Dimensions of the Universe – III

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Fundamental Questions – III

In two previous documents [1][2] we considered:

- the definition and measurement of event separation, and
- the rest-mass of photons.

We suggested, in those documents:

- an image of dimensionality in which universal expansion might affect perception of the speed of light,
- the possible multi-dimensionality of time,
- that light-speed may be altering over time (though this is not essential for the other items under consideration),
- that photons have a small (non-zero) rest mass,
- that the universal mass of photons may contribute to the magnitude and direction of the perceived universal expansion,
- that the refractive index of no part of the universe is as small as exactly 1, because there is nowhere a perfect vacuum,
- that light travels at varying speeds (dependant upon the local refractive index) even in interplanetary, interstellar and inter-galactic space – but never does light travel at Einstein's *c* (the upper limit speed).

In this document we consider our perception of the speed of light over time. This involves examining the definitions of the fundamental measurement units and the effect (if any) upon each of them of universal expansion. We also examine the perceived values of Hubble's Constant, and explore both why it is difficult to measure, and also whether it is truly constant – or depends upon the separation of events.

Constancy of Light-Speed

Metre Length

By the SI/BIPM definition of the metre [3] there can be no change in light-speed over time, as the metre (the unit of measure of length) is defined in terms of that speed. For the purposes of this document I am going to consider three alternative definitions of the metre – but I shall always make it clear to which one I am referring. If in doubt, it is to the SI/BIPM that reference is being made. I sometimes call this "Metre I" in what follows.

The two other descriptions of the metre are in terms of marks made upon physical bars. The first is a pair of marks made upon an imaginary platinum-iridium iridium bar. This bar is made of ordinary matter, and insofar as it is possible, it takes part in the universal expansion. I sometimes call this "Metre II" in what follows.

The second is a similar pair of marks made upon a bar of "unobtainium". This mythical substance is not ordinary matter – and, indeed, cannot be obtained (hence its name). This matter does not take

1 Contactable at idkk@idkk.com All the errors are my own.

part in the universal expansion, in any way. I sometimes call this “Metre III” in what follows.

Part of the consideration of this document is to look at how these three definitions/descriptions of the metre vary with respect to each other – if at all – over long periods of time.

Length of a Second

This is an SI base unit, and according to SI/BIPM “The second is the duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom” and “This definition refers to a caesium atom at rest at a temperature of 0 K”. [4][5] I sometimes call this “Second I” in what follows.

This depends upon a particular property of atomic physics. This may or may not be affected over time by slow changes in the universe: the SI definition, and the general use of that definition, assumes that no such slow change takes place.

The older definition, as “1/86400 of a mean Solar day” is of no use, when projecting the measurement (or consideration) of time onto distant events.

I am also going to consider in this document – but only for purposes of illustration – an alternative definition of a second. This alternative second is measured by a clock (perhaps also made of “unobtainium”) which for a local observer, at all times and places within the universe, marks out seconds which match the current SI definition of a second. I sometimes call this “Second II” in what follows.

Another part of the considerations in this document is whether this alternative description of the second makes a detectable difference when looking at parts of the universe very distant in time and/or space from “here and now” (at rest, upon the surface of the Earth, in 2015).

Universal Expansion

We know that the universe is expanding. There is a red shift visible in most distant objects, with the degree of shift increasing with increasing distance. It is over-simplistic to assume that there is a simple distance-shift relationship – there is a lot of astrophysical work taking place to find out the true nature (and value) of this relationship. The rate of separation with respect to distance is indicated by Hubble’s Constant. We can, for the sake of this document, take the value of Hubble’s Constant to be currently 70 km/s per Mpc [12] – that is 1 m /s /3.0856E22m [4] or about 2.268E-18 m/s/m (metres per second per metre). This value of Hubble’s Constant is known to be rather inaccurate, and better determining its value is one of the ongoing lines of research within astrophysics. From this known lack of precision, any calculations made on its basis are, inevitably, themselves imprecise.

It is normally stated that objects which are not locally bound to each other will be separating at a speed that us related to their observed distance apart (observed by an observer on one of those objects). I would like to consider the “not locally bound to each other” part of that description, and explore what the universe might look like were that part of the description relaxed or even removed.

The three cases to be considered here are firstly the usual current description of expansion – I shall sometimes call this “Expansion I” in what follows.

The second case is that of making a relationship between distance and expansion which affects the rate of expansion. The limit of this relationship is for locally bound objects, where the rate of expansion falls to zero. In this context “locally bound” means bound by something other than just gravitational force. I shall sometimes call this “Expansion II” in what follows. In this case Hubble's

Constant is not a constant at all places and times, but at any one time varies according to the distance apart of the events.

The third case is that of allowing universal expansion to take places at all distances – including sub-atomic distances – so that even bound systems expand. Intuitively the rate of expansion for a small bound system is likely to be so small that it would very difficult to observe, and for practical purposes we could usually consider it to be zero – but it is not zero (in this hypothetical case). I sometimes call this “Expansion III” in what follows. In this case Hubble's Constant is, indeed, at any one time constant – though it may, perhaps, vary over long time periods.

Cases under Consideration

From the above we have a number of cases to consider, most of which do not match the standard model. Because we believe the early development of the universe to have been in detectably different phases, I am restricting my considerations here just to the latest phase: I shall not be considering the Inflation or Dark Ages – but only the phase of the universe from the formation of the first stars onward. [6] For each case considered I shall examine the effect upon the perceived speed of light over long time periods. In this I shall be including, as an option, the suggested limits on precision discussed in [2].

The cases concerning length measurement are:

- Metres I and II and III are always identical
- Metres I and II are always identical, but Metre III appears to shrink in relation to them
- Metres II and III shrink at the same rate with respect to Metre I
- Metre II shrinks with respect to Metre I and Metre III shrinks with respect to Metre II.

The cases concerning time measurement are:

- Both clocks are always locally identical – Second I is always the same as Second II
- Second II shrinks with respect to Second I
- Second II expands with respect to Second I.

Each of these twelve possibilities could be considered with each of the three suggested types of expansion, making 36 cases in all. In fact we shall edit most of these cases out as being internally incompatible.

Unit Stability

Length Stability

The SI/BIPM definition of the metre depends upon both the speed of light[2] (to define the distance), and the vibration of the caesium atom (to define the time over which the light-movement is measured or considered). We believe that there were some periods, in the early stages of the universe, when neither light nor caesium atoms existed – but we believe we can (and we do) still project back our 2015 unit definitions to 13.7 giga-years ago – back to when there was (according to our current theories) no light.

It must always be remembered that our current definition of the metre is related to current observations light-speed, and the results of these observations are projected both back and forwards in time in our computations.

2[17] “the length of the path travelled by light in vacuum during a time interval of 1/299,792,458 of a second”.

If it turns out that over long periods light-speed varies (an heretical viewpoint!) then we will have to produce an alternative length definition: the projections of the current length unit would not be viable.

Time Stability

The SI definition of time depends just upon the oscillation of the caesium atom[3]. We assume in our calculations that this definition of the second may also be projected both back and forward in time – back to when there were, for example, no caesium atoms. We also have to assume that this rate of vibration does not directly depend upon light-speed, for if it did we would have a circular pair of definitions (the metre depends upon the speed of light and the second; the second depends upon the caesium vibration; the caesium vibration depends upon the speed of light...), and that would mean (ultimately) that we have a watertight definition for neither the second nor the metre. In this respect – and, I think, only in this respect, the older definitions of metre and second are more usable.

The definition of time also refers to measurements made at 0º K. This is a temperature we have never actually reached, and the definition itself projects back to that temperature the results of measurements made at higher temperatures. Granted, not much higher – but not the temperature contained in the official definition of the second. We have managed to cool an object to 0.004º K [18] – or possibly one nano-Kelvin [19], or even 100 pK [20] – but not used that temperature to measure the vibration of caesium [21][4]. See also [24][25][26][27][28][29][31].

Stability of Physical Parameters

As well as abstract parameters (such as the definition of a second), we have physical parameters that we need to examine. Each of these is, currently, assumed to be invariant, or nearly invariant, in the real universe:

- Stability of light-speed (under the conditions used by the SI definition)
- Stability of Caesium atom vibration rate (under the conditions used by the SI definition)
- Stability of fundamental particle mass (and other properties, such as spin, charge, *etc.*)
- Stability of Hubble's Constant

Any alteration, over long periods of time, of any of these values has a large effect upon our theoretical understanding of the structure of the universe.

Let us examine each of these;

Stability of Light-Speed

We have already had a first look at this (see page 1 above), and we know that its evaluation depends upon our definition of a second and our definition of a metre. If the definition of the metre is in terms of light-speed then it cannot (by theory) change. But if the definition of the metre is related not to light-speed but to some external measure (e.g. two marks on a platinum-iridium bar in Paris), then we can ask about change in light-speed. Similarly, we have to be sure that our definition of a second does not depend upon light-speed (see page 4 above).

We have suggested in previous publications [1][2] that real, actual light-speed in the most complete

3"The second is the duration of 9192631770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the caesium 133 atom" and "This definition refers to a caesium atom at rest at a temperature of 0º K". [4][5][17]

4The NIST-F2 clock uses the temperature of about 157.7º K [22] vacuum that we can actually achieve is less than Einstein's *c* – not by a large amount, but less. This allows the photon to have rest mass (even though it is heretical to state that photons can be at rest). I have suggested that this difference is less than 5 parts in E21; other suggestions (by other writers [32]) have suggested 4 parts in E23.

By "the vacuum we can actually achieve" I mean the most complete vacuum experienced anywhere in the universe. This vacuum may, notionally, be even more rarified than one atomic particle per cubic kilometre – indeed, I would be happy to consider as hard a vacuum as one particle in a thousand cubic kilometres. Less than that, though, I suspect occurs nowhere in the real universe.

I also suspect (without any experimental proof) that no harder vacuum *can* exist. I believe (again, without any experimental proof) that there are no "dark" parts of the real universe. That is, there is no cube, 10 kilometres on each side, that contains <u>no</u> atomic particle, and <u>no</u> photons. Photons are (under my suggested analysis) particles with mass – and hence effect the hardness of a vacuum.

This is, of course, all hypothetical. It may be that there are harder vacuums; it may be that there are dark parts of the universe. If there are, then the main substance of my argument falls down.

Stability of Caesium Vibration Rate

We have measured the oscillation of caesium atoms over a range of temperatures. We know that these oscillations vary in rate with the temperature, and we have projected down to 0º K the rate of one particular vibration. We detect this vibration, in the atomic clocks, by looking at radiation – counting the atoms that have changed state in a particular microwave environment. The microwaves used to trigger the specific state-change from which the second is defined have a particular frequency, close to the 9.2 GHz transition frequency [29]. Granted, this microwave frequency is a *trigger* for the hyperfine transitions which define the second: it is not the second itself. But in some sense we already need a definition of the second – albeit at a lower precision – before we can create the microwaves of this trigger frequency.

So far, this is only a philosophical, not a practical problem.

But are we sure, certain, that this transition frequency is independent of light-speed? I, personally, do not know what this transition actually is – I am wholly ignorant of this part of engineering, and I would welcome instruction on this.

Stability of Fundamental Particle Mass

The elementary particles of the atom have certain properties: mass, charge, spin. We have tabulated these properties – some if which we know well, and some only approximately – and from these properties we estimate the behaviour of these particles, in their interactions, one with another, and in their unprompted state-changes. As atomic theory develops, the identification of exactly which particles are fundamental, and which are composite, changes. There is, currently, the belief that most particles can be expressed in terms of (invisible) more-fundamental quarks.

There are a lot of particles that we have so far found, and more whose existence is speculated upon. There are disputes as to what, precisely, should be defined as a particle, and what as a resonance, and what as an accidental, temporary collision and adhesion of more fundamental particles. There has been discussion about which particles are elementary, and in our analysis as to how far down we have to go – below the proton is the quark (for example): what is below the quark, and below that? (For an example subset, see table on page 11).

These are a complex set of properties – and there are many more. It seems as though there is no – or very little – pattern. But we know that is not the case: there is the Eightfold Way [63][64][65], there are Lie Groups [66], the meson octet, the baryon decuplet, the baryon octet, and so on. There is Dark Matter, and its relationship to supersymmetry [67][69][71][73] (this, by the way, affects the theoretical mass of neutrinos, which are now known to not have zero mass, but very small mass – at least 1E5 times smaller than the mass of an electron). There is an attempt at bringing coherence through String Theory [68][70], there is representation theory [72], there is even Unparticle Physics [74].

The raw pattern of particles seems reasonable: the pattern of masses, though, is, at first, totally opaque. Although the Riemannian Zeta function has nothing to do with this, the spread of masses is a bit like the distribution of imaginary parts of the zeros of the zeta function [75][76], or the plot of the derivatives at the zeros [77]. The simple function $\zeta(z)=\sum_{n=1}^{\infty} n^{-z}$ has a more complex (and interesting) behaviour than you might first expect by looking at its simple definition. If there is pattern in the universe – and, as scientists, we think there is, and it is our calling to better find that pattern – then there may well be a simple function that describes these masses.

But what is the (hopefully simple) function that defines the masses of the atomic and sub-atomic particles? As yet we do not know. But is that formula independent of the speed of light, or does that formula specify (restrain) the speed of light? Is that formula dependent upon the current size of the universe (which itself depends upon the long-time behaviour of Hubble's Constant), or does that formula define the temporal size of the universe?

In the absence of that knowledge (*i.e.* what predicates the particular mass of each particular particle type) I suspect that we should feel some uncertainty as to whether the long-term (and I mean <u>long</u>-term – thousands of millions of years) properties of these particles do, in fact, remain unchanged). This, of course, is only a guess on my part – a wild hypothesis. But it is an hypothesis for which I personally would welcome some both theoretical and experimental analysis.

For the thinking in this paper I am going to assume that we cannot rely upon stability in fundamental particle mass – though I shall try to make clear which of my conclusions depend upon that assumption, and which do not.

Stability of Hubble’s Constant

<u>Consider Expansion I.</u>

With Expansion I we have just two values for Hubble's Constant – one inside bound bodies (value zero), and one outside bound bodies (value H_0). We have to decide what constitutes a bound body: is it just solid bodies, or do liquids and gases and plasmas count? And if so, under what conditions? To be more precise: where exactly is the singularity in value-change of H_0? Singularities are dangerous things in scientific explanations.

We know that interplanetary, interstellar and intergalactic space contain matter – let’s call it “gas” for the moment, though that is not always accurate – of a very low density. The density is of the order of a small number of atoms (or subatomic particles) per cubic metre – we can usefully consider densities as low as one ^1H per cubic kilometre in our calculations for intergalactic space. The larger lumps of matter – gas clouds of increasing densities, fine dust, grit, “pebbles”, rocks up to asteroid sizes, planets, stars, stellar systems, galaxies, clumps of galaxies – “float” in this gas. We have observed H_0, and tried to measure it (see [12][13][14][15][16] – and many more): because of its very low value we have had to use very long base-lines for its measure – the distances between local galaxies, and the distances between separated galaxy clusters, for example. These measurements will produce a coherent and accurate value for H_0 only if it is actually a constant, and has the same value across these base-lines of different lengths.

So there are three difficulties with Expansion I (the current model):

- there is a singularity in its value, for the “bounded object” case, and
- there is doubt as to what exactly constitutes a bounded object, and
- from the difficulty of our observations, there is doubt as to whether it actually is a universal constant, or whether it varies according to distance.

If the speed of light is constant, then (other effects being ignored) Metres I and II and III stay in step – there is no variation in our possible (and theoretical) measures of length.

<u>Consider Expansion II.</u>

With Expansion II we lose two of these difficulties: we have a definition for a bounded body (it is a solid or a liquid – or any other body in a matter-state bound by structure, and not just by gravitational force), and some of the prior difficulty in our observations of value is explained by its not actually being a constant, but varying over distance. But we still have a singularity in its value (at the boundary of bounded bodies). As observed before, singularities in scientific explanations should be avoided, if at all possible.

There might be some doubt here as to the constancy of the speed of light. If the speed of light is constant, then our Metres I and II and II still stay in step. If, however, the speed of light is somehow related to the observed value of H_0 then possibly Metres II and III stay in step, but Metre I grows (or shrinks) with respect to them. This growth (or shrinkage) would be – from our existing observations – of a very small amount, and in the standard interpretation is taken to be zero (*i.e.* light has a constant speed).

<u>Consider Expansion III.</u>

If the value of the Hubble Constant is 70km/s/Mpc then it is about 2.268E-18 m/s/m (metres per second per metre). This is a detectable quantity. We have never detected such an enlargement of closely-bound bodies – though that may be because we have not looked for it in the right way. It may also be because the “close” value for H_0 is very much smaller than the “distant” value for H_0. The hypothesis for expansion being considered here (“Expansion III”) suggests that the value of H_0 varies over distance – so, again, it is not a constant, but a function of the separation of the events between which it is being measured:

$$H_0 = h_0(f, e_1, e_2)$$

where e_1 and e_2 are the events, and f is some further list of relevant parameters, yet to be looked at. These extra parameters may include the curvature of space at and between the events, the local speed of light, the local and global gravitational influences, and so on. In this publication we shall henceforth ignore f and express h_0 only with parameters e_1 and e_2 . Note that we require function h_0 to be transitive:

$$h_0(e_1, e_2) + h_0(e_2, e_3) = h_0(e_1, e_3)$$

If we have Expansion III then our Metre III would be shrinking with respect to our Metre II. The relationship between Metre I and Metre II is, however, not clear. If there is truly <u>universal</u> expansion, then the very basis upon which *c* is defined will itself be changing over (long) time, and over (long) distances. If the evaluation of *c* is related to Metre II as a definition, then Metre I will be in step with Metre II. If the evaluation of *c* is not related to Metre II, but to some other aspect of the universe, then its growth or shrinkage with respect to Metres II and III is undefined here.

So if c is directly related to Metre II, then Metre I and Metre II stay in step, but Metre III apparently shrinks with respect to them. If, however, c is directly related to Metre III then Metre I and Metre III stay in step, but Metre II grows in respect to them. Finally, if Metre III shrinks with respect to Metre II, but Metre I is not in step with either of these, then we have to find something else upon which c depends.

Tests of Expansion

Comparing the three models for expansion, we have:

	Metre I	**Metre II**	**Metre III**
Expansion I	Constant	Equals Metre I	Equals Metre I
Expansion II	Constant? Grows? Shrinks?	Constant	Equals Metre II
Expansion III	Constant? Grows? Shrinks?	Equals Metre I? Grows?	Shrinking from Metre II

But remember that Metre III is made of “unobtainium” – it is a notional construct that we cannot have. Indeed, it maybe a notional construct which has no clear meaning. So we can, in practice, compare only Metres I and II – the Metre III column is not (and cannot be) available to us. As we directly measure Metre I and continually compare it with Metre II, do we see an apparent expansion in Metre II (*i.e.* do we better define Metre I?) at the rate of change of one part in E18 per second (or smaller)? This suggested upper bound is quite a large number, and continued over time would show an apparent shrinkage of Metre II of the rate of about three parts in E10 per year. Using interferometry we can already measure to the accuracy of one part in E9 over the distance of one metre – but we have the fundamental uncertainty imposed by $\sigma_x \sigma_P \geqslant \frac{\hbar}{2}$ where $\hbar$ is the Reduced Planck Constant (value 1.054571726E-34 J s), σ_x being the standard deviation of position (x) measurements, and σ_P being the standard deviation of momentum (P) measurements (Heisenberg’s Uncertainty Principle [9][10][11]).

What are we Measuring?

We are measuring recession velocity over a distance base-line. But we have already discussed in [1] that there is more than one definition of spatial distance. This affects two parts of our measurement: the base distance itself (metres), and also the velocity (metres per second).

We have also discussed in [1] that there is more that one definition for time. This also effects our measurement of velocity (metres per second).

We seem to be in a philosophical loop: our measurement of Hubble's Constant depends upon our definitions of distance and time; our definitions of distance (and perhaps time) depend upon the speed of light; Hubble's Constant may well depend upon the speed of light (though that is conjectural); there is doubt as to whether the speed of light, over the long term, is constant (using other, external, definitions of distance and time than the ones we currently use – but definitions that are, for the moment, and in the local space, the same as our current definitions).

Summary

These papers [1][2] have discussed a number of side issues, many completely hypothetical, and in their discussion showing the extent of my ignorance. These side issues, whilst perhaps interesting, must not take precedence over my two most important hypotheses, which are:

- Photons have rest mass
- Light does not travel at *c* but at $c(1-\epsilon)$ where ϵ depends upon the refractive index, which itself is never exactly 1, but always very slightly greater.

All the other discussions – about the shape of universal expansion, about the dimensionality of time, about the various definitions of distance – are hypothetical side issues. Some of the other discussions – about the stability of universal constants, about the finding of a pattern in the mass of atomic particles, about the possible logical (philosophical) circularity of our definitions of the space-time units – are wildly hypothetical side issues.

What is not a side issue is that if photons have rest mass, then the enormous number of photons in the universe has two measurable effects:

- the actual mass of any region of space must include the mass of the light in that space, and
- the mass of the photons in the void intergalactic space must be part of the cause for, or extent of, universal expansion.

I have suggested some ranges of figures for photon rest mass, and for space refractive index. I would welcome some thought – some experimentally verifiable thought – on the evaluation of those figure, or of methods of finding the correct values.

Particle Table

Particle	Quarks	Mass MeV/c^2	Charge	IsoSpin	Tot angular momentum	Strangeness	Charm	Bottomness
[36] Proton p^+	uud	938.272	+1	½	½+	0	0	0
[37] Neutron n^0	udd	939.565	0	½	½+	0	0	0
[38] Lambda Λ^0	uds	1115.683	0	0	½+	-1	0	0
[41] Charmed Lambda Λ_c^+	udc	2286.46	+1	0	½+	0	+1	0
[42] Bottom Lambda Λ_b^0	udb	5619.4	0	0	½+	0	0	-1
[39] Sigma Σ^+	uus	1189.37	+1	1	½+	-1	0	0
[40] Sigma Σ^0	uds	1192.642	0	1	½+	-1	0	0
[43] Sigma Σ^-	dds	1197.449	-1	1	½+	-1	0	0
[35] Xi Ξ^0	uss	1314.86	0	½	½+	-2	0	0
[44] Xi Ξ^-	dss	1321.71	-1	½	½+	-2	0	0
Bottom Xi Ξ^-_b	dsb	5791.1	-1	½	½+	-1	0	-1
[51] Charmed Omega Ω^0_c	ssc	2695.2	0	0	½+	-2	+1	0
[52] Bottom Omega Ω^-_b	ssb	6071	-1	0	½+	-2	0	-1
[53] Delta Δ^{++}	uuu	1232	+2	3/2	3/2+	0	0	0
Delta Δ^+	uud	1232	+1	3/2	3/2+	0	0	0
[54] Sigma Σ^{*+}	uus	1382.8	+1	1	3/2+	-1	0	0
[55] Charmed Sigma Σ^{*++}_c	uuc	2517.9	+2	1	3/2+	0	+1	0
[56] Bottom Sigma Σ^{*+}_b	uub	5832.1	+1	1	3/2+	0	0	-1
Xi Ξ^{*0}	uss	1531.80	0	½	3/2+	-2	0	0
Charmed Xi Ξ^{*+}_c	usc	2645.9	+1	½	3/2+	-1	+1	0
Charmed Xi Ξ^{*0}_c	dsc	2645.9	0	½	3/2+	-1	+1	0
[58] Bottom Xi Ξ^{*0}_b	usb	5945.5	0	½	3/2+	-1	0	-1
[59] Omega Ω^-	sss	1672.45	-1	0	3/2+	-3	0	0
[60] Charmed Omega Ω^{*0}_c	ssc	2765.9	0	0	3/2+	-2	+1	0
[61] Electron e^-		0.511	-1	½				
Electron Neutrino v_e		<2.2E-6	0	½				
Muon μ^-		105.7	-1	½				
Muon Neutrino v_μ		<1.70E-1	0	½				

Particle	Quarks	Mass MeV/c^2	Charge	IsoSpin	Tot angular momentum	Strangeness	Charm	Bottomness
Tau τ^-		1777	-1	½				
Tau Neutrino ν_τ		<15.5	-0	½				
Photon γ		0 ?[5]	0	1				
W Boson W^-		8.04E4	-1	1				
Z Boson Z		9.12E4	0	1				
Gluon g		0 ?[6]	0	1				
Higgs Boson H^0		1.253E5	0	0				
Graviton G		0 ?[7]	0	2				
up Quark	u	2.3	+2/3	½				
down Quark	d	4.8	-1/3	½				
charm Quark	c	1.29	+2/3	½				
strangeness Quark	s	95	-1/3	½				
bottom Quark	b	4.28E3	-1/3	½				
top Quark	t	173.34E3	+2/3	½				

Table 1: Some Particle Properties
from [62] and elsewhere

5 The value zero is disputed in these papers.

6 The zero mass of the gluon is also something to be considered – but in other papers.

7 The zero mass for the graviton is also something to be considered – always assuming that we ever find a real graviton!

References

[1] **Kelly, I. D. K.;** *Dimensions of the Universe-I*, 2015, available privately.

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[4] http://en.wikipedia.org/wiki/SI_base_unit inspected 2015-04-02, which refers to International Bureau of Weights and Measures (2006), *The International System of Units (SI)* (8th ed.), ISBN 92-822-2213-6

[5] http://physics.nist.gov/cuu/Units/second.html inspected 2015-04-02, referring to the 1967 and 1997 definitions

[6] http://en.wikipedia.org/wiki/Metric_expansion_of_space inspected 2015-04-03

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