Scientific Review
ISSN(e): 2412-2599, ISSN(p): 2413-8835
Vol. 12, Issue. 3, pp: 31-42, 2026
URL: https://arpgweb.com/journal/journal/10
DOI: https://doi.org/10.32861/sr.123.31.49

Academic Research Publishing Group

Original Research **Open Access**

Geometry of a Flat Finite Cosmology

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Article History
Received: 4 August, 2026
Revised: 27 September, 2026
Accepted: 13 October, 2026
Published: 27 October, 2026

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Abstract

A telescope pointed in any direction will see galaxies 300 million years young, emerging from a region of space 600 million light years across. Any direction points to this same small region of space occupied by the Primordial Plasma Cloud. The universe therefore acts as a lens and folds space back upon itself. A finite cosmology involving an embedding of a torus in a 6-dimensional covering space explains the observed data. The geometry of this cosmology is flat in a Euclidean sense.

Keywords: Cosmology, Big Bang, Cosmic Background Radiation, Hubble's Law, Dark Energy, Junk Science, flat geometry, non-Euclidean geometry.

1. Background: Observations About the Physical Universe

1.1. Folding Space

The cosmic background radiation can be detected upon pointing a telescope in any direction (Reference [2]). The spectrum of the cosmic background radiation is consistent with hydrogen plasma, but extremely shifted toward the infrared, providing a recession velocity of 0.94c (c being the speed of light) from the Primordial Plasma Cloud (PPC) and an initial Big Bang. The cosmic background radiation, consisting of photons (light) is therefore a view of ionized gas (mostly hydrogen) formed in the initial Big Bang (Reference [2]).

The James Webb Space Telescope (JWST) was pointed at a small section of "blank sky" to find galaxies less than 300 million years young (Reference [3]). The pointing direction was not unique. It stands to reason that any other section of blank sky will yield similar observations regarding both the PPC and young galaxies emerging from it. The PPC persisted for 180,000 years (Reference [17]), making the small PPC region to be less than 360,000 light years across. The geometry of space must be seriously contorted to enable the view of this same region of space both in front of the telescope and behind, or any other direction across a distance of 14 billion light years.

Conclusion 1. The same small PPC region of space can be viewed in any direction, providing tantamount proof that space folds back upon itself.

Einstein proposed that large masses like stars and planets cause a distortion or curvature of the geometry of space-time (Reference [4]). Geometry is therefore fundamental to understanding the nature of the universe.

1.2. The Hubble Equation

Edwin Hubble observed that the recession velocities of foreign galaxies increase in proportion to distance (Reference [7]). This relationship, recognizable as Hubble's law can be expressed in two forms,

$$v_r = H_0 \, d \quad (1)$$

$$v_r = d / t_\omega \quad (2)$$

where

v_r is velocity of the receding galaxy,
d is distance to the receding galaxy,
H_0 is Hubble's constant,
$t_\omega = 1/ H_0$ is the time from the Big Bang.

Hubble's law implies that the motion of foreign galaxies is motivated by expansion of space, and that the trajectories of foreign galaxies originate at a common point, some 14 billion years ago. At the time, many prominent scientists and astronomers, such as Fred Hoyle and the Royal Astronomic Society atheistically rejected the Big Bang theory because they refused to believe in creation. The Big Bang theory was not accepted by science until Hoyle and the old guard died.

1.3. No Need for Dark Energy

Hubble's law promotes a Big Bang theory; however, a closer examination shows that the Big Bang theory does not support Hubble's law! In particular, if one begins with galaxies emerging from a common point (the Big Bang), then a slightly different equation emerges (Reference [8]).

$$v_r = \frac{d}{t_\omega - \frac{d}{c}} \qquad (3)$$

where

v_r is recession velocity,
d is distance to a foreign galaxy,
t_ω is the time from the Big Bang,
c is the speed of light.

This equation agrees with the empirical Hubble Equation (2) for galaxies within 50 million light years. Beyond that distance, a disparity begins to occur, depicted graphically in Figure-1. An accelerating universe (Dark Energy) is not required to explain the disparity from Hubble's equation, when only a correction of the equation and a better understanding of geometry is needed.

Conclusion 2. Dark Energy is not required to explain deviations from the Hubble equation.

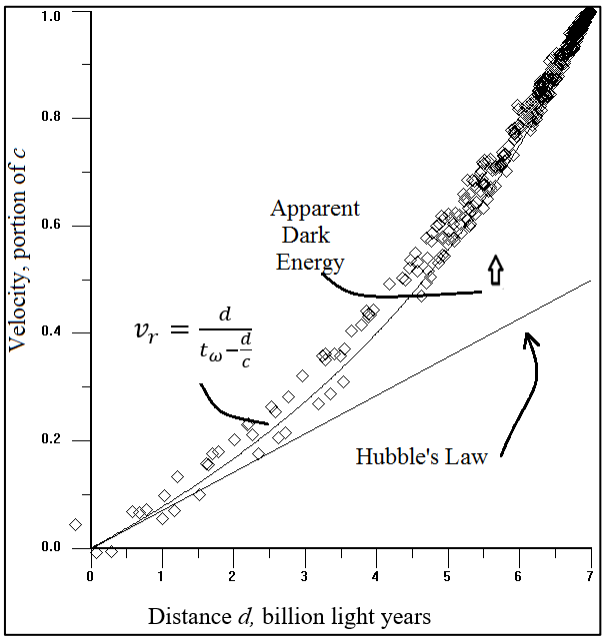


Figure-1. Simulated Recession Velocity vs Distance

1.4. The Expanding Balloon Model

The expanding universe is sometimes compared to the surface of an expanding balloon (Reference [27], [28], [29] and Equation (15)). As the balloon expands, spots on the surface of the balloon spread apart. If these spots represent individual galaxies, this model explains how recession velocity increases in proportion to distance as Hubble observed.

1.5. The Flat Universe

The expanding balloon model (Section 0.0) explains how galaxies can move away from each other at a rate proportional to distance, but fails miserably for modeling the universe. The surface of a balloon is *curved* whereas empirical evidence indicates that physical universe is *flat*, in a Euclidean sense (Reference [12], [13], [14], [15], [16]). A flat geometry supports the Pythagorean theorem and the sum of the angles in a triangle to be 180°. For curved surfaces like the surface of the Earth and the surface of a balloon, the sum of the angles in a triangle are greater than 180°, with the deviations becoming larger as the size of a triangle increases. Many scientists believe that a flat geometry implies that the universe is infinite. This belief lacks imagination. Most analyses of the cosmos are derived using an infinite three-dimensional grid.

Conclusion 3. Most scientists are unaware that a Toroidal three-dimensional manifold can have a finite geometry and be flat.

The assumption that the Hubble equation is a law of physics led modern science to discard the sacred law of conservation of energy. Julius Robert von Mayer, James Prescott Joule, and Hermann von Helmholtz are no doubt rolling over in their graves.

The issues of space folding back upon itself, and the problem with Hubble's law are geometric. It would make more sense to better understand geometry rather than introduce an exotic theory such as Dark Energy.

1.6. The Finite Universe

The visible universe consists of the Big Bang, the PPC, and galaxies which emerged from the PPC. The volume of the visible universe is therefore measurable and finite.

In a thought experiment, an observer with a telescope is placed in our own galaxy as it emerged from the Big Bang. As other foreign galaxies emerged from the Big Bang, they would be observable and not disappear as time progresses. This is a sharp contrast to internet discussions about galaxies which move away from us at velocities greater than the speed of light (Reference [37]). From a scientific point of view, a fixation on objects which are not physically observable is not warranted. Popular science is replete with such misinformation. It is difficult to refute the overwhelming Junk Science when publication standards do not usually allow references to the internet.

Throughout history, scientists have doggedly held on to old models and assumptions, even when the results disagree with observed data. The concepts of an infinite universe and Dark Energy are examples of Junk Science. If the universe were infinite, then a telescope would be able to peer past the most distant foreign galaxies and see empty space. This is not observed. The universe would have an edge. Furthermore, the internet is replete with discussions about the edge of the universe (Reference [37], [38]). This imaginative construction is not supported by telescopic data. When one peers in any direction, one observes only the Primordial Plasma Cloud (PPC) and the Big Bang, and not an edge. These discussions are reminiscent of the old Flat Earth Society who believed that anyone traveling far enough would fall off the end of the Earth.

1.7. Analysing Flatness Using Conformal Mapping

Flatness of geometry can be established using conformal mapping. A flat Domain Space S_D (such as a 2-dimensional infinite plane or 3-dimensional infinite space) is mapped into a Target Space S_T via a flat Conformal Mapping Function which preserves distance

$$Y = c_f(X) \qquad (4)$$

where

$X \in S_D$, the Domain Space,

$Y \in S_T$, the Target Space,

c_f is the Conformal Mapping Function.

If the conformal map preserves distance, then the geometry of the Target Space is flat whenever the Domain Space is flat.

1.8. Example—Flatness of a Rolled-up Tube

A flat piece of paper is rolled up to make a tube. The angles of any triangle drawn on the paper while it was laying on a table will be the same when the paper is rolled up, and the sums of the angles of the triangle will still be 180°, retaining the flatness of the original piece of paper.

The characterization a rolled-up tube is given by

$$u_1 = x \qquad (5)$$

$$u_2 = r \sin(y/r) \qquad (6)$$

where (x, y) are the coordinates of a point on the flat sheet of paper (the Domain Space),

(u_1, u_2) are the coordinates of the same point on the rolled-up paper (the Target Space),

r is the radius of the tube.

The Conformal Mapping Function in Equation (5) and (6) map many points to the same point. This characteristic does not negate flatness. Consider drawing any right triangle on the flat sheet, and then examine the same triangle on the rolled-up sheet. Because the lengths of the sides of both triangles will be the same, both triangles will satisify the Pythagorean equation, making the geometry of the rolled-up sheet Euclidean and therefore flat.

1.9. Ion Velocity in Plasma

The velocity of an ion particle in plasma is inversely proportional to particle mass (Reference [23])

$$v = \sqrt{\frac{k_B T_P}{m_P}} \qquad (7)$$

where v is velocity,

m_P is mass,

T_P is particle temperature,

k_B is Boltzmann's constant

During particle collisions, particle energy (and particle temperature) tend to equalize, causing a tight distribution of particle energy and particle temperature (Reference [21]).

1.10. Dispelling an Infinite Universe

In an infinite universe, there is no process for containing the PPC. Applying Equation (7) to an infinite universe, free electrons would have a velocity 183 times the velocity of a proton causing a rapid separation of the two species. This process is exhibited in an EMP (Electro-Magnetic Pulse) event surrounding an atomic blast. The separation of electrons from protons proceeds so rapidly that an enormous electronic field is created, wiping out power lines and communication, causing a wide separation of electrons from protons.

In an infinite universe, free electrons would continue to dissipate into infinite space, leaving a positively charged proton cloud. The remaining positively charged protons in the cloud would then repel each other and follow the escaping electrons at a lower velocity, dissipating into the infinite universe, following the electrons, making the infinite universe a virtual vacuum.

1.10.1. Mathematical Basis of Cosmology

With exception of the general relativity solution for gravity, the equations for the traditional cosmological models are derived in an infinite lattice of four-dimensional space time. These equations and the resulting conclusions need to be reexamined in favor of a backdrop of a finite universe with a flat geometry.

1.10.2. Testing Scientific Theories

The utility of a new scientific theory is its ability to make unusual but verifiable predictions. The proposed finite cosmological model herein makes many predictions which can be and have been verified through observation. The first of which is that space folds back upon itself. The predictions also provide explanations for observations which seem contradictory, such as galaxies which appear to be older than the time from the Big Bang, and differing values of the Hubble constant, depending on how it is measured.

Table-1. Lexicon of Symbols

K	Degrees kelvin
k_B	Boltzmann's constant 1.380649×10^{-23} kg (meters/sec)^2/K, a value abbreviated to 1.380649×10^{-23} kg (m/s)^2/K
c	speed of light, 2.99792458×10^7 meters per second, a value abbreviated to 3×10^7 m/s
d	distance to a foreign galaxy
d_ω	the distance traveled by our galaxy from the Big Bang. $d_\omega = v_\omega t_\omega$ is also the radius of the visible universe
G	the gravitational constant, 6.6743×10^{-11} meters^3/(kg sec^2)
H_0	Hubble's constant. $H_0 = 1/t_\omega$
m	mass or meters if unit
r	the radius of a circle or sphere
R_T	the radius of a flat Toroidal Cosmos
S	scale of the size of the Toroidal Cosmos $S=R_T/\sqrt{3}$
t_ω	time from the Big Bang, ~14 billion years. Also age of the universe
$(u_1,u_2, u_3, u_4, u_5, u_6)$	coordinates of an event in the a six-dimension covering space
v	velocity
v_χ	expulsion velocity of a galaxy from the Primordial Plasma Cloud. In an isotropic cosmos, $v_\chi \sim v_\omega$
v_r	recession velocity of a foreign galaxy
v_ω	recession velocity of our galaxy from the Primordial Plasma Cloud (PPC) and the Big Bang, about $0.94c$. v_ω is determined from the red shift of the PPC. v_ω is also the expansion rate of the universe
v_x	expansion rate of the visible universe
(x,y,z)	Coordinates of an event in three-dimensional space

Table-2. Glossary of Special Use Terms

Big Bang	A theoretical event, occurring approximately 14 years ago from which the material of the universe was ejected
blue shift	Doppler Shift (toward the blue) in frequency of light from an oncoming object or galaxy
Conformal Mapping Function	A function from a Domain Space to a Target Space which conserves distance
covering space	A space of higher dimension containing a space of lower dimension, such as an embedding of a 2-dimensional sphere in 3-dimensional space
Domain Space	Domain of a Conformal Mapping Function
Expansion Motivated cosmos	expansion is the motivating factor of motions of galaxies
flat cosmology	A cosmos with flat geometry. Flatness is defined in the Euclidean sense─the Pythagorean theorem, and the sum of the angles of a triangle is 180^o
isotropic cosmos	A cosmos for which the physical properties of the are virtually the same for an observer in any galaxy in the cosmos
JWST	James Webb Space Telescope
PPC	Primordial Plasma Cloud. A cloud of ionized gas (mostly hydrogen) formed in the initial Big Bang
Product Space	A Product Space of two spaces A×B contains elements (a,b) where a is an element of A, a ∈ A and b ∈ B.
red shift	Doppler Shift (toward the red) in frequency of light from a receding object or galaxy
Target Space	Target of a Conformal Mapping Function
Time Of Transparency	After dissipation and deionization of the primordial plasma, the universe became transparent, at about 180,000 years after the Big Bang
Toroidal Cosmos	A 3-dimensional model of the universe, formed as the Product Space of three circles (S1×S1×S1), embedded in a 6-dimensional covering space
Transparency	A condition wherein the universe becomes transparent, beginning at the Time of Transparency

2. Measuring the Recession Rate from

2.1. The Primordial Plasma Cloud

A revolution occurred in physics when the cosmic background radiation was hypothesized to be the result of radiation emitted by hydrogen molecules within the PPC referred to as the Lyman-Alpha radiation (Reference [26]). For the radiation to be created from hydrogen gas requires that our galaxy is receding from the PPC at an enormous velocity. Hydrogen gas exists within the PPC when free protons combine with free electrons.

Conclusion 4. Lyman-alpha radiation in the PPC is emitted by hydrogen gas, created when free protons and free electrons combine.

Lyman-Alpha radiation has a measurable wavelength of λ_s=1200 Angstroms (Reference [26]), whereas hydrogen in non-moving cloud (stationary cloud) has a wavelength of λ = 7100 angstroms. The redshift, z is computed from change in wavelength by the traditional formula (Reference [30])

$$z = \frac{\lambda-\lambda_s}{\lambda_s} = \frac{7100-1200}{1200} = 4.9 \quad (8)$$

where z is red shift,
λ_s is the wavelength of the Lyman-Alpha radiation from the PPC, 7100 angstroms,
λ is the wavelength of non-moving (stationary) hydrogen gas, 1200 angstroms

The relationship between recession velocity and red shift is computed from the traditional formula (Reference [30]),

$$1 + z = \sqrt{\frac{1+v/c}{1-v/c}} \quad (9)$$

where v velocity,
z is red shift,
c is the speed of light.

The Equation (9) can be manipulated to express recession velocity as a function of red shift,

$$\frac{v}{c} = 1 - \frac{2}{(1+z)^2+1} \quad (10)$$

where z is red shift,
c is the speed of light,
v is the recession velocity.

Applying the value for z from Equation (8), v becomes the recession velocity from the PPC, v_ω,

$$v_\omega = 0.94c \quad (11)$$

Transparency occurs at about 180,000 years after the Big Bang (Reference [17]). Once the universe becomes transparent, free particles quickly dissipate into rapidly expanding universe, in the same process ascribed to an infinite universe (Section 0.0).

Therefore, the PPC persisted long for the formation of massive objects (such as planets, stars, black holes and galaxies) capable of restraining free hydrogen via gravitation. Any remaining unrestrained hydrogen dissipate into the rapidly expanding universe. Surprisingly, the distribution of unrestrained hydrogen in intergalactic space is some four orders of magnitude lower than expected—virtually undetectable, indicating that virtually all free hydrogen became gravitationally attached while still in the PPC. The space between galaxies is virtually empty (Reference [33], [34]).

Conclusion 4. After transparency, the density of intergalactic hydrogen gas is insufficient to create new planets, stars, galaxies, black holes, etc.

Because new planets did not occur after the Time of Transparency, it follows that

Conclusion 5. The creation of new planets, stars, galaxies, black holes occurred within the PPC

2.2. Formation of Elliptical Galaxies

When two galaxies combine, the resulting galactic cloud of stars and gas will stretch in the merging direction. The resulting galaxy becomes elliptical.

3. Measuring the Expansion Rate of the Universe

The expansion rate of the visible universe can be measured directly. Mapping of the PPC shows the Lyman-Alpha red shift to be virtually the same in any direction at a distance

$$d_\omega = v_\omega \times t_\omega \quad (12)$$

where d_ω is the distance traveled from the Big Bang
v_ω is recession velocity of from the PPC,
t_ω is the time from the Big Bang

At a time t_ω+dt the distance d_ω increases to

$$d_\omega' = v_\omega \times (t_\omega + dt) \quad (13)$$

The rate of increase of the distance across the visible universe is therefore

$$v_x = \frac{d_\omega' - d_\omega}{dt} = \frac{v_\omega(t_\omega+dt) - v_\omega t_\omega}{dt} = v_\omega \quad (14)$$

where v_x is the is the expansion rate of the visible universe,
t_ω is the time from the Big Bang,
v_ω is recession velocity of from the PPC,
dt is a small increment of time

The expansion rate of the visible universe is therefore equal the value of v_ω from Equation (11), 0.94c

4. Achieving Transparency

In simulations, as the PPC cloud cools, the average velocity of actively interacting ions rate decreases below v_ω, until free ions virtually cease to exist. The universe becomes transparent. Transparency occurs at about 180,000 years after the Big Bang (Reference [17]).

Conclusion 6. The PPC persists only as long as it is constrained by the small size of the universe.

In simulations, once transparency is achieved, then remaining objects (molecules, planets, stars, galaxies, etc.) slip past each other without interacting and recede from each other. Over time, initial separations of galaxies become dwarfed by the expansion of the universe. The expansion of the universe becomes the primary motivating factor of recession velocity, consistent with the Hubble Equation (3).

Conclusion 7. Eventually expansion of the universe becomes the primary motivating factor of recession velocity as a function of distance.

Exceptional (blue shifted) galactic interactions occur when galaxies come close enough to merge via gravitation. Merging galaxies have been observed by the JWST (Reference [4]). Andromeda galaxy is predicted to merge with our galaxy in about 4.5 billion years (Reference [10]). Because Andromeda approaches our galaxy to merge, its light is slightly blue shifted.

5. Ghost Images

Because the speed of light exceeds the expansion velocity of the cosmos, light waves will always continue to circumnavigate the universe, creating multiple images of the same object. When the light path circumnavigates the universe, the image is a ghost image. The universe acts as an echo chamber.

A circumnavigated path will be longer, leading one to conclude that some of the viewed galaxies are older than the "currently accepted time from the Big Bang". This observed paradox (Reference [32], [33]) is resolved by realizing that the elapsed time along the light path does not necessarily determine the age of the observed event, particularly if the event is the observation of light emitted by a ghost image.

Given that pointing the JWST in any direction is a view of the same small volume of space containing images of the PPC (Section 0), and young galaxies emerging from it, viewed from a slightly different angle, the multiple images must therefore be ghost images of each other. The various views of the PPC and the galaxies emerging from it are essentially all ghost images.

The time from the Big Bang appears in the Hubble Equations (2), (3), which began with galaxy trajectories emerging from a common point (the Big Bang) at a time t_ω, in the past. t_ω is therefore the time from the Big Bang. Because the Hubble constant is the inverse of the time from the Big Bang, different values of the Hubble constant will arise, depending on the method employed.

6. A Flat Toroidal Cosmos

A simple torus is the only known finite three-dimensional topological manifold which is naturally flat. Some development is required to explain a flat expanding Toroidal Cosmos which conforms to the observed properties of the physical universe, including the modified Hubble Equation (3).

7. Embedding in Higher Dimension

Mathematical models are employed to investigate the properties of geometrical objects and physical objects. Some models, such as quantum mechanics are able to explain physical phenomena which stretch the imagination. Typical models investigate a set of equations which describe an object embedded in a higher dimensional space.

Several examples are provided before developing a flat three-dimensional Toroidal Cosmos.

7.1. Representing a Sphere

The first example embeds a sphere (such as the Earth) in three-dimensional space.

$$u_1 = r \cos(\theta_x) \cos(\theta_y) \quad (15)$$

$$u_2 = r \sin(\theta_x) \cos(\theta_y) \quad (16)$$

$$u_3 = r \sin(\theta_x) \sin(\theta_y) \quad (17)$$

where θ_x is longitude,
θ_y is latitude,
r is the radius of the torus,
(u_1,u_2,u_3) are the coordinates of the same point in the three-dimensional covering space.

Historically, mankind believed that the surface of Earth was flat until it was presented as a sphere embedded in three-dimensional space.

7.2. Product Spaces

Product Spaces provide a compact notation for representing spaces of higher dimensions. A Product Space of two spaces A×B contains elements (a,b) where a is an element of A, a ∈ A and b ∈ B.

Using this notation, a Euclidean plane, R2 can be represented as a Product Space of two real lines, R×R. Equations (15)-(17) define a sphere embedded in 3-dimensional covering space, R3=R×R×R, the product space of three real lines.

7.3. Imagining A Naturally Flat Torus

In topology, a simple torus is presented as the product of two circles (S1×S1). The product S1×S1 consists of points with coordinates (θ_x, θ_y) where θ_x lies on the first circle and θ_y lies on the second circle.
In our three-dimensional universe, a donut or coffee cup is created when a simple torus is continuously deformed. A donut or coffee cup is curved; flatness being lost in the deformation process.
Flatness of the simple torus is established by a conformal mapping of a flat Euclidean plane onto it using the methodology in Section I.0,

$$\theta_x = x \quad (18)$$
$$\theta_y = y \quad (19)$$

where (x, y) are the coordinates of a point on the plane, the Domain Space, a Euclidean plane, (θ_x, θ_y) are the coordinates of a point on the torus, the Target Space.
A flat torus can also be imagined by embedding it in a 4-dimensional covering space,

$$u_1 = \cos(\theta_x) \quad (20)$$
$$u_2 = \sin(\theta_x) \quad (21)$$
$$u_3 = \cos(\theta_y) \quad (22)$$
$$u_4 = \sin(\theta_y) \quad (23)$$

where (θ_x, θ_y) are the coordinates of a point on the torus,
(u_1, u_2, u_3, u_4) are the coordinates of the same point in the covering space.

Another way of imagining a flat torus begins with a tube imagined in Section I.0. To convert the tube into a flat torus, the ends of the tube need to be glued together without crumpling or stretching the tube. This cannot be done in our 3-dimensional universe. The surface will remain flat if one imagines the ability to extend the tube into a 4-dimensional covering space. Imagine rolling up the three-dimensional space containing the tube until the ends connect, creating a torus.

Because of the difficulty in imagining rolling up three-dimensional space in the covering space, an alternative visualization employs a construct from science fiction—a stargate, one placed at each end of the tube (Figure-2). Objects moving past the end of the tube magically appear at the front of the tube. The tube with the ends connected via star gates has a flat geometry and can be better visualized. Note that while star gates exist only in the imagination, but they help to imagine a flat torus.

8. Establishing the Flatness of a Simple 3-Dimensional Torus

In topology, a simple three-dimensional torus is presented as the product of three circles (S1×S1×S1) consisting of points with coordinates $(\theta_x, \theta_y, \theta_z)$ where θ_x lies on the first circle, and θ_y lies on the second circle and θ_z lies on the third circle.
Flatness of the three-dimensional torus is established by a conformal mapping of 3-dimensional space onto it in accordance with the methodology in Section 0.0,

$$\theta_x = x \quad (24)$$
$$\theta_y = y \quad (25)$$
$$\theta_z = z \quad (26)$$

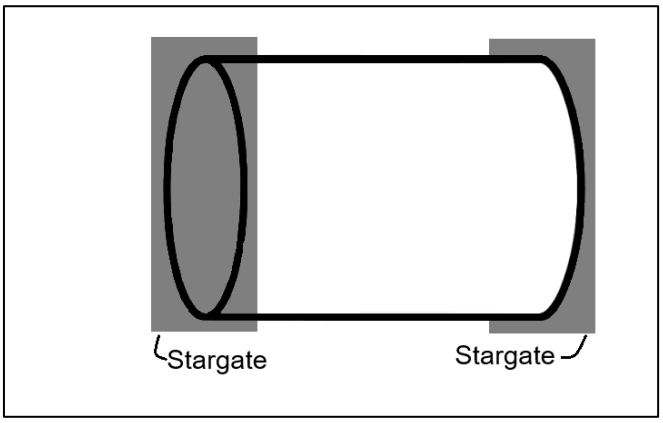


Figure-2. Constructing a Flat Torus Via Stargates

where (x, y, z) are the coordinates of a point on the plane, the Domain Space,
$(\theta_x, \theta_y, \theta_z)$ are the coordinates of a point on the torus, the Target Space.
Equations **Error! Reference source not found.**, **Error! Reference source not found.**, **Error! Reference source not found.** define the Conformal Mapping Function c_f.

9. Embedding a Flat Three-Dimensional Torus in a 6-Dimensional Covering Space

This flat 3-dimensional torus provides the model for a flat Toroidal Cosmos. A flat 3-dimensional torus can be imagined by embedding it in a 6-dimensional covering space,

$$u_1 = S \cos(x/S) \quad (27)$$
$$u_2 = S \sin(x/S) \quad (28)$$
$$u_3 = S \cos(y/S) \quad (29)$$
$$u_4 = S \sin(y/S) \quad (30)$$
$$u_5 = S \cos(z/S) \quad (31)$$
$$u_6 = S \sin(z/S) \quad (32)$$

where (x, y, z) are the coordinates of a point on the embedded three-dimensional torus,
$(u_1, u_2, u_3, u_4, u_5, u_6)$ are the coordinates of the same point in the covering space,
S scales the size of the torus.
Points which satisfy Equations (27)-(32), are equidistant from the origin (0,0,0,0,0,0), providing a radius for the torus! The radius is computed from

$$R_T^2 = S^2 \cos^2(x/S) + S^2 \sin^2(x/S) + S^2 \cos^2(y/S) + S^2 \sin^2(y/S) + S^2 \cos^2(z/S) + S^2 \sin^2(z/S) \quad (33)$$

Applying the trigonometric identity $\cos^2+\sin^2=1$,

$$R_T^2 = 3 S^2 \quad (34)$$

Taking square roots, the radius of the Toroidal Cosmos is computed

$$R_T = S\sqrt{3} \quad (35)$$

where S scales the size of the Toroidal Cosmos,
R_T is the radius of the Toroidal Cosmos.

Conclusion 8. When embedded in the 6-dimensional covering space, the Toroidal Cosmos has a radius although it is not a sphere.

10. A Uniformly Expanding Toroidal Cosmos

Given that recession velocity from the primordial plasma cloud is the same in all directions requires

$$S = v_\omega t_\omega \quad (36)$$

where t_ω time from the Big Bang,
c is the speed of light,
v_ω is the recession velocity from the PPC, $0.94c$,
S scales the size of the Toroidal Cosmos at time t_ω
This cosmological model conforms with the modified Hubble Equation (3). Energy is conserved.

11. An Expanding Toroidal Soap Bubble

The Toroidal Cosmos can be interpreted as an expanding toroidal soap bubble where objects (such as galaxies) are trapped in the surface of the soap bubble. As the torus expands, the trajectories of these galaxies will move along the ray connected to the origin (0,0,0,0,0,0). Galaxies can occupy coordinate positions outside the soap bubble, but at a different time. It is therefore appropriate to use time to measure the differences between positions along the ray in the covering space. It also offers a natural explanation for why particles cannot escape into the covering space except by moving through time.

The expanding Toroidal Cosmos is *Expansion Motivated*. Cosmological simulations show that the velocities from the expansion of the cosmos eventually overwhelm any differences in initial positions.

The observed ghost images are predicted by simulations of the universe with galaxies emerging from a common point some 14 billion years ago. However, the hypothesis of projecting the trajectories of ghost images early galaxies backwards in time requires space to be folded back upon itself to enable the early events in front of us and behind us to occupy the same small volume of space.

12. Predictable Paradoxes

The Toroidal Cosmos can explain seeming inconsistencies in observed data. The Toroidal Cosmos folds back upon itself, explaining ghost images and the universe acting as an echo chamber.
Receding from the PPC at a velocity v_ω=0.94c, the distance moved in 14 billion years is

$$x = v_\omega t_\omega = 13.16 \text{ billion light years} \quad (37)$$

From an alternative perspective, PPC became transparent at a time 13.9997 billion years ago, (300,000 years after the Big Bang), giving an elapsed time of

$$t_{elapsed} = 14 \text{ billion years} - 300{,}000 \text{ years}$$
$$= 13.9997 \text{ billion light years} \quad (38)$$

The total distance traveled must therefore be 13.9997 billion light years, a discrepancy of 840 million light years from the prior equation. The discrepancy becomes explainable when one realizes that the early universe acts as an echo chamber.

13. Extreme Observed Recession Velocities

A realistic simulation of a Toroidal Cosmos begins with random galaxies with relativistic velocities (~0.94c) emerging from the primordial cloud in random directions. For any particular foreign galaxy, consider the plane determined by our galaxy, the foreign galaxy, and the Big Bang event. From our galaxy, the observed recession velocity of the foreign galaxy will lie entirely within that plane, and be modified by the sine of the angle the two rays connecting the origin to two galaxies (our galaxy and the foreign galaxy).

$$v_r = v_\chi \sin(\theta) \qquad (39)$$

where v_χ is the expulsion velocity of a foreign galaxy from the PPC,

v_r is the recession velocity of a foreign galaxy,

θ is the angle between our own galaxy's expulsion vector and the expulsion vector of a foreign galaxy

As time proceeds, the distance between the two galaxies increases, forming the relationship defined by the modified Hubble Equation (3) and Figure-1. Because our galaxy is moving at a relativistic speed, the recession velocity of the second galaxy, when reserved from our perspective, cannot be derived from Newtonian physics, but the Lorentz velocity transform equation (Reference [19]) is needed to compute the recession velocity of the second galaxy when observed by our own, given by

$$v'' = \frac{v - v'}{1 - v\,v'/c^2} \qquad (40)$$

where v is the velocity of the second observer as observed from the first observer,
v' is the velocity of the third observer as observed from the second observer,
v'' is the velocity of the third observer as observed from the first observer,
c is the speed of light.

We place the first observer in our own galaxy, the second observer at the original source of the Big Bang, and the third observer on the foreign galaxy. Suppose that the second galaxy emerges from the Big Bang with a velocity of 0.94c in the opposite direction as our own.

$$v = v_\omega \qquad (41)$$

$$v' = v_\chi \sin(\theta) \qquad (42)$$

$$= -v_\omega \qquad (43)$$

The incorrect Newtonian approach is to add these two velocities yielding a recession velocity of 1.88c.
Applying these values to Equation (40),

$$v'' = \frac{0.94c + 0.94c}{1 + 0.94c \times 0.94c/c^2}$$

$$= 0.998c \qquad (44)$$

This result conforms with Einstein's assertion that the velocity of an object could never exceed the speed of light.

Conclusion 9. Foreign galaxies with recession rates of 0.998c can be expected even when the general expulsion velocities of those foreign galaxies is only 0.94c.
This paradoxical conclusion conforms to an observation from the James Webb Space Telescope (JWST), with a red shift of 11.45 (Reference [22]), with corresponding recession velocity of 0.987c.

14. Merging Galaxies and Iron Poor Stars

Globular cluster galaxies give way to modern elliptical galaxies when galaxies merge together. These mergers are visible throughout the history of the universe (Reference [4]). The pull from the Andromeda galaxy is predicted to merge with our galaxy in about 4.5 billion years (Reference [10]).

These mergers provide a mechanism for the formation of iron-poor stars. When two galaxies merge, globular cluster galaxies become elliptical. The gases surrounding a second galaxy stretches in the direction of the comparative velocity of the second galaxy, after which the shape becomes hopelessly elliptical with long streams of hydrogen gas. Heavier material (including metals) collects in the emerging center, but hydrogen and helium gases tend to keep moving, creating iron-poor tails of gas. Given that free hydrogen gas from the PPC is virtually non-existent (Conclusion 4), it follows that galaxy mergers are probably the principal source of iron-poor gas from which iron-poor stars are formed.

15. Clumping of Material into Early Galaxies

Alpher formulated the relative abundance of hydrogen and helium (Reference [10]) created from the Big Bang. In sharp contrast, the James Webb Space Telescope was pointed at a small section of "blank sky" to find galaxies less than 300 million years young (Reference [3]), possessing surprising amounts of metals (Reference [35]).

While Alpher's theory offers no explanation as to how hydrogen and helium congregate to form the metals and protogalaxies and within the PPC, the formation of the early universe is more consistent with large amounts of metals, already in existence from the Big Bang or very shortly after.

16. Conclusions

An expanding Toroidal Cosmos explains the observed astronomical data, including the modified Hubble Equation (3). Energy is conserved, and the cosmos is finite.

The notion that hydrogen ions and hydrogen gas within a plasma cloud can clump together without a clumping particle is absurd. Hydrogen ions *repel* each other and will not clump. Hydrogen gas molecules do not clump either. More modern cosmological theories are desperate to find heavier "metals" to explain the clumping of hydrogen necessary to form the initial stars (Reference [35]).

The physics of identifying the clumping particle would double the complexity of this paper and therefore beyond its scope. Suffice it to say that it is probably one of those "can't see the forest from the trees" issues. These issues could be resolved with a few simple experiments using a linear particle accelerator. Anyone interested in resolving this issue is welcome to contact the author via email.

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