

The Hubble Constant is a Measure of the Increase in the Energy of the Universe

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ABSTRACT

We postulate the universe to be the three dimensional surface volume of an expanding, hollow, four dimensional hypersphere, called the hypervers. Using current measurements, we find that a hypervers, whose surface volume matches the volume of the observable universe, has a radius of 27.7 billion light years, giving a radial expansion rate of twice the speed of light, and a circumferential expansion rate that matches the Hubble constant. We show that the Hubble constant is a measure of the increase in the energy of the universe, implying the hypervers surface, our universe, is composed of energy. The $2c$ radial expansion both sets the speed limit in the universe, and is the basis of time. The hypersphere model provides a positively curved, and closed universe, and its $2c$ radial expansion rate, and circumferential expansion rate matching the Hubble expansion, give strong support that the universe is the 3D surface volume of an expanding 4D hypersphere.

Subject headings: $2c$ radial expansion of space; basis of time; cosmology; Hubble constant; hypervers; shape of the universe

Introduction

We have probably all seen the balloon analogy of the expanding universe, commonly used to show how galaxies can move apart from one another; dots drawn on the balloon move apart from each other when the balloon is inflated. Arthur Eddington, in 1931, appears to have been the first to describe expansion in this way [1]. The two dimensional surface area of the balloon is intended to represent the three dimensional surface volume of a four dimensional, expanding universe.

But what if the universe was the three dimensional surface volume of a hollow, four dimensional, expanding hypersphere, what we will call a 'hyperverses'? Assuming the universe is indeed a hyperverses produces significant results.

The main idea of this paper is that we can model the universe accurately, and very productively, as the surface volume of an expanding four dimensional hyperverses.

- We find the hyperverses is expanding at twice the speed of light.
- We discuss that the the speed of light appears to be determined by the rate of radial expansion.
- The $2c$ radial expansion rate gives us a basis of time, as we find the direction to which the cosmological arrow of time points.
- The hyperverses circumference is expanding at exactly the expansion rate we measure for the universe, the Hubble constant. This is a significant result.
- We discover a simple and elegant, hyperverses-related, equation for the Hubble constant.
- The Hubble constant is a measurement of the rate that energy is added to the universe.

- The 'front' of the expanding hyperverses is energy. The universe is not a vacuum; space is energy.
- Modeling the universe as the surface volume of a hyperverses is a very productive way to describe the shape of the universe.

1. The Universe as the Surface Volume of a Four Dimensional Sphere

We will start with the concept that space actually exists, consisting of discrete units, vortex-like 'atoms of space'. Lee Smolin [2] wrote of the idea that space might consist of 'atoms of space'. We developed Smolin's idea into a model of how to build elementary particles using a vortex as the basic building block of space [3], and that led to thoughts on the structure of space.

If we assume these vortices take up space, we can ask: "if space takes up space, where is there room for the additional atoms of space created by expansion?"

Packing additional atoms of space into an already full universe is not reasonable. The universe is huge, the atoms of space small, and the addition of space is occurring throughout the universe, meaning the pressure from the added atoms of space would be identical throughout. One clear option is expansion into a fourth dimension.

A hollow, four dimensional hypersphere, or hyperverses, would easily allow, and even require, the addition of new atoms of space as its surface expanded radially into the fourth dimension. Consider a three dimensional sphere such as a balloon, the two dimensional surface area being a 'flatland, 2D universe'. Radial expansion of the balloon (making the balloon bigger) increases its surface area, requiring the addition of more surface area. Every point on the balloon's surface is in total contact with the next higher dimension. A 4D

hypersphere has a 3D surface volume. Just as every point on the 2D surface of a 3D sphere touches the next higher, third dimension, every point on the 3D surface volume touches the next higher, fourth dimension. Despite the universality of the "balloon model" to demonstrate the expansion of space, it appears to not have been examined using the measurements of today's precision cosmology.

2. The Edge of Space is Everywhere

With the universe as the surface volume of a hollow, four dimensional hypersphere, every point in the universe is on the surface of the hypervolume, and we can state that every point in space touches nothingness. The edge of space exists at every point in space; every point in the universe is on the edge of space. The center of the hypervolume, however, does not exist on the surface; it resides at the center of the hypervolume of the hypervolume, in the past. Importantly, every point in the universe lies at the same distance from the center of the hypervolume.

3. The Radius of the Observable Hypervolume

The current radius of the observable universe is around 46 to 46.5 billion light years and the age of the universe was recently revised to 13.8 billion years [4]. We can calculate the radius of the observable hypervolume by setting the surface volume of the 4D hypersphere equal to the 3D volume of our universe:

$$2\pi^2 R_H^3 = \frac{4}{3}\pi r_o^3 \quad (1)$$

where R_H is the radius of the observable hypervolume and r_o is the radius of the observable universe.

Using the mid-value of 46.25 billion light years for the radius of the observable universe, we find the hyperverses radius is 27.5866 billion light years:

$$R_H = (46.25) \sqrt[3]{\frac{2}{3\pi}} \approx 27.5866 \text{ billion light years} \quad (2)$$

4. We are Moving into the Fourth Dimension at Twice the Speed of Light

Since the universe is about 13.8 billion years old, the speed of radial expansion comes to twice the speed of light:

$$\frac{27.5866 \text{ billion light years}}{13.8 \text{ billion years}} = 1.999 \text{ light years per year} \Rightarrow 2c \quad (3)$$

The hyperverses radius is growing at $2c$, meaning the hyperverses surface is moving at two times the speed of light into the fourth dimension. Since every point in the universe is on the front of that expansion, we are moving at two times the speed of light into the fourth dimension.

It is a striking concept, even staggering. In one second of time, we have moved two light seconds of distance, or about 600,000 kilometers, in a direction to which we cannot point. The moon is 384,000 kilometers away, so the distance we move radially, in one second, is about one and a half times the distance to the moon. We are at any location for a truly tiny, fleeting moment. Do we experience or feel this somehow? We will conjecture that this is the basis of time.

Events in the past are indeed far behind us, not just in memory, but in distance, and they occurred in a location which no longer exists because the 'front', the hyperverses surface, has moved radially. We present a model of time, with relativity, in [5].

From the $2c$ radial expansion of space, we can state that the speed of light is one-half the radial expansion rate. The speed of light and the rate of radial expansion appear to be

deeply related, and it appears that the speed of light may be determined by the rate of radial expansion. Nothing can move translationally faster than one-half the radial expansion rate.

5. The Hubble Expansion is the Circumferential Expansion of the Hyperverses

Any two points on the surface of a 4D hypersphere, in any direction, lie upon its circumference. The rate of separation between two points on the circumference of a circle, is the rate of circumferential expansion. The rate of change of the circumference of a circle, relative to the radius, is 2π :

$$\frac{\Delta C_H}{\Delta R_H} = \frac{d(2\pi R_H)}{d(R_H)} = 2\pi \quad (4)$$

The rate of change of the hyperverses radius, ΔR_H , is $2c$. Substituting $2c$ for ΔR_H gives:

$$\Delta C_H = 2\pi \Delta R_H = 2\pi (2c) \quad (5)$$

Dividing the rate of change of the circumference of the hyperverses, $2\pi (2c)$, by the circumference of the hyperverses, gives the fractional change of the circumference, and that value is the Hubble constant:

$$\frac{\Delta C_H}{C_H} = \frac{2\pi (2c)}{2\pi R_H} = \frac{2c}{R_H} = H \quad (6)$$

where H is the Hubble constant, C_H is the hyperverses circumference, ΔC_H is the rate of change of the hyperverses circumference, and c is the speed of light.

Calculating the value of the Hubble constant, based on equation (6), gives us:

$$H = \frac{2c}{R_H} = \frac{2(2.99792458 \times 10^8 \text{ m s}^{-1})}{27.5866 \text{ million light years}} \approx 21.73 \text{ kilometers per second per million light years} \quad (7)$$

The Hubble constant is the measure of the rate of separation of galaxies in the universe, or simply, the rate space expands. Estimates of the Hubble constant range from around

20.78 to 22.69 kilometers per second per million light years [6], and our calculated value falls squarely in this range; the Hubble expansion is the circumferential expansion of the hyperverses.

6. The Mass of the Observable Universe

Fred Hoyle [7] calculated the mass of the universe to be $\frac{c^3}{2GH}$. By substituting our term for the Hubble constant, $\frac{2c}{R_H}$ for H , we get, in hyperverses terms, a mass of $\frac{R_H c^2}{4G}$.

The Schwarzschild radius can be defined as the distance between points at which the accumulated expansion of space produces a separation speed equaling the speed of light. If we divide the speed of light, by the Hubble constant, we get the Schwarzschild radius:

$$R_{schw} = \frac{c}{H} \quad (8)$$

Since the hyperverses is radially expanding at twice the speed of light, at one-half the hyperverses radius, the universe is radially expanding at the speed of light:

$$R_{schw} = \frac{c}{\left(\frac{2c}{R_H}\right)} = \frac{R_H}{2} \quad (9)$$

The equation of the Schwarzschild radius, where G is the gravitational constant and M is mass, is:

$$R_{schw} = \frac{2GM}{c^2} \quad (10)$$

Inserting Hoyle's mass value of $\frac{R_H c^2}{4G}$ into the Schwarzschild radius equation, (10), gives:

$$R_{schw} = \frac{2GM}{c^2} = \frac{2G\left(\frac{R_H c^2}{4G}\right)}{c^2} = \frac{R_H}{2} \quad (11)$$

Fred Hoyle’s mass produces an exact match to equation (9), and thus we will define the mass of the universe, M_o , as:

$$M_o = \frac{R_H c^2}{4G} = 8.8358 \times 10^{52} \text{ kg} \quad (12)$$

7. The Hubble Constant Measures the Change of the Mass and Energy in the Universe

If we take the rate of change of the mass of the observable universe in respect to the radius, we get:

$$\frac{\Delta M_o}{\Delta R_H} = \frac{\Delta \frac{R_H c^2}{4G}}{\Delta R_H} = \frac{c^2}{4G} \quad (13)$$

Rearranging, the rate of change of mass, ΔM_o , is

$$\Delta M_o = \frac{c^2}{4G} \Delta R_H \quad (14)$$

Since $\Delta R_H = 2c$, we see that $\Delta M_o = \frac{c^3}{2G}$:

$$\Delta M_o = \frac{c^2}{4G} (2c) = \frac{c^3}{2G} \quad (15)$$

We can also obtain this value by dividing the mass of the observable universe by the age of the universe, which is the inverse of the Hubble constant:

$$\Delta M_o = \frac{\frac{R_H c^2}{4G}}{\frac{R_H}{2c}} = \frac{c^3}{2G} \quad (16)$$

If we divide the total change in mass, by the total mass of the observable universe, we get the incremental change in mass, which matches the Hubble constant:

$$\frac{\Delta M_o}{M_o} = \frac{\frac{c^3}{2G}}{\frac{R_H c^2}{4G}} = \frac{2c}{R_H} = H \quad (17)$$

From mass-energy equivalence, the Hubble constant is the incremental change in the energy of the observable universe:

$$H = \frac{\Delta E_o}{E_o} = 2.285\,027\,734\,440\,597\,113\,7 \times 10^{-18} \text{ J/s/J} \quad (18)$$

where E_o is the energy of the observable universe, and ΔE_o is the rate of change of energy in the observable universe.

Thus we can argue that the Hubble constant is not just a measure of the rate of separation of galaxies, or of the circumferential expansion of the hyperverses, but is, at a deeper level, a measure of the increase of mass and energy in the observable universe.

The Hubble constant, defined here as 21.73 kilometers per second per million light years, is a value expressed as distance per time per distance. The distance values cancel out; the Hubble constant is a dimensionless number per second, $\frac{2.285 \times 10^{-18}}{\text{s}}$. Therefore, there is no inherent conflict in stating the Hubble constant as $2.285 \times 10^{-18} \text{ J/s/J}$.

This calculation implies that the universe is composed of energy. The difference between space, and the nothingness into which it expands, is the presence of energy, and it is energy that forms the advancing front of the hyperverses. Space exists, and it is energy.

The Universe is the Surface Volume of the Hyperverses

A radial expansion rate of twice the speed of light, and a circumferential expansion rate matching the Hubble constant, are striking observations that are unlikely to be coincidental. Additionally, a universe as the surface volume of a hollow, four dimensional sphere gives us a positively curved, closed, and finite universe. The Hubble constant as a measure of the increase of energy of the universe implies the hyperverses has a surface composed of energy, and this energy is added continually as space expands. These features help make an

expanding multiverse an appealing model for the structure of the universe.

The multiverse model is developed much further in [5], [8], and [9], where we give mechanisms for the creation of time, quanta, and matter and gravity.

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