Knot physics: Dark Energy

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Abstract

We describe features of cosmology in knot physics that have the characteristics of dark energy. Knot physics assumes that spacetime is a branched 4-manifold embedded in a Minkowski 6-space. The cosmology of an embedded spacetime manifold is described by the expansion and contraction of the manifold in the embedding space. We show that the motion of the manifold in the embedding space contributes to the redshift of photons on the manifold. In this way, the embedded manifold model provides an alternative explanation for the redshift data that has been used as evidence for dark energy.

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I. INTRODUCTION

Knot physics is a unification theory that assumes spacetime is a branched 4-manifold embedded in a Minkowski 6-space [1]. In this paper, we discuss a few cosmological features of knot physics, focusing on the cosmological properties of an embedded manifold. In particular, we discuss aspects of this theory that address the same data that are currently explained by dark energy. (A complete list of the assumptions of knot physics can be found in the Appendix of this paper.)

Dark energy is an unknown form of energy that is hypothesized to exist everywhere in space and accelerate the expansion of the universe. Evidence for dark energy comes from redshift data from multiple sources, which indicate that the rate of universal expansion is increasing over time [2]. In this paper, we will describe the cosmology of a closed compact spacetime manifold embedded in a higher dimensional Minkowski space. The embedded spacetime model offers a new contribution to redshift that may explain the data associated with dark energy.

II. A TOY MODEL

In knot physics, we assume the spacetime manifold is embedded in a higher dimensional Minkowski space. For simplicity, we begin by using a toy model, a circular 1+1 spacetime embedded in a 2+1 Minkowski space, to illustrate certain cosmological features of the spacetime manifold (see Fig. 1). A few key features of this toy model are applicable to the general case of a spacetime manifold expanding in a Minkowski space.

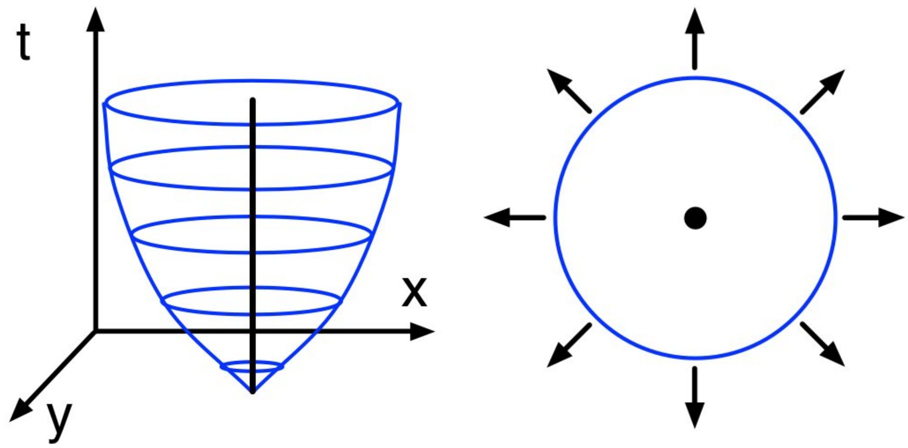

FIG. 1 – On the left is a diagram of the 1+1-manifold embedded in a Minkowski 2+1-space. This is the toy model universe that we will use in this paper. Constant time slices are shown. In each time slice, the spacetime manifold is a 1-manifold S^1, a circle. The diagram illustrates the expansion of the circle over time. The black line indicates the center of the universe. In the diagram on the right, we see one of the time slices with arrows indicating the expansion of the circle away from the center.

III. DARK ENERGY

Dark energy is hypothesized to accelerate the expansion of the universe. Much of the motivation for assuming dark energy comes from comparing the redshift of astrophysical light sources to their estimated distance, for example, by comparing supernova redshifts to their luminosities. The luminosities are used to derive the distance of the supernova and the redshift is used to derive the amount of cosmological expansion that has occurred since the time that the light was emitted by the supernova. Using standard cosmological models, comparison of the luminosity and redshift data suggests that the rate of cosmological expansion is increasing with time. We use our model of an embedded spacetime manifold to show an additional factor that affects redshift and hypothesize that this may explain the data with a rate of universal expansion that is decreasing, rather than increasing, over time.

In Fig. 2, we see a diagram illustrating two different cosmological factors that contribute to a photon's wavelength. We consider an earlier time and a later time in the expansion of this model universe. At the earlier time, a photon leaves the source, labeled A. At the later time, the photon arrives at the destination, labeled B. The source and destination are moving in the radial direction, away from the point that indicates the center of the expanding circular universe. The expansion of the universe stretches the spacetime manifold during the time that the photon is in transit between A and B. Because of the stretching of the spacetime manifold, the photon is also stretched, which increases its wavelength. This is the standard cosmological redshift.

In addition to the standard cosmological redshift, the fact that the manifold is embedded in a higher dimensional space results in a second effect on the photon redshift. The photon is on a manifold that has a radial velocity, $\dot{r}$. For a manifold embedded in a Minkowski space, the expansion of the manifold changes the energy of a particle on the manifold by a Lorentz factor $\gamma = (1 - \dot{r}^2)^{-1/2}$. The initial and final radial velocities are $\dot{r}_i$ and $\dot{r}_f$, which have corresponding factors γ_i and γ_f. We can compute the energy of the photon in the frame where the center of the universe is at rest by combining the Lorentz factor with the formula for photon energy, $E = h\nu$. The initial energy is $E_i = \gamma_i h\nu_i$. The final energy is $E_f = \gamma_f h\nu_f$. There are two contributions to the ratio ν_f/ν_i. One contribution is the redshifting of the photon due to the expansion of the manifold, the cosmological redshift. The other contribution is the relative values of γ_i and γ_f. If the rate of expansion is decreasing, then $\dot{r}_i > \dot{r}_f$, and therefore $\gamma_i > \gamma_f$, which implies the ratio of photon frequencies ν_f/ν_i would be larger than would be expected if only cosmological redshifting were considered. In other words, older photon sources would have a boost to their photon energy that results from the larger radial velocity of the spacetime manifold at the time of emission. This would make older sources appear bluer than one would expect to see in a comparable model that does not include the Lorentz factor. The Lorentz factor contribution offers an alternative explanation for data that has previously been used to imply that the rate of universal expansion is increasing.

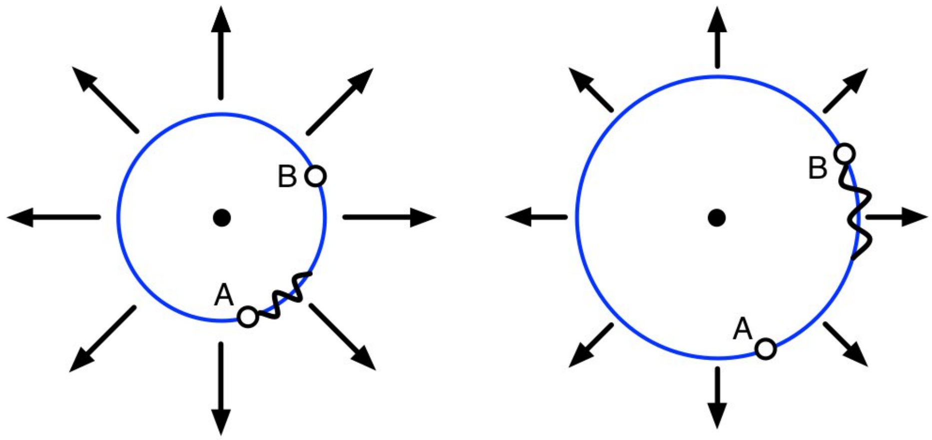

FIG. 2 – The diagrams show an earlier time and a later time in the expansion of this model universe. At the earlier time, a photon leaves the source, labeled A. At the later time, the photon arrives at the destination, labeled B. We assume that the motions of the source and destination are purely in the radial direction, away from the point that indicates the center of the expanding circular universe. Then there are two effects that contribute to the change of photon wavelength. The first effect is the stretching of the spacetime manifold during the time that the photon is in transit between A and B, and this is the standard cosmological redshift. The second effect is that the photon is on a manifold that is in motion. That motion Lorentz transforms the energy E by a factor γ so that the photon energy in the frame of the center of the universe is γE. The factor γ depends on the radial velocity of expansion, which changes with time.

In the embedded universe model, the entire spacetime manifold has an energy associated with its expansion. We can consider the spacetime manifold to be an elastic material that exchanges kinetic energy for potential energy as it expands. We have seen how the energy of expansion is related to photon energy through the Lorentz factor. We now consider how the energy of expansion is related to photon energy through the cosmological redshift. The expansion of the universe has kinetic energy, and that kinetic energy is exchanged for potential energy as the universe expands. A photon on the manifold has linear momentum and it travels on a curved spacetime. The linear momentum of the photon pushes outward on the expanding universe. As the universe expands, some of the kinetic energy of the photon is converted into the potential energy of the expanding universe. The reduction of photon energy causes a corresponding reduction of photon frequency. In this interpretation, the cosmological redshift is a transfer of energy from the photon to the spacetime, as measured in the center of mass frame.

In the embedded universe model, we find that the redshift data associated with dark energy may be explained without requiring the additional assumption of dark energy. Alternatively, we could say that the energy associated with the expansion of the embedded manifold is the dark energy of this theory.

IV. CURVATURE ON A 3+1 MANIFOLD

We used a toy model to demonstrate a few properties of cosmology for embedded manifolds. In some ways, these properties carry over to a 3+1-dimensional spacetime manifold without modification. Regardless of the dimension, expansion of the spacetime manifold implies the manifold has velocity in the embedding space. That velocity produces the properties that were described here as dark energy. The 1+1-dimensional toy model is overly simplistic, however, because the curvature of the 1+1 spacetime manifold is in many ways trivial.

Astronomical observation indicates that the large scale curvature of the universe is flat, to within experimental error. In the Standard Model, cosmological curvature is interpreted as the result of a delicate balance between matter, relativistic particles, and dark energy. In "Knot Physics: Dark Matter"[4], we describe the relationship between cosmological curvature and the fundamental assumptions of knot physics. In particular, we show that the average curvature of the universe is constrained to be zero by the assumptions of knot physics. This eliminates the need to explain a delicate balance between multiple factors.

V. CONCLUSION

In this paper we described the cosmology of a spacetime manifold that is embedded in a higher dimensional Minkowski space. By Lorentz invariance, it is not possible to measure an absolute velocity of a point in the Minkowski space. Measurement at multiple points, however, can provide information that determines the relative velocity of those points in the Minkowski space.

One relevant measurement is redshift. Using the standard cosmological model and astronomical redshift data, it appears that the expansion of the universe is accelerating. This acceleration is attributed to dark energy, whose exact nature remains to be shown. In this paper, we provided qualitative arguments showing that the embedded manifold cosmology of knot physics could also produce a similar redshift effect, without adding any assumptions that were not already present for other reasons. With moderate abuse of terminology, one could say that the kinetic energy of the expanding spacetime manifold is the dark energy of knot physics.

VI. APPENDIX

Knot physics is a unification theory that assumes spacetime is a branched manifold embedded in a Minkowski space. The theory is described in [1], and that description will be helpful for a more complete understanding of this paper. We list the assumptions of knot physics here for reference.

- **We assume a Minkowski 6-space Ω.** The metric on Ω is $\eta_{\mu\nu} = \text{diag}(1, -1, -1, -1, -1, -1)$. The coordinates are x^ν.
- **We assume a branched 4-manifold M embedded in Ω.** A *branch* of M is any closed unbranched 4-manifold B without boundary that is contained in M. The metric $\bar{\eta}_{\mu\nu}$ on M is inherited from Ω. For convenience of coordinates we assume that, if M is flat, then M is in the subspace spanned by x^0, x^1, x^2, x^3.
- **We assume non-self-intersection of each branch of M.** For any branch B, the branch B cannot intersect itself. This is necessary to prevent knots from spontaneously untying.
- **We assume a vector field A^ν.** The field satisfies $\det(A_{\alpha,\mu}A^{\alpha}{}_{,\nu}) = -1$.
- **We assume a conformal weight ρ.** Then we define the metric $g_{\mu\nu} = \rho^2 A_{\alpha,\mu}A^{\alpha}{}_{,\nu}$ and a Ricci curvature $\hat{R}^{\mu\nu}$ based on $g_{\mu\nu}$.
- **We assume a constraint on $g_{\mu\nu}$ relative to $\eta_{\mu\nu}$.** The metrics $g_{\mu\nu}$ and $\eta_{\mu\nu}$ define sets g^+ and η^+, and we assume that g^+ must intersect η^+.
- **We assume Ricci flatness $\hat{R}^{\mu\nu} = 0$ for $g_{\mu\nu}$.**

- **We assume that the weight** $w = (-\det(g))^{1/2} = \rho^4$ **is conserved at branching.**
- **We assume a lower limit** $w \geq 1$**.** This implies that the manifold can branch only a finite number of times.

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[1] C. Ellgen **www.knotphysics.net** Physics on a Branched Knotted Spacetime Manifold

[2] S. Perlmutter et al, Measurements of Omega and Lambda from 42 High-Redshift Supernovae Astrophys.J. (1999) arXiv:astro-ph/9812133

[3] C.L. Bennett et al, Nine-Year Wilkinson Microwave Anisotropy Probe (WMAP) Observations: Cosmology Results Astro-PH (2013)

[4] C. Ellgen **www.knotphysics.net** Knot Physics: Dark Matter