Scale Expanding Cosmos Theory I –An introduction

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A new cosmological theory is presented based on the proposition that all four metrical coefficients of space and time change with the cosmological expansion. Such a universal scale expansion would preserve the four-dimensional spacetime geometry and therefore by general relativity most physical relationships. In addition, if the scale expansion were exponential with time, all epochs would be equivalent. The theory resolves several outstanding problems with the Big Bang theory and better agrees with four observational programs. It also provides a simple explanation to the Pioneer anomaly.

Keywords: Space and time expansion, Space and time Equivalence, Scale expansion, Space and time symmetry, Cosmic drag, Tired light, Pioneer anomaly

1. Introduction

The Standard Cosmological Model (SCM) based on the Big Bang has recently come under scrutiny since it has become increasingly clear that the SCM is difficult to reconcile with modern observations, some

using the Hubble Space Telescope (HST), see for example Bouwens, Broadhurst and Silk, 1998. The modifications to the SCM demanded by new observational findings are numerous and sometimes mutually contradictory, suggesting that the SCM no longer is an accurate cosmological model.

In reviewing the developments that led to the SCM, three important milestones may be identified. The first is Einstein's application in 1917 of his General Relativity (GR) theory to the cosmological problem (Einstein, 1917), proposing a static universe with a Critical Density and a Cosmological Constant. This article pointed the way to future cosmological modeling based on GR, a theory that still is of fundamental importance to cosmology. The second decisive event is the discovery of redshift of cosmological origin that increases with distance by Slipher, 1914, confirmed by Hubble, 1929. The third is the papers by Friedmann 1922 and by Le Maître 1927, in which they showed that a spatially expanding universe could satisfy the GR equations without a cosmological constant. Although Friedmann considered a GR line element with a fixed temporal metrical coefficient and time-varying spatial metric he very carefully pointed out that this merely is a convenient choice of coordinates, since there are innumerable GR-equivalent line elements related by continuous variable transformations. Since the redshift could be explained in Friedmann's spatially expanding universe this type of line element was eventually favoured leading to the Big Bang model with its further refinements that is now the SCM.

This article will introduce an alternate path of development, which leads to a radically different cosmological model.

A basic philosophical and physical difficulty with the SCM is the creation event in which the universe was created instantaneously. This idea is unpalatable because it implies the breakdown of physics at the time of creation, which would make the origin of the universe

forever incomprehensible. Identifying an alternative explanation that could address the origin of the universe while staying within the bounds of physical laws would therefore be quite attractive.

Exploring the question whether there might be a viable alternative to the SCM, which does not imply a creation event, various Steady State theories have been proposed, most notably those by Bondi and Gold (1948), and by Hoyle (1948). These theories assume cosmological spatial expansion that opens up voids between galaxies, which are filled by the creation of new matter, for example the C-field cosmology proposed by Hoyle and Narlikar (1962). The continuous creation of new matter and the Cosmic Microwave Background (CMB) are problematic for these theories. Superposed black body radiation at different redshifts does not preserve the black body spectrum in a spatially expanding universe. Other researchers have proposed stationary models where the cosmological redshift is caused by spacetime curvature, for example Browne, 1995.

As an alternate approach we could consider various variable transformations of the Friedmann-Robertson-Walker (FRW) line element. One particularly interesting possibility is the simultaneous expansion of all four metrical coefficients rather than just the spatial coefficients. Such a symmetric expansion would be equivalent to scale expansion. Developing this idea leads to the Scale Expanding Cosmos (SEC) theory presented in this paper.

The structure of the article is as follows: The justification and reasoning that lead to the SEC theory is presented in section 2. Section 3 discusses scale invariance, which is central to the theory. A new phenomenon, cosmic drag, is introduced in section 4. Section 5 summarizes several problems with the SCM and how they are resolved by the SEC. Section 6 discusses tired light redshift and the Pioneer anomaly is addressed in section 7. Observational evidence for the theory is presented in section 8 and section 9 is the summary.

Throughout this article technical aspects are kept to a minimum. The reader interested in the technical details is referred to the appendices and the references.

This is a first in a series of articles presenting various aspects of the SEC theory.

2. Justifying the SEC theory

The celebrated paradox by Parmenides (born 510 BC) poses the following riddle:

> *Only being **is** - non-being **is not**. But, if only being **is**, there can be nothing outside this being that articulates it or could bring about change. Hence being must be conceived as eternal, uniform and unlimited in space and time.*

Clearly, something that exists cannot have been created from nothingness; put differently *existence rules out non-existence*. Accepting this fundamental conclusion, and taking into account the finding that the universe expands, motivates the search for a cosmological expansion mode without cosmological aging that permits eternal existence. The fact that the universe is scale invariant, as discussed in section 3, naturally leads to the SEC theory. Since there is no absolute cosmological reference scale, the cosmological scale of space and time may eternally change with time.

The SEC universe evolves by changing all four metrical coefficients of space and time while retaining the relationship between the four metrics. This is equivalent to scale expansion. Changing all four metrical coefficients in Minkowski spacetime by the same factor, i.e. the scale of space and time is a well-known gauge symmetry that preserves equivalence. The GR relations are identical for line elements of different scales; all laws of physics modeled by GR are scale invariant. At first we might reject the idea that the scale

of the universe might change with time, but then a valid question would be: "If the scale of bodies in the universe were fixed, what could determine this fixed scale?" Since the GR equations are identical regardless of scale all physics should remain the same and no physical process or feature of the universe can determine the scale. Therefore there is no predetermined scale – all scales should be equivalent. If this is the case, it is possible that the cosmological scale is not fixed but may change with time, which immediately suggests that the cosmological expansion could be an expansion of both space and time.

If this were true, there ought to be no physical difference between different epochs; by symmetry reasons all epochs should be equivalent. The scale expansion could well be eternal, which would eliminate the enigmatic creation event. To preserve temporal symmetry the expansion must be a geometrical progression whereby the universe expands by a constant, miniscule, fraction each second. This means that distance and time scales accelerate relative to a fictional observer in a universe with fixed scale. In such an exponential scale expansion all locations in space and time would be equivalent.

The SEC line element is (with $c = 1$):

$$ds^2 = e^{2t/T}(dt^2 - dx^2 - dy^2 - dz^2) \tag{1}$$

T is the Hubble time.

This line element is defined relative to a cosmological rest frame generated by the scale expansion. This will be discussed in the second paper in this series.

The redshift-distance relation in the SEC is the same as for tired light, which in Appendix 1 is derived from the geodesic for the line element (1). It is caused by the scale expansion and is given by the exponential frequency shift of light with time and distance:

$$f = f_0 \cdot e^{-t/T} = f_0 \cdot e^{-d/cT} \tag{2}$$

$$d = cT \cdot \ln(f_0 / f) = cT \cdot \ln(z+1) \tag{2a}$$

In the SEC there is also time dilation, see further Appendix 1.

3. Scale invariance in the SEC model.

The reader might object that the SEC line element may be transformed into a FRW line element by the transformation *t'=Texp(t/T)* and that therefore the SEC line element does not offer anything new. *However, the SEC line element is physically equivalent for translations in space and time.*

Obviously, the line element remains the same for spatial translations, for example *x=x'+x₀* where *x₀* is a constant position vector.

Temporal translation *t=t'+t₀* gives:

$$ds^2 = e^{2t_0/T} \cdot e^{2t'/T} (dt^2 - dx^2 - dy^2 - dz^2) \tag{3}$$

Einstein's GR equations for this transformed line element are identical to those of the SEC line element; all physical relationships remain the same after a discrete scale change. In general, this also applies to all line elements of the form:

$$ds^2 = S^2 g_{mn} dx^m dx^n; \quad S = \text{Constant} \tag{4}$$

Thus, scale expansion of flat or curved spacetimes does not alter physical relationships; scaled spacetimes are equivalent and scale invariance is a fundamental, universal, gauge invariance.

The SEC line element models the universe from the perspective of an observer at t=0 looking back at the earlier universe for which t<0. By scale invariance the same line element applies to all observers in the SEC universe regardless of epoch. Another way to visualize this scale expansion mode would be to allow the increment of proper time

to change $ds => ds \cdot exp(t_0/T)$ in (3), which would restore the line element (1).

Invoking scale invariance takes us "beyond GR" by generalizing it to include discrete scale transformation. This is the main new idea of the SEC theory. In the SEC context GR models the four-dimensional geometry, but *it does not model the progression of time*, which is modeled by the discretely changing scale. This should not come as a surprise; it is widely known that GR is a purely geometrical construct that will not model the progression of time. GR does not distinguish between the past and the present. Also, there is no provision for changing the pace of proper time in GR, since proper time corresponds to the global reference increment ds. Yet, it is conceivable that the pace of proper time, as measured out by a stationary atomic clock on a geodesic, might change with the cosmological expansion.

To be able to apply GR for modeling the SEC universe, the pace of proper time must be held constant, for example at the present rate, which permits application of the SEC line element and the GR machinery at this particular epoch. With this approach the universe, *as modelled by the SEC line element*, appears denser in the past and the CMB temperature higher. By the pace of present time the age of the universe equals the Hubble time. However, this is true for all observers regardless of their epoch.

In a fourth paper of this series I will show that repeated, discrete, scale expansion could model the progression of time and that this also could provide the missing link between GR and Quantum Mechanics.

The SEC theory implies new physics, and I realize that this might be a deterrent. However, this first paper will show that the SEC line element accurately models the universe as observed.

4. Cosmic drag – a new phenomenon.

In the SEC relative velocities of freely moving objects diminish exponentially, with a time constant that equals the Hubble time. Also, angular momenta of rotating systems dissipate similarly. This new phenomenon, which follows directly from the GR geodesic for the SEC line element, is derived in Appendix 1. Cosmic drag explains the motion of matter in spiral galaxies and predicts that the planets slowly spiral toward the Sun with accelerating angular velocities. Optical observations in the solar system since the intoduction of atomic time have now detected this acceleration, which will be discussed in my second paper.

5. Problems with the SCM in view of the SEC

Most of the following problems with the SCM may be found in the summary by Van Flandern, (2002):

1. The Big Bang creation.

The SEC universe might be eternal. Eternal existence does not violate the laws of physics. It might seem like the universe eventually would run out of energy, but this is not the case if the pace of (proper) time slows down with the expansion. Energy is a relative concept and the progression of time is intimately related to energy. In the SEC energy lost by the spatial expansion is recovered by a slowing pace of time.

2. The horizon problem.

All regions communicate and have always communicated in the SEC. Infinite distance corresponds to infinite redshift. Signals are attenuated by tired light redshift and gradually disappear with increasing distances.

3. The "Omega problem".

If the SCM universe we see today were to be extrapolated back close to the Big Bang creation, the initial ratio of the actual density of matter in the universe to the Critical Density must have differed from unity by a very, very, tiny amount. Any larger deviation would have resulted in a universe that either should have already collapsed or dissipated by expansion. This seems like too much of a coincidence. However, in the SEC universe the scale may expand forever without changing the relationship between the four spacetime metrics or the geometry. Scale expansion preserves all physics including all relative distances. The cosmological mass density always remains the same.

4. The age problem.

In an eternal universe objects like stars, galaxies, clusters, filaments, walls etc. may be much older than the Hubble time.

5. The universe has too much large-scale structure.

The SEC universe could be limitless in time and space permitting the existence of formations at all scales

6. Invisible dark energy of unknown but non-baryonic nature dominates the universe.

In the SEC universe the energy-momentum tensor for vacuum does not disappear. Informally it might be viewed as consisting of two different parts. A Cosmological Constant with a temporal mass density component T_{00} equal to the Critical Density and a positive cosmological pressure. The Cosmological Constant corresponds to negative energy density due to the spatial expansion, which is exactly balanced by positive energy density due to the temporal expansion. Although the net gravitating energy disappears in the SEC universe, spacetime contains vacuum energy, see further Appendix 2.

7. Very distant galaxies in the Hubble Deep Field show insufficient evidence of evolution, with some of them having higher redshifts (z=6-7) than the highest redshift quasars.

All epochs are equivalent in the SEC universe. There is no cosmological evolution; on the average high redshift galaxies are similar to nearby galaxies.

8. The end of the universe.

The much-discussed end of the universe is in the SCM almost as enigmatic as the creation event. The SEC universe does not change with time; there is no beginning and no end.

9. Accelerating expansion.

Recent supernovae Ia observations suggest that the cosmological expansion accelerates (see the papers by Perlmutter *et al.*, Riess *et al.* and Schmidt *et al.*). However, the supernova Ia observations agree with the SEC theory's predictions; there is no cosmological acceleration, see Figure 4 and section 8.

10. Nature of the cosmological redshift.

In the SCM model the cosmological redshift is caused by the expanding space, which would generate redshift similar the Doppler shift. However, this redshift mechanism does not agree with several cosmological tests, (see below), while the SEC theory's redshift appears to be consistent with these tests.

11. The Cosmic Microwave Background (CMB).

The almost perfect black body spectrum of the CMB is taken as evidence for its origin; it is believed to have originated with the primordial plasma following the Big Bang. The fact that the Planck spectrum is not preserved during spatial expansion of the SCM strongly suggests that the CMB radiation has been cooling down with the cosmological expansion from an initially very high temperature. However, in the SEC universe the Planck spectrum is preserved much like in a classical cavity and the CMB is a consequence of temperature equilibrium between radiated energy and energy dissipated by tired light redshift, see further section 6.

12. Spiral galaxy formation.

The rotation curves of spiral galaxies typically are flat and these galaxies usually exhibit a well-defined structure that cannot be explained by standard physics. Simulations show that the standard laws of physics cannot create the spiral shapes we observe. Well-defined spiral arms do not form and the rotating disc is too thick.

In the SEC universe galaxies could be very old objects in which matter continuously is falling toward the cores due to cosmic drag. Since we only see a few distinct galaxy types, these structures may remain stable over long time spans. Preservation over such long time requires that most galaxies be in steady state conditions with matter steadily flowing inwardly at the same rate for all radial distances. This simple condition, which is required to preserve the structure, will automatically create the flat velocity curves and form the observed spiral shapes. This will be discussed in my second paper.

13. The Pioneer anomaly.

The SEC model explains the Pioneer anomaly, see section 7.

6. A few comments in defense of the tired light redshift distance relation.

The belief is widespread that recent supernovae Ia observations definitely refute tired light redshift. This is discussed below and in section 8, where ample evidence in favour of the tired light distance-redshift relation is presented. I will show that the temporal expansion in the SEC eliminates several objections to tired light.

The most common arguments levelled against tired light are (Wright, 2001):

- ***There is no known interaction that can degrade a photon's energy without also changing its momentum, which leads to a blurring of distant objects. This is not observed.***

In any GR model for an expanding universe there always is a corresponding relationship between distance and redshift. In the SEC model like in the de Sitter model this redshift-distance relationship is the tired light relation.

Thus tired light redshift is a cosmological spacetime effect in the SEC that results from the scale expansion. One might say that it is a gravitational effect since it can be derived directly from the GR geodesic (see Appendix 1), but this would suggest that it is caused by some kind of spatial energy density gradient, which is not the case.

- ***The tired light model can not produce the blackbody spectrum of the CMB.***

It is well known that Planck's spectrum is retained during the cosmological expansion if the energy density is diluted by a factor $1/(1+z)^4$ and the temperature simultaneously is reduced by a factor $1/(z+1)$, see for example Masreliez, 1999. The Planck spectrum is preserved during cosmological scale expansion in the SEC, which is four-dimensional rather than three-dimensional. According to the SEC line element, all three spatial dimensions expand by the factor *exp(t/T),* or by *(z+1)* according to the redshift relation (2a). Therefore a volume element expands by *(z+1)³* and the energy density is diluted by *1/(z+1)³*. In the SEC the fourth dilution factor comes from the temporal expansion. This new and unfamiliar aspect will here be investigated in some detail.

Consider the scalar product for the momentum:

$$p_m p^m = m^2 = g_{mn} p^n p^m =$$

$$g_{00}(p^0)^2 + g_{11}(p^1)^2 + g_{22}(p^2)^2 + g_{33}(p^3)^2 \qquad (5)$$

With the SEC line element we get:

$$m^2 = e^{2t/T}((p^0)^2 - (\bar{p})^2)$$

The last term is the ordinary spatial momentum vector.

For a photon $m = 0$ and the spatial momentum equals the energy:

$$E_{ph}{}^2 = (p^0)^2 = (\bar{p})^2$$

p_0 is a constant of motion in GR. Lowering the indices on the left hand side we get:

$$(e^{-2/T} p_0)^2 = (\bar{p})^2$$

Thus, according to GR the photon energy decreases exponentially with time in the SEC with a time constant $T/2$:

$$\left|\bar{p}\right| = p^0(t) = p_0 \cdot e^{-2t/T} \rightarrow E_{ph}(t) = \text{Constant} \cdot e^{-2t/T} \qquad (6)$$

However, in general the momentum satisfies:

$$\left|\bar{p}\right| = m_0 \frac{dx}{d\boldsymbol{t}} = m_0 \frac{dx}{dt}\frac{dt}{d\boldsymbol{t}} = m_0 \frac{dx}{dt} e^{-t/T} \boldsymbol{g} = m \frac{dx}{dt} e^{-t/T} \qquad (7)$$

Denoting the momentum *relative to atomic time t* by:

$$\left|\bar{p}\right|_t = m \frac{dx}{dt}$$

$$\left|\bar{p}\right| = \left|\bar{p}\right|_t e^{-t/T} \qquad (7a)$$

On the other hand, with the corresponding spatially expanding (de Sitter) line element (with constant temporal metric) we get from (5):

$$m^2 = 0 = (p^0)^2 - e^{2t/T}(\overline{p})^2 = (p_0)^2 - e^{2t/T}(\overline{p})^2$$

$$(\overline{p})^2 = e^{-2t/T}(p_0)^2 \rightarrow E_{ph}(t) = \text{Constant} \cdot e^{-t/T} \qquad (8)$$

Comparing (8) to (6) the additional factor $e^{-t/T}$ in (6) is due to the temporal expansion and provides the fourth dilution factor $1/(z+1)$. Therefore, Planck's black body spectrum is preserved in the SEC.

Note that GR does not model the universe as experienced by an inhabitant in the past; it models how it would appear if the pace of proper time were constant during the cosmological expansion. As modelled by GR with the SEC line element it appears that the CMB temperature was higher at redshift z at an elevated temperature $Tz=(z+1)T_{CMB}$. In Masreliez, 1999 I reach the same conclusion using the line element (A1.20) of Appendix 1. However, by scale invariance, which is not covered by GR, an earlier observer at redshift z saw the same CMB temperature as presently is seen locally. In other words, interpreting the CMB in the context of GR would give the impression that the CMB was generated at an earlier time at redshift z and temperature $(z+1)T_{CMB}$. This is also consistent with black body radiation energy density proportional to $[(z+1)T_{CMB}]^4$, which by the cosmological expansion has been diluted by the factor $1/(1+z)^4$.

The tired light model does not predict the observed time dilation of high redshift supernova light curves.

Like in the SCM there is both redshift and time dilation in the SEC (see Appendix 1). In the SCM there are two cosmological dimming factors $1/(z+1)$; one is due to the redshift, the other to time dilation, which often is explained as being caused by a spatial recession velocity. These two dimming factors are also present in the SEC where there is no recession, see further Appendix 1. Since there is both redshift and time dilation in the SEC, the model agrees with the supernovae observations (Appendix 3).
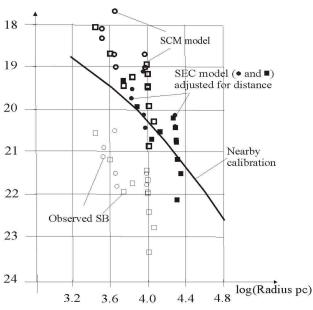
Figure 3: Surface brightness comparison
Circles: I band data for cluster Cl1604+4304 at z=0.90
Squares: I band data for cluster CL1324+3011 at z=0.76

The tired light model fails the Tolman surface brightness test.
     It agrees with the Tolman test if there also is time dilation (Figure 3). In the SEC all distances remain the same on the average during the cosmological expansion, as measured by timing a light beam, and therefore surface brightnesses decrease in proportion to $1/(z+1)^2$ rather than $1/(1+z)^4$, see Section 8.

7.   The Pioneer anomaly is direct evidence for tired light redshift.

A simple resolution of the Pioneer 10 anomaly is direct evidence for tired light redshift of cosmological origin in the solar system as modelled by the SEC. This anomaly, which has remained unresolved for two decades in spite of extensive investigation by the Jet Propulsion Laboratory (Anderson *et al.*, 2002), has by JPL been interpreted as acceleration of unknown origin of about $7.5 \ 10^{-8}$ cm/s^2 toward the Sun. What is actually detected, and interpreted as acceleration, is a discrepancy between a directly measured frequency shift of the signal returned from the space probe and a modelled Doppler shift based on estimating the velocity if the space probe using ranging measurements. Discrepancies between measured and modelled frequency shifts have also been noted with Pioneer 11 and with the Ulysses and Galileo spacecrafts, indicating possible cosmological origin.

Assuming that the measured frequency shift correctly accounts for the velocity, JPL has been interpreting the discrepancy as being due to unmodeled constant acceleration directed toward the Sun. However, if there is tired light redshift in the solar system, the signal returned by the probe would in addition to the Doppler induced frequency shift be redshifted by tired light.

If the SEC theory is right the anomalous acceleration of Pioneer 10 is $a=c/T$. With the measured $a= 7.5 \ 10^{-8}$ cm/s^2 we get T=12.7 billion years in good agreement with independent estimates of the Hubble time. JPL also has noticed annual modulation of the anomaly with min and max values occurring when the Sun, Earth and the space probe align. Obviously, this cannot be a Doppler effect but could be caused by distance dependent tired light redshift when the Earth orbits the Sun. The estimated SEC tired light modulation agrees well with

the observed values (Masreliez, "Explaining the Pioneer 10 acceleration anomaly").

8. Astronomical observational evidence in favor of the SEC theory

Several investigators beginning with Edwin Hubble have argued that astronomical observations better agree with tired light than with the Doppler-like redshift of the SCM. In an important paper Paul LaViolette, 1986 presents clear observational evidence showing that tired light agrees with several cosmological tests without resorting to any of the speculative evolutionary scenarios needed to reconcile the observations with the SCM. But, unfortunately this significant contribution has largely been ignored. Since 1986 our observational capabilities have improved dramatically with new tools like the HST and Very Long Baseline Interferometry (VLBI) and it has become clear that the SCM simply does not agree with the observations.
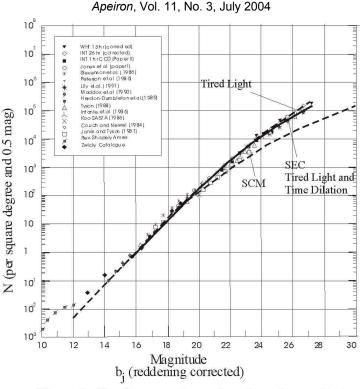
The following paragraphs will discuss four observational programs, the galaxy number count test, the angular size test, the surface brightness test and the supernovae Ia observations.

Figure 1: Number count as a function of magnitude.

The number count test.

This test was originally designed to discriminate between competing cosmological theories. Any candidate cosmological model should be able to predict how the number of galaxies (galaxy count) increases with distance. Since the luminosity depends on the distance there also is a corresponding test for number count as a function of luminosity. Figure 1 shows a summary from sixteen different number count programs taken from a paper by Metcalf *et al.*1995. The SCM model
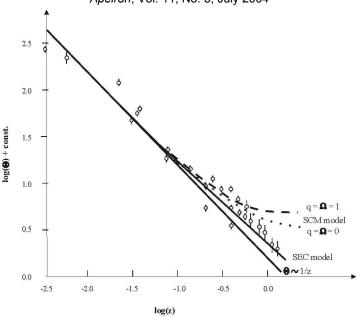
Figure 2: Angular sizes vs. redshift

clearly fails the test, while the SEC model agrees well with the observations.

The angular size test.

The angular size of a cosmological object, for example a galaxy, may be used to test candidate models. The SCM predicts that the angular size will start to increase with distance beyond a certain distance of minimum size, while the SEC predicts that it will decrease monotonically with increasing distance. Figure 2 is from a paper by Djorgovski and Spinrad, 1981. The tired light prediction has been added. Clearly, The SEC model's agreement with the observations is superior.

The surface brightness test.

The Surface Brightness test is a powerful and robust discriminator between candidate cosmos theories (Tolman, 1930). According the SCM, surface brightness scales with redshift in proportion to $1/(1+z)^4$. One factor $1/(1+z)^2$ is due to redshift and time dilation and an additional factor $1/(1+z)^2$ comes from the viewing angle, which decreases with the cosmological expansion (Lubin and Sandage IV, 2001). On the other hand, in the SEC universe the distance and the viewing angle remain constant during the scale expansion and the surface brightness is proportional to $1/(1+z)^2$, see Appendix 1. The difference between the fourth and the second power of $(1+z)$ becomes large at high redshifts, which makes the surface brightness test very powerful. Observational results reported by Lubin and Sandage (2001) show that the SEC theory agrees with observed galaxy surface brightnesses while the SCM does not. The solid line in Figure 3 is the calibrated surface brightness baseline estimated from nearby galaxies. Observed galaxy luminosities in the I-band at z=0.75 and z=0.90 corrected by the factor $(1+z)^2$, and with the radii adjusted to the SEC model, agree well with the local surface brightness (filled symbols). However, there is disagreement with the SCM as shown by the heavier outlined open symbols.

The supernovae Ia observations.

The recently reported supernovae Ia (SNe Ia) observations by the Supernova Cosmology Project (Perlmutter *et al.* 1995) and by the High-Z Supernova Search Team (Schmidt *et al.* 1998) show that these observations do not agree with the SCM unless the cosmological expansion accelerates. However, as shown in Figure 4

the SNe Ia observations agree well with the theoretical predictions of the SEC model, see further Appendix 3. This good agreement with the SEC model is obtained without any adjustable parameters.

Thus, five independent observational programs (including the Pioneer) all agree with theory if there is cosmological redshift and time dilation according to the SEC model. On the other hand, the SCM model disagrees with all five programs.

9. Summary

A new cosmological theory is presented, the Scale Expanding Cosmos theory, based on the proposition that all four metrical coefficients of space and time expand. This corresponds to cosmological scale expansion by which all locations in space and time are equivalent. Scale expansion preserves the spacetime geometry and all laws of physics.

Not only does the SEC resolve a number of conceptual and philosophical problems encountered with the SCM but it also agrees with observations where the SCM fails. In short, the SEC universe looks and behaves just like our universe.

The proposition that the cosmological scale expands is new and perhaps unfamiliar. However, since four-dimensional scale invariance is well-known gauge symmetry in physics it is not unreasonable that the cosmological scale might change with time. Like with the Copernican worldview, which challenged the belief that the Earth is immovable, the SEC theory challenges the belief that the cosmological scale always has remained the same.

The Standard Cosmological Model assumes that the spatial expansion only takes effect between galaxies. In other words, space presumably expands between galaxies but not within them. On the

other hand, by the SEC model space and time expands uniformly everywhere and at all levels.

Tired light redshift and time dilation of the SEC theory agrees with several cosmological tests where the SCM fails and would provide a simple explanation to the Pioneer 10 anomaly if the Hubble time is about 13 billion years.

Thus, the SEC theory agrees well with observational data and resolves many issues, which makes further investigation worthwhile. Fortunately, cosmic drag will soon either confirm or falsify the theory. Although the planetary accelerations predicted by the theory are quite small, modern astronomical optical observations are sufficiently accurate to detect cosmic drag in the solar system, since positional deviations from the Post-Newtonian predictions increase quadratically with time. This will be discussed in my second paper.

Of course, the SEC theory is quite unorthodox since it would invalidate basic laws of physics, for example Newton's first law of motion. However, the theory is conceptually simple with only one free parameter, the Hubble time, and it is based on two fundamental symmetries of the universe – scale invariance and equivalence between all locations in space and time.

The reader might still feel somewhat uneasy about the SEC theory, since it relies on new, unproven, physics. However, if one accepts that the scale of spacetime is not absolute and might change with time, all epochs should be equivalent by symmetry. If true, it should be possible to model the universe with the same line element regardless of epoch, but this is impossible in GR. We must conclude that either different epochs are not equivalent, or GR falls short when trying to model a scale expanding universe. Accepting the second possibility leads to the SEC theory and, as we shall see in subsequent papers, an explanation to the progression of time and a link between General Relativity and Quantum Mechanics (QM).

This is the first in a planned series of articles presenting different aspects of the SEC theory. Three additional papers are in process:

- Second paper: Cosmic drag – observational evidence and galaxy formation.
- Third paper: Gravitation in the SEC – truncation of the gravitational field at the Hubble distance, gravitational field energy and the prevention of black holes.
- Fourth paper: A link between GR and QM.

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APPENDICES

Appendix 1. Geodesics in the Scale Expanding Spacetime

The General Relativity geodesic relations are given by:

$$\frac{d^2 x_a}{ds^2} + \Gamma_{mn}^{a} \cdot \frac{dx_m}{ds}\frac{dx_n}{ds} = 0 \qquad (A1.1)$$

Γ_{mn}^{a} are the Christoffel symbols, which for the SEC line element:

$$ds^2 = e^{2t/T}(dt^2 - dr^2 - r^2 dq^2 - r^2 \sin^2(q)\, dj^2)$$

with $x_0 = t$; $x_1 = r$; $x_2 = q$; $x_3 = j$ are given by:

$$\Gamma_{00}^{0} = 1/T;\; \Gamma_{11}^{0} = 1/T;\; \Gamma_{22}^{0} = r^2/T;\; \Gamma_{33}^{0} = r^2 \cdot \sin^2(q)/T \quad (A1.2)$$

$$\Gamma_{01}^{1} = \Gamma_{10}^{1} = 1/T \;\; \Gamma_{22}^{1} = -r \qquad \Gamma_{33}^{1} == r\sin^2(q)$$

$$\Gamma_{02}^{2} = \Gamma_{20}^{2} = 1/T \;\; \Gamma_{12}^{2} = \Gamma_{21}^{2} = 1/r \;\; \Gamma_{33}^{2} = -\sin(q)\cos(q)$$

$$\Gamma_{03}^{3} = \Gamma_{30}^{3} = 1/T \;\; \Gamma_{13}^{3} = \Gamma_{31}^{3} = 1/r \;\; \Gamma_{23}^{3} = \Gamma_{32}^{3} = \cos(q)/\sin(q)$$

All other Christoffel symbols are zero.

The geodesic equations are:

$$\frac{d^2t}{ds^2} = -\frac{1}{T}[(\frac{dt}{ds})^2 + (\frac{dr}{ds})^2 + r^2 \cdot (\frac{d\boldsymbol{q}}{ds})^2 + r^2 \cdot \sin^2(\boldsymbol{q}) \cdot (\frac{d\boldsymbol{j}}{ds})^2] \qquad (A1.3)$$

$$\frac{d^2r}{ds^2} = -\frac{2}{T}(\frac{dt}{ds})(\frac{dr}{ds}) + r \cdot (\frac{d\boldsymbol{q}}{ds})^2 + r \cdot \sin^2(\boldsymbol{q}) \cdot (\frac{d\boldsymbol{j}}{ds})^2 \qquad (A1.4)$$

$$\frac{d^2\boldsymbol{q}}{ds^2} = -\frac{2}{T}(\frac{dt}{ds})(\frac{d\boldsymbol{q}}{ds}) - \frac{2}{r} \cdot (\frac{d\boldsymbol{q}}{ds})(\frac{dr}{ds}) + \sin(\boldsymbol{q}) \cdot \cos(\boldsymbol{q}) \cdot (\frac{d\boldsymbol{j}}{ds})^2 \qquad (A1.5)$$

$$\frac{d^2\boldsymbol{j}}{ds^2} = -\frac{2}{T}(\frac{dt}{ds})(\frac{d\boldsymbol{j}}{ds}) - \frac{2}{r} \cdot (\frac{d\boldsymbol{j}}{ds})(\frac{dr}{ds}) - 2 \cdot \frac{\cos(\boldsymbol{q})}{\sin(\boldsymbol{q})} \cdot (\frac{d\boldsymbol{j}}{ds})(\frac{d\boldsymbol{q}}{ds}) \qquad (A1.6)$$

The first terms on the right hand side model a new physical phenomenon – "cosmic drag" (Masreliez, 1999).

Solving for radial motion setting $dr/dt = v = \boldsymbol{b} \cdot c$ and $v(0) = \boldsymbol{b}_0 \cdot c$:

$$\boldsymbol{b} = \frac{\boldsymbol{b}_0 \cdot e^{-t/T}}{\sqrt{1 - \boldsymbol{b}_0^2 + \boldsymbol{b}_0^2 \cdot e^{-2t/T}}} \qquad (A1.7)$$

$\boldsymbol{b}$ is the velocity of a free particle on a geodesic in the SEC. If the initial velocity equals the speed of light so that $\boldsymbol{b}_0 = 1$ it follows that $\boldsymbol{b} = 1$ for all times. A photon will therefore always move at the speed of light. On the other hand, if the inital velocity is less than the speed of light the velocity decreases with time.

In particular if $\boldsymbol{b}_0 << 1$:

$$\boldsymbol{b} = \boldsymbol{b}_0 \cdot e^{-t/T} \qquad (A1.8)$$

$$\dot{\boldsymbol{b}} = -\boldsymbol{b}/T$$

This property of the SEC is cosmic drag. The length of a geodesic, *Lr*, for a particle with non-zero rest mass is finite and may be obtained by integrating (A1.7) from zero to infinity:

$$Lr = T \cdot \ln\left(\sqrt{\frac{1 + \boldsymbol{b}_0}{1 - \boldsymbol{b}_0}}\right) \qquad (A1.9)$$

Setting:

$$z_0 + 1 = \sqrt{\frac{1 + \boldsymbol{b}_0}{1 - \boldsymbol{b}_0}}$$

We get:

$$L_r = T \cdot \ln(z_0 + 1) \qquad (A1.10)$$

(The expression (A1.9) for *Lr* is wrong in Masreliez, 1999.)

The cosmological redshift when the particle finally has come to rest is the same as the initial Doppler redshift. It may be shown that the redshift remains the same at all times giving the impression that the particle moves at a constant speed rather than being slowed by cosmic drag.

Thus, relative velocities of freely moving particles with non-zero rest mass will decrease with time in the SEC. Since these geodesics have finite lengths, all particles will converge toward the same frame. Therefore, all inertial coordinate systems will merge into one single reference system. This also implies asymmetry in the equations of motion defining the direction of time.

Similarly we find by setting $d\boldsymbol{j} = 0$ in (A1.5) that the angular momentum decreases with time in the SEC. Proceeding as above we get:

$$r^2 \cdot \dot{\boldsymbol{q}}^2 = \frac{r_0^4 \cdot \dot{\boldsymbol{q}}_0^{\,2} \cdot (1 - \dot{r}^2) \cdot e^{-2t/T}}{r^2 \cdot [1 - \dot{r}_0^{\,2} - (r_0 \cdot \dot{\boldsymbol{q}}_0)^2] + r_0^4 \cdot \dot{\boldsymbol{q}}_0^{\,2} \cdot e^{-2t/T}} \qquad (A1.11)$$

For velocities much lower than the speed of light this reduces to:

$$r^2 \cdot \dot{\boldsymbol{q}} = r_0^{\,2} \cdot \dot{\boldsymbol{q}}_0 \cdot e^{-t/T} \qquad (A1.12)$$

The angular momentum decreases with time. The energy of a particle with mass m and rest mass m_0 is given by:

$$E = m = \frac{m_0}{\sqrt{1 - \boldsymbol{b}^2}} \qquad (A1.13)$$

From (A1.7) this implies:

$$E = \frac{m_0}{\sqrt{1 - \boldsymbol{b}_0^2}} \cdot \frac{\boldsymbol{b}_0}{\boldsymbol{b}} \cdot e^{-t/T} = E_0 \cdot \frac{\boldsymbol{b}_0}{\boldsymbol{b}} \cdot e^{-t/T} \qquad (A1.14)$$

For a photon with frequency $\boldsymbol{n}$ we have $\boldsymbol{b}_0 = \boldsymbol{b} = 1$ and

$E = h\boldsymbol{n}$ so that:

$$\boldsymbol{n} = \boldsymbol{n}_0 \cdot e^{-t/T} \qquad (A1.15)$$

This is the tired light redshift mechanism.

In the SCM there is redshift, popularly (but not quite correctly) explained as a Doppler effect. There is also time dilation, which diminishes the photon arrival rate and further reduces the observed flux. The SEC line element may be transformed into a line element of the FRW (Friedmann-Robertson-Walker) type, which models expanding space rather than expanding space and time (scale) and therefore is similar to the SCM line element in that it exhibits both redshift and time dilation. Since all line elements that can be derived via continuous variable transformations are equivalent in General Relativity, the observed luminosity in the SEC universe should diminish not only by the redshift, which contributes with a factor $1/(1+z)$, but there should also be additional cosmological extinction, which contributes by the same factor.

The SEC line element can be transformed into a FRW line element by:

$$u = T \cdot e^{t/T} \tag{A1.17}$$

$$ds^2 = du^2 - (\frac{u}{T})^2 (r^2 dq^2 + r^2 \sin^2(q)\, dj^2) \tag{A1.18}$$

At $t=0$ and $u=T$ both line elements are Minkowskian and we have $dt=du$. Since these line elements are physically equivalent the photon arrival rate should be the same and since there is both redshift and time dilation in the FRW line element the same is true in the SEC universe.

Another way to see this is to use the transformation:

$$t' = T \cdot \cosh(r/T) \cdot e^{t/T} \tag{A1.19}$$
$$r' = T \cdot \sinh(r/T) \cdot e^{t/T}$$

The SEC line element transforms into:

$$ds^2 = dt'^2 - dr'^2 - r^2 \cdot e^{2t/T}(dq^2 + \sin^2(q) \cdot dj^2) \tag{A1.20}$$

Here r and t in the last term are implicitly defined by the two relations above. With this line element there is neither redshift nor time dilation for radial light propagation, but the received light intensity is diluted inversely proportional to the surface element:

$$(r \cdot e^{t/T})^2 = [T \cdot \ln(1+z) \cdot (1+z)]^2$$

This agrees with the SEC luminosity relation (c=1).

$$I = \frac{L}{4p \cdot [T \cdot \ln(1+z) \cdot (1+z)]^2} \tag{A1.21}$$

However, the luminosity relation presented in Masreliez 1999, which is the traditional relation for tired light redshift, is incorrect since the second factor $1/(1+z)$ is missing. Again, since there are two dimming factors $1/(1+z)$ in the SEC model, there is both redshift and time dilation, like in the SCM model.

In the SEC universe the cosmological scale expansion does not change the average distances between galaxies or their angular sizes, since the metrical coefficients of both space and time expand.

Appendix 2. The Cosmic Energy Tensor

The assumption that the only contribution to the energy-momentum tensor is the cosmological mass distribution is questionable since it appears that the universe contains more energy than what is contained in baryonic mass and radiation. This has motivated a so far futile search for the missing mass. However, there is another possibility - perhaps the assumption that the cosmic energy is dominated by mass is erroneous.

Einstein's General Relativity equations are usually stated in a form, which may be interpreted as saying that the curving of spacetime (left hand side) is caused by the energy density (right hand side). However, these equations may also be put in the equivalent form:

$$T_{mn} - \frac{1}{2} g_{mn} \cdot T = K^{-1} \cdot R_{mn} \qquad (A2.1)$$

This relation could be interpreted as saying that the energy distribution in the universe is caused by spacetime curvature. The view that the geometry of spacetime defines the energy-momentum tensor is as valid as the view that the energy-momentum tensor decides the geometry of spacetime. Both views apply - the energy defines the spacetime geometry and vice versa.

Instead of postulating some energy-momentum tensor and then deriving the corresponding line element, I will take the opposite approach and assume that a certain spacetime curvature determines the energy-momentum tensor for vacuum. This curving of spacetime is generated by the scale expansion and the energy momentum tensor for vacuum is the tensor satisfying Einstein's General Relativity

equations given the SEC line element. The energy-momentum tensor for vacuum therefore directly follows from the principle of scale equivalence.

Substituting the metrics given by the line element into Einstein's GR relations we find that these relations are satisfied with the following energy momentum tensor $T_{\mu?}$ setting $c = 1$:
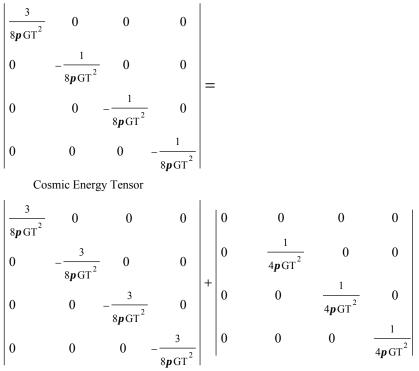
$$T_{00} = \frac{3}{8\mathbf{p}\,GT^2} \qquad\qquad (A2.2)$$

$$T_{11} = T_{22} = T_{33} = -\frac{1}{8\mathbf{p}\,GT^2} \qquad\qquad (A2.3)$$

The off-diagonal elements are all equal to zero. The equivalent mass density corresponding to the energy density component T_{00} equals the critical mass density. Therefore, there is no missing mass - spacetime itself contains energy equivalent to the critical mass density.

The tensor $T_{\mu?}$ could be the fundamental energy-momentum tensor for the cosmos - the energy-momentum tensor of vacuum. I will call it the "Cosmic Energy Tensor". It is invariant for all fundamental observers regardless of their location or epoch.

The equivalent gravitating energy corresponding to the Cosmic Energy Tensor is zero since the sum of the diagonal elements is zero (zero equivalent mass density). This suggests that, although the net energy content of vacuum is zero, *the energy-momentum tensor of vacuum is not identically equal to zero.* The principle of equivalence implies a Cosmic Energy Tensor with zero net gravitational energy consisting of components, which contribute equal amounts of positive and negative energy. The spatial expansion corresponds to a Cosmological Constant (equal to $3/T^2$) with negative equivalent energy. This negative energy is in the SEC balanced by the temporal expansion, which has the effect of generating a cosmological pressure

with positive energy density. Informally, the Cosmic Energy Tensor may be viewed as the sum of a Cosmological Constant corresponding to the spatial expansion and a "Field Pressure" due to the temporal expansion.

$$
\begin{vmatrix}
\dfrac{3}{8\pi GT^2} & 0 & 0 & 0 \\
0 & -\dfrac{1}{8\pi GT^2} & 0 & 0 \\
0 & 0 & -\dfrac{1}{8\pi GT^2} & 0 \\
0 & 0 & 0 & -\dfrac{1}{8\pi GT^2}
\end{vmatrix}
=
$$

Cosmic Energy Tensor

$$
\begin{vmatrix}
\dfrac{3}{8\pi GT^2} & 0 & 0 & 0 \\
0 & -\dfrac{3}{8\pi GT^2} & 0 & 0 \\
0 & 0 & -\dfrac{3}{8\pi GT^2} & 0 \\
0 & 0 & 0 & -\dfrac{3}{8\pi GT^2}
\end{vmatrix}
+
\begin{vmatrix}
0 & 0 & 0 & 0 \\
0 & \dfrac{1}{4\pi GT^2} & 0 & 0 \\
0 & 0 & \dfrac{1}{4\pi GT^2} & 0 \\
0 & 0 & 0 & \dfrac{1}{4\pi GT^2}
\end{vmatrix}
$$

Spatial expansion, Cosmological Constant   Temporal expansion, Field Pressure

Thus, scale expansion and equivalence implies that vacuum might contain energy that corresponds to the critical mass density. Spacetime itself, not matter or radiation, might contain the "missing mass" and could be the primary fabric of the universe.

Appendix 3. The supernovae Ia observations

The SEC distance-redshift relation is given by (2) with c=1:

$$d_{SEC} = T \cdot \ln(z+1) = \frac{1}{H_0} \cdot \ln(z+1) \qquad (A3.1)$$

H_0 is the Hubble constant. There is an expression by Mattig in flat spacetime for the corresponding distance in the SCM, (Carroll, Press and Turner, 1992):

$$d_{SCM} = \frac{1}{H_0} \int_0^z [(1+x)^2(1+\Omega_M x) - x(2+x)\Omega_\Lambda]^{-1/2} dx \qquad (A3.2)$$

where $\Omega_M = \frac{8pG}{3H_0^2} r_M$ and $\Omega_\Lambda = \frac{\Lambda}{3H_0^2}$ with $\Omega_M + \Omega_{.\Lambda} = 1$.

r_M is the (dark) matter density and Λ the cosmological constant.

The apparent luminosity is given by:

$$I_{SCM} = \frac{L}{4p \cdot d_{SCM}^2 (1+z)^2} \qquad (A3.3)$$

For the SEC model the apparent luminosity expression is (see Appendix 1):

$$I_{SEC} = \frac{L}{4p \cdot d_{SEC}^2 \cdot (1+z)^2} \qquad (A3.4)$$

These two expressions for the apparent luminosity agree within 0.02 magnitudes in the range 0<z<1 if O_M =0.52 and $O_?$ =0.48. Furthermore, the SEC luminosity prediction agrees well with the SNe Ia observations as can be seen in Figure 4, which is based on Perlmutter, 2003. This remarkable good agreement with the SEC model is obtained without any adjustable parameters.   The dark
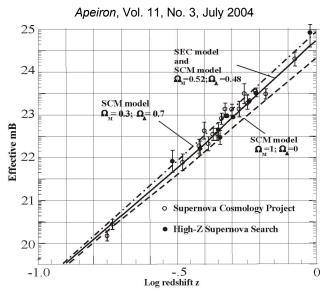
Figure 4: SNe Ia Magnitudes vs. redshift

energy needed to explain the observations in the SCM is implicit with the SEC model.