A new quantum gravity framework based on the twin-tori model of cosmology. (Part 1)

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Abstract:

In this, the final paper in the recent series on the new twin-tori model of cosmology, the model is developed in a logical way. Its historical development is included, and what follows is a statement of the central axioms of the theory. The reasons for them are described and their use in the theory is shown. What then follows is a brief description of the cosmological side of the theory, and its application to large scale structures and astrophysics. The paper then begins to develop the opposite length scale of the model, that on the order of the nuclear scale and ranging down to planck scale physics and Quantum Gravity.

The theory is developed by laying theoretical foundations and mathematical idea's and structures and building on these using phenomenology and statistical techniques to fit parameters for the theory, including the dark energy – dark matter coupling constants. Many basic simplified models are then set out in various dimensions and with varying degrees of physical relevance.

The models are also tested against current theory using observations of various physical systems ranging from nuclear physics, both earth-bound and stellar, to galactic dynamics and rotations. Historical deatils are included to increase readability from a variety of backgrounds.

Introduction:

The greatest mysteries in modern cosmology and physics are Dark Matter, Dark Energy, and Quantum Gravity.

Dark Matter was first proposed as a solution to a problem encountered by the swiss mathematician and astronomer Fritz Zwicky in 1933, in relation to the rotational properties of the coma cluster. In summary, he attempted to derive the mass of the cluster using 2 methods, the first was to apply the well known virial theorem to the motions of the outer galaxies and derive the mass, whilst the second was to compare the luminosity with a standard luminosity-mass ratio and find the mass by direct multiplication. On doing so he found that the mass predicted by the motions of the outer galaxies was approximately 800 times higher than the mass predicted using standard techniques using luminosity. Obviously 2 solutions are apparent, either there is a considerable amount of mass which is not luminous and hence does not contribute to the luminosity and is not included in the luminosity-mass ratio, or Newtons Law of Universal Gravitation is not applicable on such scales. The standard approach in physics is to assume the former, and experimental evidence has borne this out quite well as the law of Newton has since been verified down to, and below, the value of the acceleration involved in the coma cluster problem.

The second great mystery of modern science, dark energy, has an equally interesting history. In esscence, however, and for simplicity dark energy may be introduced as something similar to the cosmological constant, Λ, in Einstein's equation of general relativity:

$$R_{\mu\nu}-\frac{1}{2}g_{\mu\nu}R+\Lambda g_{\mu\nu}=8\pi Gc^{-4}T_{\mu\nu}$$

In recent years experimental evidence has built up to show that, not only is $\Lambda\neq0$, but also that the expansion of the universe is accelerating! That is to say that the decelleration parameter $q<0$.
Dark energy, in conventional physical and cosmological thinking, produces a repulsive force that is somewhat in the vein of an 'anti-gravitational' force. It is often thought and indeed formalised in physical investigations and theories that there is a dirtect relationship between dark matter and dark energy.

The third point, that of quantum gravity, is the one in which the most theoretical progress has been made.
In most situations in the universe, gravity and quantum systems are usually seperate and hence QFT and GR can be used individually. However, there can arise certain situations such as black holes and elementary particle physics where a quantum theory of gravitation must be used to avoid nonsensical infinite answers. In the last 30 years many possible suggestions for a quantum theory of the gravitational force have been made, with the most successful attempts being superstring theory (and its more recenty successor, the even more mystical M-Theory), and loop quantum gravity a nice mathematical structure based on rigour rather than evidence from experiment. Neither of these theories have yet shown themselves to be truly mathematically consistent, or even finite! More importantly neither has been able to offer a truly testable physical prediction, and any test to wich they have been subjected has been that of its mathematical predictability.

There are many differences betwen the afforementioned theories and speculations, and the new twin-tori model. The first, and most striking, difference is that the twin-tori models original objectives were to provide a consistent and testable theory of cosmology, through an understanding of known physics and a new understanding of the function and nature of dark matter and dark energy. In the process of developing such a model, from a methematical point of view, it became clear that certain specualtive hypotheses would be required, including such things as the shape of the universe, its overall topology, and several ambiguously observed particles. In accepting these hypotheses as axioms of the theory, it became clear that it was possible without too much mathematical difficulty to extend the model to a theory encompassing fundamental particles. At this point ambition took over and it was decided that an attempt to formulate a full theory of particle physics and cosmology, including gravitation, was to be the aim.

As it is formulated in other papers, the twin-tori model is an exercise in pure mathematics, and not a physical theory. However, the authors offer in this paper examples of its potential interpretation as a physical theory and also examples of its full form and application to many physical situations at a wide variety of length and energy scales. This is the most physical paper in the recent series.

The Twin-Tori Model As An Axiomatic Theory:

As with almost all theories of physics, and in particular the cosmological and astrophysical disciplines, theories are constrained quite tightly by several factors such as experimental and observational data, empirical facts, mathematical consistency. This is also the case with the twin-tori model. The main constraints imposed on this model are those given by observational data in the context of cosmology, in that all known data collected, even by the most advanced satellites such as WMAP, are consistent with a big-bang, flat space, $\Omega=1$, $\Lambda>0$, universe. This leads to the 1st, and most important, axiom of the twin tori model:

Axiom 1: The universe takes the shape of a torus containing both baryonic and dark matter, but not dark energy, and is surrounded and encased by an outer torus which contains the dark energy nessecary to maintain the illusive big-bang type dynamics.

For more information on this particular axiom please refer to the references [1],[2],[3][4].

The second axiom is also one motivated by serious experimental evidence, as well as tremendous theoretical success. It is the fundamental postulate of quantum field theory, and also fundamental in the special and general theories of relativity, and is one of the few common characteristics of the current theories of gravitation and quantum physics:

Axiom 2: The laws of physics retain the same form under a general Poincare transformation $x'=Lx+C$, and also under the restricted Poincare transformation $x'=Lx$ (Postulate of Lorentz/Poincare Invariance) at all length scales $X>l_{planck}$.

The next axiom is also associated with relativistic physics, and is often called the second postulate of the special relativity:

Axiom 3: The speed of light in a vacum, denoted c, is independant of the reference frame in which it is measured.

The next three axioms are standard axioms of most cosmological models, and are also very important in the development of the twin-tori cosmological model:

Axiom 4: The laws of physics are universal, different physical laws do not apply in different area's of the universe.

Axiom 5: The universe is, to good approximation, homogeneous and isotropic in space. It need not be homogeneous and isotropic in time.

Axiom 6: We are not observing the universe from any special position within it.

Axiom 6 is often referred to as the Copernican principle.

Also important in modern theoretical physics is a specification of the dimensionality of any theory, and this is embodied in the following axiom:

Axiom 7: The universe is made up of 3 spatial dimensions (x,y,z), and one time direction which is denoted t

The Twin-Tori Model On Astrophysical Scales

The aim of this section is to provide a detailed account of the cosmological side of the theory, which also includes applications of the model to astrophysics and planetary science, and presents its logical development using a mixture of detailed description, theoretical development, phenomenology, description of data, and results obtained by statistical and probabilistic techniques.

Description of the astrophysics of the model on the scale of the solar system, with extrapolations to a general model for all planetary systems around a main sequence stars.

This analysis is centered on solar system data, and based against physical predictions based on theoretical models of stellar and planetary formation.

Physical prediction 1: The chemical composition of planetary matter should be broadly similar across the spectrum of planets, and of a similar type to that of the parent star. This is based on the theoretical prediction that planets are formed from the same protostellar disk as the parent star, or stars. This is refuted by considering statistical analysis of solar sytem data in the following way:

Case Study 1: Multiple Linear Regression Analysis.

This case study tests the prediction that chemical composition of planets should be broadly similar over the range of planets accompanying the parent star, and also directly related to the composition of the parent star.
This is done using multiple linear regression analysis based on the fact that the chemical composition of a planet is directly proportional to its mean density. In this case study the only part of the chemical composition nessecary to study is the percentage of hydrogen by mass, which will be represented by Φ. So, in symbols, the fundamental fact on which the analysis is based is given by: $\Phi \propto \langle\rho\rangle$.

An assumption to which a model can be fitted must now be formulated. The fundamental assumption of this model is that the mean density of a planet in the system varies as a linear function of the planets semimajor axis and its mass. In symbols this is given by: $\rho(m,a)=C+Bm+Aa$ where A,B,C are constant real numbers. This is the functional form of mean density predicted by standard theories of plaetary and stellar formation, and it will now be tested in the case of the solar system.

The data used in this analysis is shown in this table:

Planet	Mass/10^24 kg	Equatorial Radius/km	Average Density/(kg/m^3)	Semimajor Axis/AU	Semimajor Axis/km
Mercury	0.33	2439	54000	0.387	57895200
Venus	4.87	6052	5.2	0.723	108160800
Earth	5.97	6387	5.52	1	149600000
Mars	0.64	3393	3.9	1.524	227990400
Jupiter	1900	71398	1.4	5.203	778368800
Saturn	569	60000	0.69	9.54	1427184000
Uranus	87	25559	1.19	19.18	2869328000
Neptune	103	24800	1.66	30.06	4496976000

N.B: Pluto, Eris etc are not included in the analysis as by the 2006 IAU definition of a planet these bodies are designated as ‘minor planets’ and, in the context of the solar system, as ‘trans-neptunian objects’.

The next stage in the case study can be summarised as a 3-step process:
Step1: Formulate the multiple linear regression model.
Step 2: Analyse the accuracy and predictive power of the model.
Step 3: Analyse the validity of the model by checking the truth of the assumptions of the regression model.

To formulate the model, the form of the function is assumed, and coefficients are fitted to maximise the explanation of the variability of the data. The model calculated for the solar system is given in the computer output, from statistical package MINITAB, below:

```
The regression equation is
Average Density/(kg/m^3) = 13507 - 6.3 Mass/10^24 kg
                           - 0.000004 Semimajor Axis/km


Predictor                Coef     SE Coef       T       P
Constant                13507       10571    1.28   0.257
Mass/10^24 kg           -6.33       12.00   -0.53   0.620
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```
Semimajor Axis/km  -0.00000367  0.00000489  -0.75  0.487


S = 20966.8   R-Sq = 13.8%   R-Sq(adj) = 0.0%


Analysis of Variance

Source          DF          SS         MS     F      P
Regression       2   353194044  176597022  0.40  0.689
Residual Error   5  2198041928  439608386
Total            7  2551235972
```

And so the regression equation, giving the functional form of ρ(m,a) is calculated, based on the data given for the solar system (which is taken to be a typical planetary system for a star of the same spectral type and average physical paramaters as the sun) is given by the following equation in 3 variables: ρ(m,a)=13507-6.3m-0.000004a, where m is the mass in units of 10^24kg and a is the semimajor axis in units of km. This is step 1 of the analysis process complete.

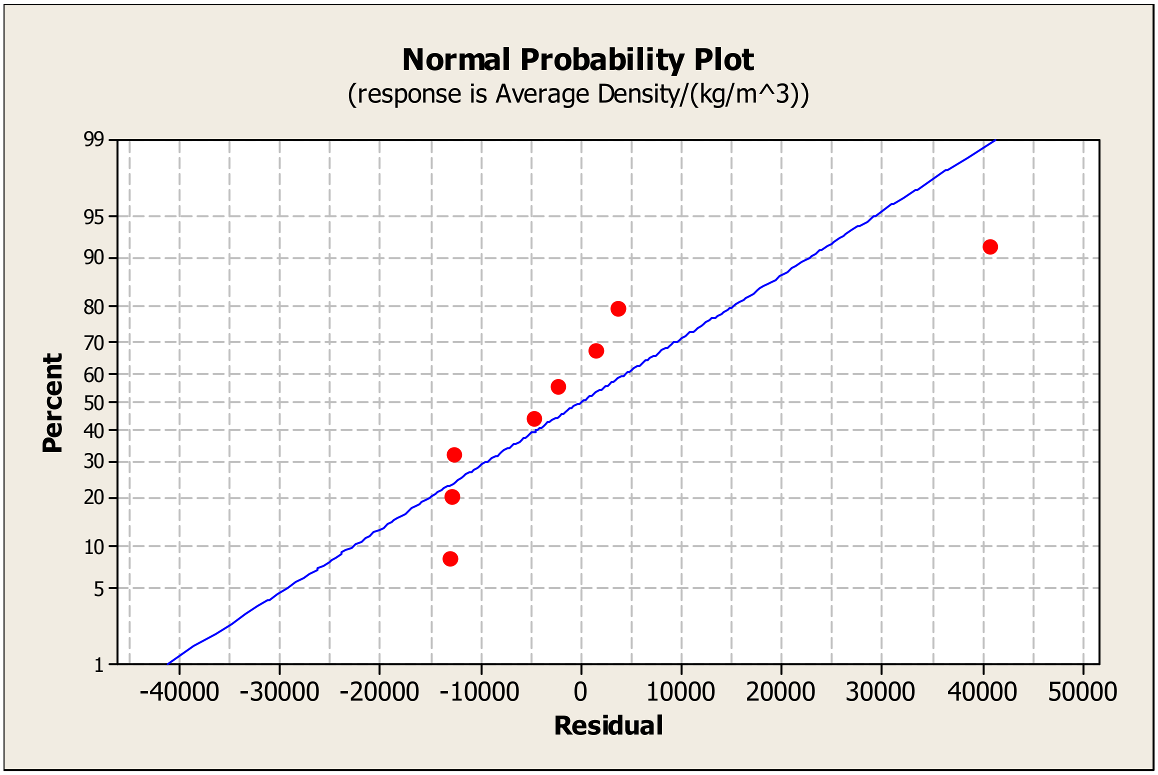
Step 2 in the process is to analyse the validity and predictive power of the given model.
A good 1st step in this process is to take a look at the value of the multiple linear correlation coefficient, R^2.

From the output given above, R^2=0.138. This is a very low value for this statistic, and a statistical test of H_0: R^2=0 against H_1: $R^2 \neq 0$ yields that there is insufficient evidence to reject the null hypothesis. This means that the model above is a poor model for explaining the variability in ther data, and hence the assumption of a linear model in these variables is invalid. This, however, does not disporve the prediction given by current theoretical models of planetary formation yet.

Step 3 in the process is to check the validity of the assumptions used in the formulation of the above regression model. These are the standard assumptions of multple linear regression analysis and are given here:

1) The mathematical form of the relation is correct, and the expected value of the errors is zero.
2) The variance of the errors associated with all variables are the same
3) The variables are independant
4) The residuals are normally distributed

These can be tested individually. The main way of testing the first is to plot a graph and observe its form. This is not possible in the case of multiple linear regression as a graph in more than 2 dimensions is required. The 2 assumptions most easily tested are 3 and 4. First we test 4 by examining a normal probability plot computed by MINITAB:



This plot shows that the assumption of normality holds, but only approximately. This however is not a great concern as mathematical tools such as transformation functions can be applied to the data to ensure that the normality assumption holds.

The method chosen to analyse the third assumption, that of independence of the 2 independent variables from each other, is to use a set of statistical tests based on the assumption that there is a relationship between them.

Firstly, it is assumed that there exists a linear relationship between the 2 independent variables (mass and semimajor axis). Pearson's correlation coefficient is then calculated using MINITAB and tested appropriately:

Correlations: Mass/10^24 kg, Semimajor Axis/km

```
Pearson correlation of Mass/10^24 kg and Semimajor Axis/km = -0.050
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```
P-Value = 0.907
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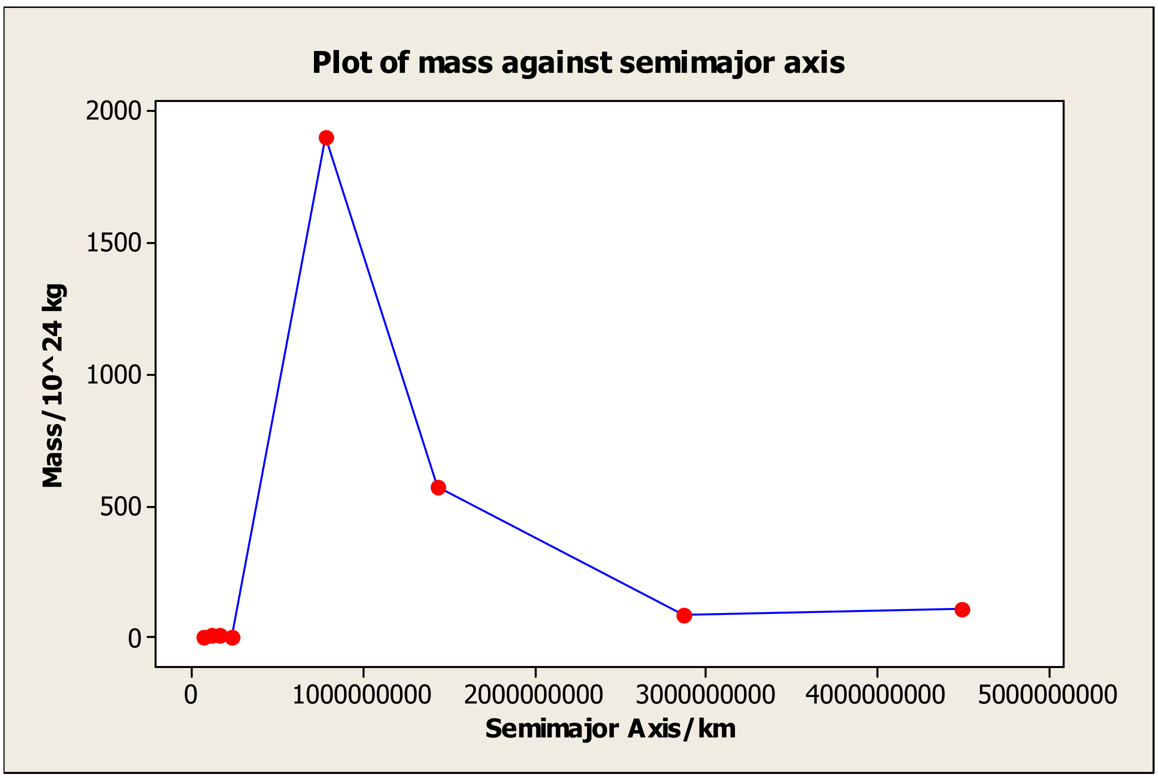
From the output, the value of r=-0.05, which indicates almost no linear relationship between these variables. A statistical test confirms this, and is included only to show rigour:

H_0: r=0
H_1: r≠0

The p-value, taken from the output, yields p=0.907, and this implies that there is insufficient evidence to reject the null hypothesis. Therefore there is no linear relationship between mass and semimajor axis. To assess if there is any kind of relationship between the two variables, it is possible to anaslyse a scatterplot of m against a:



This plot shows no noticeable relationship between these variables. Hence it is a forced conclusion that the two variables are independent.

Following these analyses it must be concluded that the relationship between average density, mass, and semimajor axis is not linear. This disproves, using phenomenology and empirical evidence, the prediction given by current theoretical models of stellar and planetary formation. Whilst not direct evidence for the twin-tori model, it does show cracks in current theory. The planetary formation problem and other aspects of astrophysics that can be addressed by the twin-tori model are discussed in case study 3.

A note on the statistical issue of small sample size: The usual argument of insufficient data to make reliable analyses does not apply in this case. This is because the data given represents not a sample but the whole population. Therefore the coefficients and statistics calculated are indeed the population parameters.

Cosmological side of the twin-tori model:

The aims of this section are to describe the main aspects of the new cosmological model proposed by the authors. The main tools used are theoretical methods, most of which have been derived from the quantum gravity framework to be described and formulated in the next part of this paper. These are supplemented by graphical and statistical methods to show consistency with current observational data, and in some cases current theory, within certain theoretical bounds which become clear in the latter part of this discussion.

Case Study 2: Theoretical explanation of the observed recessional dynamics of the universe

The first part of this case study is the proof, based on the afforementioned axioms and quantum-gravitational framework, of the following theorem:

THEOREM 1: At the time at which the big bang is predicted to have occured the universe could have a non-zero spatial extension in all spatial directions.

The expansion dynamics of the universe are governed, according to axiom 7, by one equation for each spatial dimension.

These equations give the time evolution of each individual spatial dimension.

For their most convenient expression, a definition is first required:

Definition: the time-derivative operator (d/dt) is to be represented by D.

$i.e\ D=d/dt \rightarrow D^2=d^2/dt^2$.

The equations for the time-evolution of the spatial dimensions as derived from the quantum-gravitational framework are:

$$tD^2x+Dx=0$$

$$tD^2y+Dy=0$$

$$tD^2z+Dz=0.$$

These equations are obtained in matrix form and, obviously, yield the same solution.

The solution to these equations are given by: $x(t)=A+B\ln(t)$, $y(t)=C+D\ln(t)$, $z(t)=E+F\ln(t)$. $A,B,C,D,E,F \in \mathbb{R}$.
The quantum gravity gramework of the twin-tori model [5], imposes an extra and stronger condition on $\{A,B,C,D,E,F\}$. This condition is that the set $\{A,B,C,D,E,F\}$ is a subset of the rational numbers $\mathbb{Q}$.
These solutions, and several other results, including the 'twin-tori cosmological formula' yielding the flux of the gravitational force exerted by the outer dark energy torus, give a basic model for the structure of the universe according to the twin-tori model.

It should, at this point, be noted that these equations also do not hold at all times. This is easily shown by analysis of the initial conditions found in the model: $t=0 \Rightarrow x=y=z=-\infty$. $\forall A,B,C \in \mathbb{Q}$.
Therefore this description, though based around a theory of quantum gravity, it does not hold for all times. However, as is to be shown later, these equations hold very well as an approximation. Hence for the purposes of this discussion these solutions hold.

Hence theorem 1 is proven.

The next step in this analysis is to show that these solutions are qualitatively consistent with those of the currently accepted and empirically verified 'big bang' model.

Linearity derivation:

A fundamental result, which unlike many in physics can be derived theoretically and also inferred from empirical data, of the big bang model is the well known Hubble's law $v=H_0d$. This result, obviously, implies a linear relationship between distance and time. The purpose of this analysis is to show that for most times including the current cosmological era, that the solutions given above can be well approximated by a linear function $x(t)=\alpha+\beta t$. The data used are not intended to produce the correct Hubble constant for this era, as this is done later in the paper in a different way. The data used here are chosen to represent early times in the universe according to the twin-tori model, and are close to the limit of validity of the approximation used to derive the solutions given above.

A summary table of the data, in units of c=1, used in the analysis is given in the tables below:

A=B=C=D=E=F=1

T	x	y	z
1	1	1	1
10	3.302585	3.302585	3.302585
100	5.60517	5.60517	5.60517
1000	7.907755	7.907755	7.907755
10000	10.21034	10.21034	10.21034
100000	12.51293	12.51293	12.51293
1000000	14.81551	14.81551	14.81551
10000000	17.1181	17.1181	17.1181
1E+08	19.42068	19.42068	19.42068
1E+09	21.72327	21.72327	21.72327
1E+10	24.02585	24.02585	24.02585
1E+11	26.32844	26.32844	26.32844
1E+12	28.63102	28.63102	28.63102
1E+13	30.93361	30.93361	30.93361
1E+14	33.23619	33.23619	33.23619
1E+15	35.53878	35.53878	35.53878
1E+16	37.84136	37.84136	37.84136
1E+17	40.14395	40.14395	40.14395

1E+18	42.44653	42.44653	42.44653
1E+19	44.74912	44.74912	44.74912
1E+20	47.0517	47.0517	47.0517
1E+21	49.35429	49.35429	49.35429
1E+22	51.65687	51.65687	51.65687
1E+23	53.95946	53.95946	53.95946
1E+24	56.26204	56.26204	56.26204
1E+25	58.56463	58.56463	58.56463

The next step in the analysis is to establish that there is a set of correlations: $\{(x,t),(y,t),(z,t)\}$ that are statistically significant.

The analysis from MINITAB is:

Correlations: x, t

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Pearson correlation of x and t = 0.426
P-Value = 0.069
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Correlations: y, t

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Pearson correlation of y and t = 0.426
P-Value = 0.069
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Correlations: z, t

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Pearson correlation of z and t = 0.426
P-Value = 0.069
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All of the values are identical and satisfy: $0.05<p<0.1$, and hence are significant at the 10% level. These correlations increase dramatically at even earlier times, as the linearity becomes more pronounced. This is sufficient to allow a set of regression equations to be calculated:

Regression Analysis: x versus t

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The regression equation is
x = 2.19 + 0.0287 t


Predictor       Coef   SE Coef      T      P
Constant     2.19018   0.08352  26.22  0.000
t           0.028658  0.001436  19.96  0.000


S = 0.414472   R-Sq = 80.3%   R-Sq(adj) = 80.1%


Analysis of Variance
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Source	DF	SS	MS	F	P
Regression	1	68.432	68.432	398.35	0.000
Residual Error	98	16.835	0.172		
Total	99	85.267			

Unusual Observations

Obs	t	x	Fit	SE Fit	Residual	St Resid
1	1	0.0000	2.2188	0.0823	-2.2188	-5.46R
2	2	0.6931	2.2475	0.0810	-1.5543	-3.82R
3	3	1.0986	2.2762	0.0798	-1.1775	-2.90R
4	4	1.3863	2.3048	0.0786	-0.9185	-2.26R

R denotes an observation with a large standardized residual.

As can be seen from this output the value of R^2 is statistically significant and non zero. The strength of the model is confirmed in the ANOVA table also. The regression equations for the other two spatial variables can be obtained by comparison. This analysis shows that the observed linear recessional dynamics are a feature of the twin-tori model within the current cosmological dark energy era.

The twin-tori model on length scales less than or equal to the atomic scale. Including applications to, and models of, Planck scale physics, fundamental particle theory, and Quantum Gravity.

Introduction:

In the previous paper 'Mathematical and Phenomenological elements of the twin-tori model', [2], some of the basic mathematical structures on which the twin-tori description of quantum gravity and particle dynamics is built were introduced rather informally and without obeying strict mathematical rigor. The purpose of this section of the paper is to rigorously define and develop the mathematical structures to be used, and also to provide explanation of their physical relevance and uses. What follows is a demonstration of a particular feature of the mathematics which is very similar to supersymmetry, as it is used in and applied to other theories of particle physics. Physical consequences of the framework are described, and a critical evaluation is given. Conclusions are then drawn and details of further work to be undertaken are given.

Description of the mathematical formulation of the twin-tori description of the motion of a single particle.

Consider a single particle, a point particle, and define a Cartesian coordinate system with origin (0, 0, 0, 0), and general coordinate (ct, x, y, z). The particle has instantaneous co-ordinates (ct, x, y, z). In the twin-tori formulation at any time later, $t+\Delta t$, the co-ordinates of the particle are described by the vector $(\tau(ct), \psi(x), \varphi(y), \sigma(z))$ such that the functions τ, ψ, φ, & σ all obey three basic conditions:

I. They are continuous for all values of the independent variables that are within the domain upon which the co-ordinate system is defined.
II. They are n-times differentiable with respect to the independent variable and $n>3$.
III. The function $\tau(ct)>0\ \forall t$.

It can be shown that the x-, y-, and z-functions (which at this point are still purely arbitrary) form a mathematical structure called a group with respect to both addition and multiplication. That is to say that if it is defined that G is the set of all functions obeying the three conditions stated above. Then the systems $\{G,+\}$ and $\{G,\times\}$ obey the following axioms:

1) Closure property: $a(x),b(x)\in G \Rightarrow a(x)+b(x)\in G,\ a(x)b(x)\in G$.
2) Associative property: $a(x),b(x),c(x)\in G$ then $a(x)[b(x)c(x)]=[a(x)b(x)]c(x)$ & $a(x)+[b(x)+c(x)]=[a(x)+b(x)]+c(x)$.
3) Identity element: $\exists I_+\in G$ such that $a(x)+I_+=I_++a(x)=a(x)\ \forall a(x)\in G$ & $\exists I_\times\in G$ such that $b(x)I_\times=I_\times b(x)=b(x)\ \forall b(x)\in G$
4) Inverse elements: $\forall a(x)\in G\ \exists a^{-1}{}_+\in G$ such that The combination $a(x)+a^{-1}{}_+=a^{-1}{}_++a(x)=I_+$. & $\forall b(x)\in G\ \exists b^{-1}{}_\times\in G$ such that $b(x)b^{-1}{}_\times=b^{-1}{}_\times b(x)=I_\times$

The above axioms are satisfied for the functions of all spatial variables x, y, z.

Then physical considerations yield that the functional form of $\tau(ct)=ct+\Delta ct=c(t+\Delta t)$.

The next step in the mathematical formulation of the model is to define, develop and interpret the algebra obeyed by the space-time functions. This has to be done, as restrictions must be placed upon the transformations that can be allowed to happen between particles. Transformations such as Boson→Fermion, and also Baryonic Matter→Dark Matter, clearly cannot be allowed on physical grounds.

Denoting the group of functions of spatial variable x as $G_1(x)$, and in a similar fashion $G_2(y)$ and $G_3(z)$, it is now possible to define the commutation relations that the functions obey:

The general commutator is [A,B]=AB-BA.

Definition: Space-time Algebra

$$[f(x),g(x)] \stackrel{\text{def}}{=} 2f(x)g(x) \Rightarrow \{f(x),g(x)\}=0 \ \forall f(x),g(x)\in G_1(x).$$
$$[j(y),k(y)] \stackrel{\text{def}}{=} 0 \Rightarrow \{j(y),k(y\}=2j(y)k(y) \ \forall j(y),k(y)\in G_2(y).$$
$$[a(z),b(z)] \stackrel{\text{def}}{=} 0 \Rightarrow \{a(z),b(z)\}=2a(z)b(z) \ \forall a(z),b(z)\in G_3(z).$$

What the second two sets of relations imply is that $G_2(y)\equiv G_3(z)$, which can be read as 'The group $G_2(y)$ is isomorphic to the group $G_3(z)$'. Also it implies that both $G_2(y)$ and $G_3(z)$ are abelian groups.

Representation of theoretical result showing great similarity to supersymmetry

As defined in the previous section, the anti-commutator of the x-dimensional space-time functions is given by $\{f(x),g(x)\}=0$. This equation has some hidden content, in that it holds a functional algebra specific to the twin-tori model, which has to the best knowledge of the authors, never arisen in any other area of theoretical research into fundamental physics. This is demonstrated in the following piece of algebra:

$$\{f(x),g(x)\}=0$$
$$\rightarrow f(x)g(x)+g(x)f(x)=0$$
$$\rightarrow f(x)g(x)=-g(x)f(x)$$

If both particles have motion in the x-direction described by the same equation then f(x)=g(x):

$$\rightarrow [f(x)]^2=-[f(x)]^2$$

$\Leftrightarrow f(x)^2=0. \forall x.$

This does not imply that f(x)=0. Therefore, in taking a lead from the way the complex numbers are defined, it is possible to define an algebra in which the general element has the form a+bf(x), such that a and b are real numbers, though in this case they are constrained further to being rational numbers. This algebra is defined only in the case where f(x) can be approximated well by a polynomial function, because it then follows that a+bf(x) can also be expressed as a polynomial, and hence will form a vector space.

The similarity with supersymmetry becomes more obvious when, following Rodger Penrose,[5], the supersymmetry generator ε is introduced as an anticommuting number. i.e one that satisfies $\varepsilon\varepsilon=-\varepsilon\varepsilon \rightarrow \varepsilon^2=0$. Hence the supersymmetry algebra is given by elements of general form a+εb, where a,b are Grassman numbers. There is, however, a major difference between the two formulations in that the general element of the twin-tori algebra is a function which can be evaluated to be a real number, whereas in the supersymmetry algebra the general element can be regarded as a 'number' and cannot be evaluated any further.

References:

[1] 'A Short Article On A Newly Proposed Model Of Cosmology' Dan Visser, Chris Forbes, Keith Lees viXra:0909.0005

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