a logical system L concerns the notion of logical consequence and uses instead models and their satisfiability to characterize what is to be true in the system: "If $\Sigma \cup\{\varphi\}$is a set of formulas in L, we say that φ is a logical consequence of Σ, denoted by $\Sigma \models \varphi$, if and only if all models of the premises (Σ) are models of the conclusion (φ)". An equivalent formulation is the following: $\Sigma \models \varphi$ if and only if $\Sigma \cup\{ \neg\varphi\}$ is not satisfiable (it does not have a model).

These two approaches, the semantic and the proof-theoretic one turn out to be equivalent in some logical systems such as classical logic. This equivalence is proven via two meta-theorems which state the following: Soundness theorem: "Every formal derivation is a logical consequence (all theorems are valid truths)" and Completeness theorem: "Every logical consequence has a formal derivation (all universal valid formula are theorems)"

4 As noted in [Gro95, page46]: "In the Henkin construction for first-order logic, or propositional modal logic, the notion of maximal consistent set plays a major part, but it needs the classical structural rules. For example, Permutation, Contraction and Expansion enable you to think of the premises of an argument as a set; Reflexivity is needed to show that for maximal consistent sets, membership and derivability coincide."

5 The following are inference rules for the conjunction of consequents and the disjunction of antecedents, each of them fixing the meaning of conjunction (&) and of disjunction (v):

$$\frac{X \Rightarrow C \qquad X \Rightarrow A}{X \Rightarrow C \,\&\, A}\ \&$$

$$\frac{X \Rightarrow C \qquad Y \Rightarrow C}{X \vee Y \Rightarrow C}\ \vee$$

6 This extension implies a reformulation of the representation theorem into a completeness theorem, for a logical language without operators (recall that structural rules are pure, they have no connectives). Instead, to obtain a full logic, it requires the extension of the logical language, as to include axioms and operators in order to formulate rules with connectives and so construct adequate logical calculi. This way to proceed, which is to obtain a syntax out of a structural characterization, has been explored with success for logical systems such as dynamic, relevance and categorical [18].

7 It is well known that not even cautious monotonicity or any form of reflexivity is valid throughout all logical systems. For an in-depth discussion of the failed search of universal structural rules, see [23,27].

8 For a brief history of Cosmology, see article by prof. Narlikar [28], this volume.

9 However, as noted by Avril Styrman (personal communication): "They should be refutable by tests, but as the case with dark energy proves, when the model does not match perceptions, it is complemented by metaphysical parameters. In effect, its relative simplicity decreases. This is one reason why economy is important."

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QUANTUM PHYSICS AT THE CROSSROADS OF PHILOSOPHY, MATHEMATICS, AND NATURAL SCIENCES

[**Abstract**] The purpose of the talk is to place Quantum Physics in the context of other pursuits of human knowledge and to show how and why it occupies a central place among them. The ideas and theories in Quantum Physics have been influenced by other areas of research, and vice versa, advances in Quantum Physics, both theoretical and experimental, have provided new insights into those other fields. Thus, Quantum Physics appears as a very rich and diverse, perhaps even confusing, area of research. It is a property of nature that things are this way, not a man-made choice. However, this exceptional diversity provides also a justification for using many different and seemingly unconnected approaches and strategies for research in Modern Physics, from Mathematical Logic, to giant accelerators and space missions.

Quantum Physics occupies an unquestionable position in the context of Physics in general. Modern physics stands firmly on three legs: Quantum Physics, Statistical Physics, and Relativistic Physics. All these three are connected to some 'constants of nature', and each one of them through the concept of energy ($E=hf$, $E=\frac{1}{2}kT$, $E=mc^2$). Other fundamental constants of nature (e, G, ...) also appear in Physics, and it is incumbent to try to understand their possible connections and interconnections, even by playing with numbers, or experimenting with very simple and crazy-looking ideas. This approach may be dismissed as too cheap, or too easy, or even as numerology, but it may also give us cost-effective shortcuts into some of the great unsolved mysteries in modern physics.

The diverse and multifaceted nature of Modern Physics should encourage us to try to see different approaches as not necessarily contradictory, but rather as possibly mutually compatible intellectual incursions into a single reality, albeit a very diverse and complex reality.

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