DARK SOURCE FLUX COSMOLOGY
An Occam's Razor Universe

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The Hubble Puddle metaphor

On a rainy day, imagine a shallow puddle of water in the street. The puddle grows in size as the rain keeps falling. Some leaves are floating on the surface of the puddle. We notice how the leaves drift apart metrically, due to the rain that uniformly expands the puddle. As seen from anyone of the leaves, all other leaves move away radially. No net forces act on the leaves. They are at rest relative to the most nearby water, but they still move apart since the water between them is expanded by the rain. They actually drift apart at an accelerating speed, due to the cumulative effect of the rain constantly falling over the growing area of open water between them. The rain expands the puddle but not the individual leaves, since these are held together by strong cohesive forces.

In this metaphor, the expanding water corresponds to dark energy, the leaves correspond to galaxies and galaxy clusters, and the agent behind the metric expansion is a uniformly distributed source flux: the rain, corresponding to the dark source flux.

This Hubble Puddle is a 2+1 dimensional miniature model of the metrically expanding universe.

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Preface

Occam's razor is a heuristic principle attributed to the English franciscan friar William of Occam (1287 – 1347). It can be stated: *'Among competing hypotheses, the one with fewest assumptions should be selected'*. Or, more to the point: 'Don't complicate things unnecessarily'. This statement is in complete agreement with my engineering experiences, and it also is the fundamental idea behind the work presented here.

I have been fascinated by astronomy and cosmology as long as I can remember. As a young boy I borrowed all popular science books about these subjects I could find in our local library. Gradually, my choice of literature became more advanced and by the time of my retirement a few years ago I considered myself a fairly qualified layman in the field. My basic academic training is within a totally different field – engineering sciences – and eventually I became a Professor of Materials Science (specializing in micro engineering) at Uppsala University. But my fascination for cosmological questions never ceased.

As I studied the scientific literature on cosmology, I was surprised about the tendency to address problems – for example the issue of metric expansion of space – at the highest and most cumbersome theoretical level (Einstein's field equation), and then introduce simplifying constraints until a workable level is reached. This is a top-down procedure, which works well in some cases but leads astray in others. My engineering experience tells me the opposite: start from basics with experimental facts and build a problem-oriented model upwards. In this bottom-up approach, more advanced elements are added *if and when* they become necessary, but not otherwise. This is the Occam's razor philosophy, implemented in this publication.

This publication deals with the fascinating phenomenon of the metric expansion of the universe. Most cosmologists believe that this issue is satisfactorily explained by the expansion model ΛCDM, which is one part of the Standard Model of Cosmology, which in turn is based on the curved-metric, covariant tensor formalism of General Relativity (GR). It is not easy to convince the cosmology community that the prevailing GR-based standard expansion model is overly complicated and therefore suffers from disturbing problems. In a comprehensive Wikipedia post on non-standard cosmology it is stated: 'Today, heterodox non-standard cosmologies generally are considered unworthy of consideration by cosmologists…'

The present publication aims at challenging this profoundly unscientific attitude by pointing out obvious shortcomings of the standard expansion model and by presenting simple, non-standard ways to avoid them. I shall make frequent use of Occam's razor and demonstrate that the standard model can be replaced by a considerably simpler model without loss of generality; in fact, in important parts the new model is more developed than the standard model – as is amply illustrated by the 'new achievements list' on pages 12-13.

Uppsala, February 2017

Jan-Åke Schweitz

1. Introduction

1.1 Background

In 1929 Hubble [1] observed that distant galaxies appear to be receding with velocities that increase with increasing distance from Earth. To avoid a geocentric interpretation of this observation, it was soon concluded that this effect is due to non-centric, metric expansion of the universe. Conclusive observational evidence of *accelerating* expansion was reported by Riess et al. [2] and Perlmutter et al. [3]. In 2011 this achievement was awarded the Nobel Prize in physics. As mentioned in the Preface, standard cosmology is based on the curved-metric formalism of General Relativity. Recent spacecraft data (*WMAP* [4] and *Planck* [5]) indicate, however, that the universe is flat-metric on a global scale even in a curved-metric ΛCDM setting, suggesting that it could be handled within a much simpler but still rigorous mathematical framework – in Occam's spirit.

There are several disturbing obscurities in the standard cosmology expansion model; not so surprising in view of the fact that it essentially is based on a picture of the curved-metric universe prevailing in the 1920-ies, and on the pioneering work of Alexander Friedmann [6] and others at that time. Much has happened since then, warranting a reconsideration of the basic ideas on which the theory was founded. Still, the most celebrated expansion results available today – the *WMAP* and the *Planck* values – are evaluated by means of the ΛCDM model with its inherent shortcomings, and cosmologists tend to judge other cosmological models by comparing with the allegedly 'most credible' ΛCDM standard expansion model.

It is shown here that a number of issues in standard cosmology are avoided by a new set of initial assumptions, consistent with earlier and recent observations. Our theory is free-standing from GR but adopts the mass-energy equivalence principle from Special Relativity. It is considerably simpler than the ΛCDM theory, but still readily explains the observed expansion features of the universe, *qualitatively as well as quantitatively*.

1.2 Global flat space postulate

We here apply the *flat global space assumption* at all stages of metric expansion, which in GR would correspond to curvature constant $k = 0$. As mentioned above, this assumption actually is in concord with observations, since *WMAP* and *Planck* data indicate that our present universe is spatially flat on a global scale also in a ΛCDM framework. This is a case for Occam's razor: no observations contradict the assumption that the universe was *always* spatially flat; curvature on the global scale is an unnecessary hypothesis if flat-metric expansion can be otherwise explained (see also Sec 16.3).

For someone with a background in materials engineering, an analogy comes to mind. If a surface coating, for instance an oxide, is deposited on a substrate like a silicon wafer, residual stresses will usually appear in the coating. If the stresses are tensile, the substrate will experience concave buckling as seen from the coated side. Compressive stresses cause convex buckling. For a given stress level, the radius of curvature depends on the size of the substrate: small size – small radius, large size – large radius. For unlimited size, the radius of curvature is infinite, i.e. the substrate remains perfectly flat – *irrespective* of residual stress level in the coating, or of coating and substrate thicknesses.

The size of the flat universe is indeterminate, but we assume it to be effectively unlimited outside the observable part. These are points of crucial importance; the entire universe is here assumed to be flat-metric and effectively unlimited *at all times* from the high density primordial epoch to the low density ultimate universe. For metric expansion, this is fully consistent with the fact that the observable universe is limited and the expansion flow (the 'Hubble flow') appears to be receding radially from our location in space. It does not, however, imply that the entire universe expands from that or any other preferred point in space; space is non-centric (the Copernican principle).

It must be emphasized that the alternative model presented here is not intended to question the validity of GR in general – GR is indispensable when dealing with *local, curved-metric* space phenomena like black holes or gravitational lensing, where global metric expansion can be neglected. In the global, flat-metric, uniform universe approximation, on the other hand, GR's inherent curved-metric complexity (which really is unnecessary in a flat-metric context) tends to lead astray; several examples will be given.

Before going into details about our new model, there is one fundamental issue that must be clarified. Is energy really conserved on a local or global basis in our expanding universe?

2. About energy conservation

2.1 The energy conservation principle

The energy conservation principle today is seen as one of the most holy principles of physics. One should remember, however, that the energy concept is just a clever *formal* device, invented in the nineteen's century by Rudolf Clausius [7] and others in the development of the theory of thermodynamics. Newton never used an energy concept, and he did exceptionally well without it, long before it was invented. Nonetheless, the energy concept *is* a practical device, and conservation of energy *is* a useful rule, although of limited validity. It is valid only in inertial reference frames, for isolated systems, in flat-metric theories like Newtonian mechanics or Special Relativity. Most real systems do not fulfil these requirements (even if we sometimes 'cheat' with mathematical artifices like fictitious inertial forces to mimic inertial frames in accelerating systems).

2.2 Energy conservation or not in Newtonian theory

Indeed, in flat space there are strong reasons to question an unconditional implementation of energy conservation in a system undergoing accelerating flat-metric expansion, i.e. a system where Newtonian inertial frames do not exist. Not even a co-expanding frame is inertial, since the total mass-energy content (including dark energy) of each co-expanding volume element increases over time. This is true also for any infinitesimal volume element co-moving with the metric. Hence, energy is not conserved in such a system – neither globally nor locally.

2.3 Energy conservation or not in General Relativity

In curved-metric General Relativity, energy conservation is not well defined. In this theory, an attempt to salvage the conservation principle is made by generalizing the formal conservation criterion, going from vanishing divergence of the energy-momentum tensor in flat spacetime, to vanishing *covariant* divergence of the same tensor in the curved spacetime manifold. Thus the landscape is remodelled in agreement with Einstein's new map. Or, perhaps, the map is redrawn in agreement with Einstein's new landscape. Either way, the purpose is to uphold the energy conservation principle. But is this change of definition really enough to do the job?

Seemingly, in General Relativity local energy conservation is ascertained in Einstein's field equation through the *a priori* requirement of vanishing covariant divergence. Einstein purposely constructed his field equation (including the cosmological constant term) in a way fulfilling this criterion, i.e. local energy conservation was at that time thought to be postulated in GR.

Today's prevailing notion that flat space expands locally with accordingly decreasing matter density *but* constant level of dark energy density is in apparent conflict with this local energy conservation criterion. Some cosmologists argue that this is no inconsistency, since vanishing covariant divergence is not enough to guarantee energy conservation anyway. If the background metric is evolving with time – metric expansion, for instance – the time symmetry requirement in Noether's theorem may not be fulfilled, and energy is not necessarily conserved. So, in that case, vanishing covariant divergence does not ascertain energy conservation in GR after all.

2.4 The zero energy universe hypothesis

Some cosmologists invoke the 'zero energy universe hypothesis' as a way to salvage energy conservation in an accelerating universe. In this hypothesis, the positive energy bound in all types of cosmic media is thought to be balanced by the negative gravitational energy generated by the same media, resulting in a zero energy universe. If the positive energy of the media increases, the negative gravitational energy is thought to increase accordingly, thus maintaining zero energy balance. This would, for instance, open up for a universe created from nothing; at least from an energy point of view. The ultimate free lunch, as Alan Guth puts it [8]. This is an attractive idea, but lacks scientific basis. The main reason is the fact that a gravitational energy density cannot be unambiguously quantified in a flat universe with spatially boundless, nonzero mass density (this is a well known problem). Hence a zero energy universe is an arbitrary concept, leading anywhere or nowhere.

2.5 Conclusion on energy conservation

Let's face it: the idea of energy conservation in the flat, accelerating universe does not hold, whichever way we look at it, and we should perhaps again invoke Occam's razor and accept that *energy is simply not conserved* in such a system. After all, that is the simplest conclusion, and it does not contradict any observations at all. Thus, you might say that the energy conservation principle is more hollow than holy in the accelerating universe.

In agreement with this conclusion, *the dark source flux theory presented below states that the non-inertial, accelerating expansion of the flat, physical universe is driven by a non-conservative influx of new energy, in natural agreement with commonly accepted physics.* The origin of this influx is a different question, to be addressed later (Sec 4.3).

3. The nature of dark energy and dark source flux

3.1 The great conundrum of dark energy

The nature of dark energy has been a major conundrum within astrophysics for several decades. The assumed properties of this cosmic medium indeed make it bizarre. Negative pressure is a strange property, which is attributed to dark energy (in conflict with any classical definition of pressure). Another strange property is the fact that it does not dilute under expansion; it maintains constant density in space under all circumstances. Furthermore, dark energy is assumed to possess a gravitational mass density, but it does not – as far as we know – aggregate around huge mass concentrations (galaxies, black holes etc.) as baryonic and dark matters do. It is also completely transparent to light; it does not seem to interact with photons in any way. Finally, no elementary particle has been associated with the dark energy field.

The invariance of the dark energy density in space has led to the assumption that dark energy in fact is a physical manifestation of space itself. It is seen as an invariant ground state energy density, which always is present in space; even when space is completely devoid of all other cosmic media. Actually, this is consistent with Einstein's field equation, when a cosmological constant Λ is included (postulated) on the spacetime side. Invariant dark energy is a *basic postulate* also in the theory presented here.

3.2 The dark source flux

This basic postulate is of profound importance to the understanding of the metric expansion of space. Whatever mechanism is driving this expansion, we know that metric expansion of space can only happen if more volume – i.e. more dark energy – is added everywhere in space. This is a compelling consequence of our postulate – dark energy is somehow infused or created everywhere in space during metric expansion. This influx of dark energy shall here be called *dark source flux (DSF)*. Again: in metric expansion, the existence of DSF is a logical and unavoidable consequence of our basic postulate.

Flat space is assumed to be invariant, i.e. dark energy manifesting space is also invariant, which means that its ground state density must stay constant even under metric expansion. So now we know one more thing about the DSF: at any given expansion rate, the DSF provides just enough new dark energy to keep the dark energy density everywhere constant and space invariant during expansion. This will be expressed in mathematical terms in Sec 5.5.

We have now accepted – in fact postulated – one of the bizarre properties of dark energy mentioned above: the invariance of the dark energy density, and the consequential existence of DSF. As we will see later, this connection in fact goes both ways: dark energy can also be seen as a consequence of DSF; neither one exists without the other (Sec 5.8).

Another conclusion about dark energy and DSF is a bit disturbing: they violate the law of energy conservation. If dark energy does not dilute during expansion, it cannot be conserved. More dark energy is continuously being added by the DSF during expansion, in conflict with the energy conservation law. This has already been discussed in some detail in Sec 2.

The role of DSF in the new model is discussed in Sec 4.3.

3.3 Kinetic expansion energy

We can now take next step and deduce what kind of energy dark energy is. Accelerating expansion of the flat physical universe is a dynamical process, necessarily involving a growing amount of kinetic expansion energy. Additional kinetic energy must continuously flow into space everywhere, in order to maintain accelerating flat-metric expansion of the physical system. The only influx of energy we have in our universal system is the DSF. Thus we can conclude that the DSF is an influx of kinetic energy, and in a global perspective the dark energy density can be identified as the kinetic expansion energy density. *The dark energy density is the global, kinetic expansion energy density of the universe.* (*Note*: Dark energy is a well established denomination, so we stick to that in the following, but now we know what it really means.)

3.4 Kinetic expansion energy in local and global perspectives

Hubble's law ($\mathbf{v} = H\mathbf{r}$; see Sec 5.2) is the centrepiece of the metric expansion theory. Obviously, a frame of reference is needed to define magnitude and direction of the position vector $\mathbf{r}$ and the velocity vector $\mathbf{v}$. Once we have chosen such a frame, we have adopted a *local perspective*. We can now define a local value of the apparent kinetic recession energy of a particle 'embedded' in the expanding metric.

In the *global perspective* things look different. No fixed reference frame is defined in this perspective. Instead, we look at the *non-centric* metric of space. An embedded particle does not move relative to the expanding metric, and no net force is acting on it (cp. a leaf in the Hubble Puddle). Consequently, in the global perspective, the kinetic energy of an embedded particle is zero relative to the metric. But is this vanishing kinetic energy really consistent with a *non-vanishing* global, kinetic expansion energy density (the dark energy density)? Yes it is, if we remember our basic postulate that the dark energy density – or its equivalent mass density – is a physical manifestation of space itself. In this picture, expanding flat space possesses a kinetic energy density of its own, and particles embedded in the metric drift along without resistance in the expanding dark energy, just like the leaves in the Hubble Puddle.

The local and global perspectives may appear to yield conflicting results on the dynamics of an embedded particle. This is not true. In the global perspective, we study the motion of an embedded particle relative to the expanding metric, and find it to be at rest. In the local perspective, we study the motion of an embedded particle relative to an observer at rest at the origin $\mathbf{r} = 0$, and find the particle to be moving. Both perspectives are correct and compatible, meaning that any *space invariant* expression derived in a local frame also is valid in the global perspective. This fact is utilized in Secs 5.6 and 5.7.

What about relativistic particles like photons and neutrinos? Unlike non-relativistic particles, these are not embedded, but move fast relative to the expanding metric. But their space averaged *densities* are embedded and expand with the metric, just like the density of non-relativistic particles.

3.5 Issues of optical transparency, gravitational aggregation, and negative pressure

We are now prepared to address a peculiarity mentioned in Sec 3.1. Why do not photons seem to interact with dark energy? Light is believed not to interact with dark energy since it is completely transparent, i.e. a photon does not lose energy as it travels through it (the redshift is due to metric expansion, not to energy absorption). The idea of lossless propagation can be understood if photons and dark energy both are manifestations of pure, rest mass-less kinetic energy. In that case, the directed kinetic energy of a travelling photon will just superpose the isotropic kinetic energy of the dark energy, and no net energy transfer or energy conversion will occur. In this picture, the propagation of a photon through dark energy will be lossless.

Why does not dark energy aggregate around galaxies like baryonic and dark matters do? Well, we really don't know if it aggregates or not. Even if it does aggregate, it would be impossible to distinguish it from the dark matter distribution in and around a galaxy. Our basic postulate about invariant flat space, and the related invariance of dark energy density, is not necessarily valid close to local mass concentrations like galaxies, where the metric of space is curved, not flat. We do know that the ever ongoing DSF tends to expand the dark energy distribution within and outside a galaxy, thus counteracting an assumed aggregation, but we do not know to what extent.

But we know that the dark and baryonic matter densities in a galaxy are huge, and the expansive effect of DSF on these matters is completely negligible compared with their huge gravitational cohesion. So the DSF does not make a galaxy expand at all.

What about negative pressure? The cosmological pressure concept, which is of central importance in standard cosmology, is ambiguous and not compatible with pressures as defined in thermodynamics or fluid mechanics. In these disciplines pressures are defined as kinetic energy densities – making negative pressures meaningless. A negative pressure concept requires a radical redefinition of the pressure concept as a whole. But *in the DSF theory, neither positive nor negative pressures appear in explicit form.* Hence we can avoid making precarious conjectures about pressures, as well as about equations of state that explicitly relate pressure to energy density in different cosmic fluids.

4. The dark source flux (DSF) model

4.1 The cosmic media

In our model we assume that all species of matter and energy behave like homogeneous and isotropic cosmic media, uniformly distributed throughout the entire universe. Each medium interacts gravitationally over long range within itself and with other media. The media are: non-relativistic baryonic and dark matter, relativistic radiation, and dark energy. All this is in agreement with standard cosmology.

4.2 Dark source flux (DSF) and the Hubble Puddle metaphor

The new theory presented here conforms to standard cosmology in the sense that it predicts Big Bang and postulates the existence of vacuum energy (dark energy), but it does not comply with all details of the Friedmann formalism in the ΛCDM model. The main 'non-standard' feature of the new model concerns the expansion mechanism. In the ΛCDM model the expansive effect in flat space is due to a negative pressure induced by a cosmological constant Λ with unclear physical foundation. In the present model, the expansive effect is instead introduced through a non-conservative source flux of energy with clear physical significance: it acts as a tangible and easily understood expanding agent, vividly illustrated by the Hubble Puddle metaphor on the front page of this publication.

Of course, all metaphors are incomplete and have limited validity. In the Hubble Puddle metaphor, cohesive long-range gravity is not included; the cohesive effect is instead provided by intermolecular forces in the water. Still, this simple model mimics several important features of metric expansion, and illustrates that metric expansion can be driven by other means than a mysterious medium with negative pressure.

We here present a simple but rigorous flat-metric model, based on an expansive dark source flux, corresponding to the rain in the Hubble Puddle metaphor. All dark energy stems from the DSF and is, after creation, preserved. The infused dark energy is effectively not transported anywhere in space; it is non-localized and is created everywhere and simultaneously in the expanding space. In the DSF model all mass-energy elements – except photons and neutrinos – are embedded in the expanding flat metric and co-move with it, i.e. do not move relative to it. Photons and neutrinos move at the speed of light (or close to it) relative to the expanding flat metric, but their averaged density distributions in space are embedded and co-expand with the metric.

During expansion, the source flux creates new space without action of forces (cp. the forceless movement of the leaves in the Hubble Puddle). No *net* gravitational (or inertial) forces act on individual mass elements and expansive and contractive energy densities always cancel out, as we shall see. From a local observer's viewpoint, all matter in the universe drift along without resistance in the radial Hubble flow like driftwood in a river, and it is easily shown that Hubble's law follows as a simple consequence of the expansive effect of the uniformly distributed DSF (Sec 5.3).

4.3 Origin of the dark source flux

One might raise the objection that the suggested source flux of energy is just as mysterious as negative pressure. From where is this source flux supposed to come? We can, of course, speculate on the deepest origin of the suggested cosmic source flux. It should be borne in mind, though, that this question is no stranger than the question about the primeval origin of *all* existing matter in the universe. It is in fact the same old question; essentially, a continuing source flux neither adds a new mystery nor solves an old one as far as original creation is concerned.

In the Hubble Puddle metaphor, the influx of the expansive medium (the rain) emanates from a higher dimension. Likewise, in expanding space the proposed dark source flux may be imagined to emanate from some higher, unperceivable dimension. Or, equivalently, it may be dissipated/excreted/created everywhere in space from a non-localized *intrinsic source*. In that case, we attribute an expansive property to spacetime itself. After all, since we assign an intrinsic, physical property – dark energy – to expanding spacetime, it is not unreasonable to imagine an intrinsic source of it. Remember that it is not the dark energy that expands space; it is the underlying source flux that serves as the expanding agent.

The hypothesis that the dark energy density is generated by balanced creation-annihilation of virtual particle-antiparticle pairs (vacuum fluctuations) does not provide an ever ongoing source flux, which could drive the expansion. A hypothetical *non*-balanced creation-annihilation process could possibly generate some kind of source flux, but no such theory exists today.

Another speculative idea about the origin of DSF is mentioned in Sec 18.

4.4 The DSF model compared with the standard model

Our new expansion theory is free-standing from GR and its offspring ΛCDM , but they have several concepts in common, for example the Hubble constant (or, rather, the time-dependent Hubble parameter) and a non-vanishing ground state energy density (vacuum energy or dark energy) permeating all of space. These parameters are not 'borrowed' from GR, but are natural consequences of the new theory. Hubble's law (stating that distant galaxies recede with velocities that increase with increasing distance from Earth) is an observed fact, which furthermore is theoretically predicted by our source flux theory (Sec 5.3). A non-vanishing ground state energy density is a natural consequence of the source flux assumption, too. This is clear from the Hubble Puddle metaphor, and theoretically derived in Sec 5.8.

There are several important differences of general character between our expansion theory and the standard ΛCDM expansion theory. Most important, as discussed already in Sec 2, we are compelled to abandon one of the most holy principles of physics: the energy conservation principle. This renegade behaviour was justified in some detail in Sec 2. (It was pointed out that the same diversion actually is done in the standard expansion theory too; albeit a bit under cover.)

The Friedmann formalism of standard cosmology is based on the adiabatic perfect fluid assumption. In contrast, the DSF model is more general; it neither presumes that the expansion is always adiabatic, nor that all cosmic media behave like perfect fluids (i.e. are completely characterized by their rest frame energy densities and rest frame isotropic pressures). In standard cosmology, these are forced constraints, introduced in order to make the energy-momentum tensor diagonal and the field equation mathematically manageable.

As is already mentioned in Sec 3.5, another important difference concerns the concept of pressure, which is avoided in our theory. Assumptions about incoherent equations of state, relating pressure to density for different cosmic media, play important roles in standard cosmology. Again, these are forced constraints that we can easily do without in DSF theory.

4.5 New achievements by the DSF model

OK, so we will present a new expansion theory, which differs from the standard expansion theory in several important ways. But what are the added values of this new theory? Why bother? Well, there are numerous new accomplishments described throughout this publication. One important example is already given. It concerns the dark energy, which in standard cosmology appears to be some elusive stuff with mysterious properties, maybe to be associated with some new, sexy elementary particle in the future. In our theory, dark energy quite naturally emerges simply as the non-localized kinetic expansion energy density of the universe. Not so sexy, but much more tangible.

Another finding, to be presented, is a surprisingly close relationship between the dark energy and all other media in the universe. This is a new revelation, not present in standard cosmology. Furthermore, the Planck unit system may have found an attractive physical significance: it may relate to a *non-singular* primordial state of the universe. Also, 'the worst theoretical prediction in the history of science' (the 10^{120} error) may have found an explanation.

In summary, improved features of our new model, compared with the standard ΛCDM model, are:

- Non-relativistic simplicity
- Tangible driving agent behind the metric expansion
- Dark energy identified as the kinetic expansion energy of the universe
- Flatness, horizon, and coincidence problems do not arise
- No inconsistent energy conservation criteria
- No adiabatic perfect fluid constraint
- No over-simplified and incoherent equations of state
- Expansion model in concise, closed mathematical form
- All expansion parameters numerically evaluated from merely two experimental parameters
- No best-fit procedures (in contrast to the Λ*CDM* evaluation of *WMAP* and *Planck*)
- Seamless connection between the Big Bang singularity and the ultimate state
- New intimate relation revealed between dark energy and other cosmic media
- Comprehensible cosmological arrow of time defined by the dark source flux
- Non-singular primordial state of the universe defined and related to the Plank unit system
- 'The worst theoretical prediction in the history of science' possibly explained

We intend to demonstrate all these virtues in following parts of this publication. So, keep an open mind and please enjoy the ride!

5. Theory of dark source flux

5.1 Mass density parameters

We divide the total mass density of the universe into two parts: $\rho(t) = \rho_{\mathrm{g}} + \rho_{\mathrm{bdr}}(t)$, where ρ_{g} is the ground state (dark energy) density and $\rho_{\mathrm{bdr}}(t)$ is the density comprising all species of mass *excluding* ground state density (i.e. baryonic matter, dark matter, radiation). The sum of these three mass species is *not explicitly assumed to be conserved*. However, in Sec 7 it will be shown that this feature follows from the theory, i.e. the sum of non-dark energy species actually *is* conserved and their collected density ρ_{bdr} therefore dilutes in inverse proportion to the volume expansion. The *composition* of ρ_{bdr} changes over time though, due to energy conversion. For instance, the early, rapid drop of the radiation-to-matter ratio is discussed in Sec 12.

5.2 Hubble's law

Hubble's law was first derived in 1927 by Lemaître [9] from Einstein's field equation, and was for some time considered to be a general relativistic effect. Later it was shown that it can be derived from purely Newtonian theory. In any chosen local frame of reference, the metric expansion is given by Hubble's law:

$$\mathbf{v}(\mathbf{r},t) = H(t)\mathbf{r} \,. \qquad (1)$$

$\mathbf{v}$ is the recession velocity of the Hubble flow at the radial position $\mathbf{r}$ at cosmic time t, and $H(t)$ is the time-dependent Hubble parameter. The expansion rate function $H(t)$ constitutes the 'observed' net result of all expansive and contractive effects, *including pressure and gravity* in whatever forms these effects may be manifested. Thus, the effects of pressure and gravity are not explicit in Eq. (1), but are nevertheless implicitly included in the 'empirical' parameter H and consequently in all expansion parameters based on Eq. (1).

It is important to note that a *spatially linear* expression of this type is valid for flat-metric expansion in the full interval $0 < t < \infty$; also in the early epoch of rapid inflation. Any deviation from spatial linearity would imply deviation from the non-centricity criterion. (In some textbooks it is stated that Hubble's law 'deviates from linearity'. This statement sometimes refers to the time dependence of H, or to deviation from flat space, or to the non-linearity of the scale factor. But in flat space Hubble's law *always* is linear in $\mathbf{r}$; see below.)

5.3 Hubble's law derived from the source flux

A Newtonian derivation of Hubble's law is given in Sec 5.7. In the relativistic as well as in the classical derivations, gravitational effects play a central role.

A new derivation, given below, is more fundamental: it is not based on any form of physical interaction or any form of equation of state. The only constraint introduced in this derivation is spatial uniformity in an expanding space (i.e. homogeneity and isotropy implying non-centricity); the rest is straightforward differential geometry. Hence it is shown here that Hubble's law is a simple consequence of the non-centricity criterion (the Copernican principle) in a source flux-driven expanding universe.

The concept of *source flux* is here used to indicate non-conservative addition of mass-energy to a system (*drain flux*, if mass-energy is subtracted). The physical mechanism behind this addition or subtraction is of no importance here. Quantum physicists are familiar with such concepts; creation and annihilation operators serve similar purposes.

We study the mass content $M(t) = \rho(t)V(t)$ of an expanding volume element $V(t)$ containing a uniformly distributed, time dependent mass density $\rho(t)$. A uniformly distributed source flux $s(t)$ can be defined as the time derivative of the mass content divided by the volume:

$$s(t) = \tfrac{d}{dt} M(t) / V(t) \quad \text{(change of mass per time unit and volume unit)} \qquad (2)$$

Note that this definition of source flux does not rely on any physical effect; it is pure differential geometry. The time derivative is:

$$\tfrac{d}{dt} M(t) = V(t) \tfrac{d}{dt} \rho(t) + \rho(t) \tfrac{d}{dt} V(t) . \qquad (3)$$

Divide by $V(t)$ to obtain $s(t)$:

$$s(t) = \tfrac{d}{dt} M(t) / V(t) = \tfrac{d}{dt} \rho(t) + \rho(t) \tfrac{d}{dt} V(t) / V(t) . \qquad (4)$$

This equation can be rewritten in terms of an unknown function $f(t)$:

$$\tfrac{d}{dt} V(t) / V(t) = \frac{s(t) - \tfrac{d}{dt} \rho(t)}{\rho(t)} \equiv f(t) . \qquad (5)$$

For a spherical volume $V(t) = 4\pi r(t)^3 / 3$ we obtain:

$$3\tfrac{d}{dt}r(t)/r(t) = f(t)\,, \tag{6}$$

or:

$$\tfrac{d}{dt}r(t) = (f(t)/3)r(t)\,. \tag{7}$$

Define:

$$H(t) \equiv f(t)/3\,. \tag{8}$$

Eq. (7) becomes:

$$\tfrac{d}{dt}r(t) = H(t)\,r(t)\,, \tag{9}$$

or:

$$\mathrm{v}(t) = H(t)r(t)\,, \tag{10}$$

which is *Hubble's law* derived without gravitational interaction. In Sec 5.7, the same law is derived from a dynamic energy balance argument including gravity, and a relationship between H and Newton's gravitational constant G is established there.

5.4 The continuity equation derived from the source flux

In Sec 5.6, the *continuity equation* for a space expanding by source flux is derived from a general, mathematical equation of continuity. However, using the differential expressions derived above, we can precede this derivation in a very simple manner.

Hubble's law implies $\tfrac{d}{dt}V = 3HV$; i.e. $\tfrac{d}{dt}V/V = 3H$ and Eq. (4) becomes:

$$s(t) = \tfrac{d}{dt}\rho(t) + 3H(t)\rho(t)\,, \tag{11}$$

which is the continuity equation for source flux driven expansion.

For vanishing source flux, i.e. $s(t) \equiv 0$, Eq. (11) expresses mass conservation, i.e. it shows how the mass density $\rho(t)$ will decrease with time for a given expansion rate when no mass is added or subtracted. But such a conservation equation does not provide a physical cause of expansion; without such a cause there will be no expansion and the density will stay constant ($s = 0$, $H = 0$ and $\tfrac{d}{dt}\rho = 0$). A non-vanishing source flux in Eq. (11), on the other hand, may serve as a driving agent behind the expansion by means of the mechanism proposed in our expansion model.

5.5 Basic formulation of the dark source flux hypothesis

Hubble's law describes the linear metric expansion: $\tfrac{d}{dt}\mathbf{r} = H\mathbf{r}$. It is easily shown that the corresponding volumetric expansion is given by: $\tfrac{d}{dt}V = 3HV$. If the expanding volume is filled with dark energy of constant mass density, the corresponding relation for the growing mass content of dark energy in the expanding volume is: $\tfrac{d}{dt}M_{\mathrm{de}} = 3HM_{\mathrm{de}}$. Dividing this expression by V , we obtain:

$$s(t) = 3H(t)\rho_g \ , \tag{12}$$

where $\rho_{\mathrm{g}} = M_{\mathrm{de}}(t)/V(t) =$ *constant* and $s(t) = \frac{d}{dt}M_{\mathrm{de}}(t)/V(t)$. The dark source flux function $s(t)$ is the amount of dark energy mass infused per units of time and volume at the cosmic time t. The source flux $s(t)$ expands space and maintains constant ρ_{g} level at all expansion rates $H(t)$. In principle, the model allows for ρ_{g} being exactly zero, but in that case our model is reduced to a degenerate state of the universe (verified in Sec. 5.8).

Eq. (12) is *the basic mathematical formulation of the dark source flux hypothesis*. Ultimately, when only dark energy remains in the observable universe (outside our own 'leaf in the puddle', i.e. our non-expanding local galaxy cluster), Eq. (12) is reduced to a simple and fundamental relationship between *three universal constants* (subscript g indicates ground state values at $t \to \infty$):

$$s_{\mathrm{g}} = 3H_{\mathrm{g}}\rho_{\mathrm{g}} \, . \tag{13}$$

5.6 The continuity equation, again

In a universe expanding due to source flux, dark mass-energy is infused from a uniformly distributed, dissipative source in the system. It is not possible to define an unambiguous Lagrangian or Hamiltonian for such a system, since dissipative processes lack well-defined potential functions. Instead, the source flux will here be defined in terms of an equation of continuity of general mathematical validity:

$$s(\mathbf{r},t) = \tfrac{\partial}{\partial t}\rho(\mathbf{r},t) + \nabla \cdot \boldsymbol{\sigma}(\mathbf{r},t) \, , \tag{14}$$

where ρ is the total mass density (including ρ_{g}), s is the rate of dark source flux entering a volume, $\frac{\partial}{\partial t}\rho$ is the rate of change of density inside the volume, and $\boldsymbol{\sigma}$ is the flux of the radial Hubble flow leaving the volume through its surfaces. This equation makes the trivial statement that the rate of change $\frac{\partial}{\partial t}\rho$ in an infinitesimal volume element equals the difference between the rate of influx s into the element (due to source flux) and the rate of outflux $\nabla \cdot \boldsymbol{\sigma}$ through its surface (due to Hubble flow). Note that this equation does not imply mass or energy conservation, since s and $\nabla \cdot \boldsymbol{\sigma}$ may assume any values and the corresponding value of $\frac{\partial}{\partial t}\rho$ then follows from the equation. In fact, conservation of energy is fundamentally incompatible with a system undergoing flat-metric accelerating expansion (Sec 2).

The radial flux can be expressed: $\boldsymbol{\sigma}(\mathbf{r},t) = \rho(t)\,\mathbf{v}(\mathbf{r},t)$, where the velocity field is the Hubble velocity $\mathbf{v}(\mathbf{r},t) = H(t)\mathbf{r}$. Remembering that $\nabla \cdot \mathbf{r} = 3$, Eq. (14) becomes:

$$s(t) = \tfrac{d}{dt}\rho(t) + 3H(t)\rho(t) \, , \tag{15}$$

where the $\mathbf{r}$-dependence has been omitted, since the homogeneous, isotropic, and non-centric nature of metric expansion demands uniformity in space, in concord with the cosmological principle. This equation is identical to Eq. (11), derived in Sec 5.4. We repeat that the effects of pressure and gravity are implicit in this equation.

Eq. (15) is the basic equation of continuity for a universe expanding due to source flux. This continuity equation is valid at every location in any local frame, and accordingly constitutes a relationship of global validity. Nothing limits the time parameter in this equation, so Eq. (15) also is valid in the full time interval of metric expansion. It will be shown that our expansion model is singular at $t = 0$, thus displaying an implicit era of rapid early inflation. This epoch and our contemporary epoch of slower metric expansion are seamlessly linked by the common equation of continuity (15). In the ultimate limit $t \to \infty$, Eq. (15) reduces to Eq. (13), as expected.

5.7 Dynamic balance

In order to derive basic expansion parameters as functions of time, it is necessary to investigate how a local observer sees the balance between the dispersive kinetic energy generated by the source flux on one hand, and the opposing, cohesive gravitational energy on the other. Similar analyses have previously been performed in relativistic as well as non-relativistic contexts arriving at identical results. This correspondence is no random coincidence; it supports our notion that flat-metric expansion of the universe is a phenomenon in the classical limit of relativity. We here repeat the non-relativistic line of argument, but now in a source flux context:

The net dynamic energy density ε_{dyn} (not including rest mass-energy) equals the sum of the expansive kinetic energy density ε_{kin} and the contractive gravitational energy density $\varepsilon_{\text{grav}}$:

$$\varepsilon_{\text{dyn}}(\mathbf{r},t) = \varepsilon_{\text{kin}}(\mathbf{r},t) + \varepsilon_{\text{grav}}(\mathbf{r},t) = \rho(t)\left|\mathbf{v}(\mathbf{r},t)\right|^2/2 - 4\pi G\rho(t)^2\left|\mathbf{r}\right|^2/3 \,. \tag{16}$$

$\mathbf{v}(\mathbf{r},t)$ is the velocity field, generated by the source flux, as seen by a local observer. In the gravitational term, Newton's shell model for gravitation in spherical symmetry has been used. (*Note*: The rest mass density ρ_{rest} is included in ρ, but the corresponding energy density $\rho_{\text{rest}}c^2$ is not included in ε_{dyn}. Hence $\varepsilon_{\text{dyn}} = 0$ does not express energy conservation, nor is it a 'zero energy universe' criterion.)

In Eq. (16) we make no *a priori* assumption about the nature of the velocity field other than spherical symmetry (i.e. Hubble's law is not presupposed in Eq. (16)). A state of dynamic balance implies $\varepsilon_{\text{dyn}} = 0$, and the scalar version of Hubble's law now follows directly:

$$\left|\mathbf{v}(\mathbf{r},t)\right| = H(t)\left|\mathbf{r}\right| , \tag{17}$$

with Hubble parameter:

$$H(t) = \pm\sqrt{8\pi G\rho(t)/3} \,. \tag{18}$$

In this derivation of Hubble's law, metric expansion according to Hubble's law can be seen as a simple consequence of dynamic energy balance. It is evident that in dynamic balance every non-degenerate state (i.e. $\rho(t) > 0$) of the universe must be expanding ($H(t) > 0$) or contracting ($H(t) < 0$). It is also clear that Hubble's law is valid for expansion/contraction *only* in dynamic balance ($\varepsilon_{\text{dyn}} = 0$). *Hence the astronomical observation of Hubble's law constitutes an experimental verification of the principle of dynamic balance in expansion.*

Eq. (18) can be expressed in a more familiar form:

$$\rho(t) = 3H^2(t)/(8\pi G) \ . \tag{19}$$

Formally, this is Friedmann's critical density, but in the DSF model this is the criterion for *dynamic balance during expansion*, rather than a point of balance between contraction and expansion, as is the case in the ΛCDM theory for $k = 0$ and $\Lambda = 0$. The fact that experimental present-day values of ρ and H satisfy Eq. (19) quite well is by no means a coincidence; Eq. (19) is satisfied at all times in the DSF model. *Thus, a 'coincidence problem' does not arise in DSF theory*.

Asymptotically ($t \to \infty$) we have:

$$\rho_{\text{g}} = 3H_{\text{g}}^2/(8\pi G) . \tag{20}$$

5.8 Expansion parameters as functions of cosmic time

The three equations (12), (15) and (19) relate the three functions $\rho(t)$, $s(t)$ and $H(t)$ to each other, and Eq. (20) relates ρ_{g} to H_{g}. Eliminating $s(t)$, $\rho(t)$ and ρ_{g} from this equation system, we obtain *a cosmological expansion equation*:

$$2\tfrac{d}{dt}H(t) + 3H^2(t) = 3H_{\text{g}}^2 . \tag{21}$$

This equation is based on the dark source flux hypothesis embodied by Eq. (12) and is of central importance in our theory. It is a first order, non-linear differential equation, which can be solved analytically for $H_{\text{g}} \neq 0$ by separation of variables. The solution is a hyperbolic function:

$$H(t) = H_{\text{g}} \coth(3H_{\text{g}}t/2) , \tag{22}$$

displaying a singularity $H(0) = \infty$ at $t = 0$ as expected, and $H(\infty) = H_g$, also as expected.
(*Notes*: Strictly, Eq. (22) should include an integration constant, which is disregarded here since it does not affect the reasoning in this section, but we shall return to it later (Sec 15.2). Mathematically, there is an alternative solution of Eq. (21) involving a tanh function rather than coth, but this solution cannot be reconciled with our current picture of the evolution of the universe.)

In the case: $H_{\text{g}} = 0$, Eq. (21) only has the degenerate solution $H(t) \equiv 0$, whereby $\rho(t) \equiv 0$ follows from Eq. (19). Non-degenerate states require non-zero ground state constants ($H_{\text{g}} > 0$, implying $\rho_{\text{g}} > 0$). *Non-vanishing dark energy density thus is a compelling consequence of the DSF.* In Sec 3.2 the reverse dependence was deduced. Neither one exists without the other.

Inserting Eq. (22) into Eqs (12) and (19), we obtain source flux and density as functions of cosmic time t:

$$s(t) = 3H_g \rho_g \coth(3H_g t/2)\,, \tag{23}$$

$$\rho(t) = \rho_g \coth^2(3H_g t/2)\,. \tag{24}$$

Dividing the scalar version of Hubble's law: $\frac{d}{dt}r = Hr$ with an arbitrary reference length, it can be expressed in terms of a dimensionless scale factor: $\frac{d}{dt}a(t) = H(t)a(t)$. Solving this equation for the scale factor $a(t)$, and using Eq. (22), we obtain:

$$a(t) = \sinh^{2/3}(3H_g t/2)\,, \tag{25}$$

where the normalization constant for simplicity is set to unity. Usually it is chosen so as to make $a(t_0)$ equal unity at our present cosmic time t_0. The choice of normalization constant does not affect the other expansion parameters in Eqs (22 – (24).

All four expansion parameters in Eqs (22) to (25) can be expressed as compact functions of one single variable (cosmic time) and two universal constants (ρ_g *and* H_g*), which in turn can be determined from experimental data (see Sec 9).*

By the way, Eq. (25) is the standard cosmology solution of Friedmann's equation in the special case of a flat, pressure-less dust universe with a cosmological constant $\Lambda = 3H_g^2$; a case that excludes radiation (which has non-vanishing pressure). In the DSF model, on the other hand, it is not relevant to distinguish between pressures of different cosmic media; total pressure is an implicit property. By definition, radiation *always* is included as one component of ρ_{bdr} and ρ.

5.9 Essentials of the DSF theory summarized

For convenience, a quick overview of the results of Secs 5.4 – 5.8 is given here.

The source flux makes possible a concise mathematical formulation of the metric expansion in terms of one single variable (cosmic time t) and two measurable universal constants (H_g and ρ_g). The expansion is described in terms of the following four parameters:

- The Hubble parameter $H(t)$ expressing the rate of metric expansion (s^{-1})
- The total mass density $\rho(t)$ ($kg\ m^{-3}$)
- The source flux $s(t)$ expressing the infusion rate of dark energy mass per units of volume and time ($kg\ m^{-3} s^{-1}$)
- The scale factor $a(t)$ (dimensionless).

The theory is based on the following four fundamental relationships:

$H(t) = \frac{d}{dt}a(t)/a(t)$	(metric expansion rate function)	(26)
$s(t) = 3H(t)\rho_g$	(basic expression for source flux-driven expansion)	(27)
$s(t) = \frac{d}{dt}\rho(t) + 3H(t)\rho(t)$	(basic equation of continuity)	(28)
$\rho(t) = 3H(t)^2/(8\pi G)$	(criterion for expansion in dynamic balance)	(29)

These equations express the initial postulates of the DSF theory in mathematical terms, and are – naturally – not in complete concord with the Friedmann formalism of the ΛCDM model. The dark source flux concept is here of central importance. Pressure does not appear as an explicit parameter but its effect is implicitly included in ρ, s and H. Eqs (27) to (29) can be combined into a *cosmological expansion equation*:

$$2\tfrac{d}{dt}H(t)+3H^2(t)=3H_{\mathrm{g}}^2. \tag{30}$$

The Big Bang singularity and the subsequent evolution follow from the solution of this equation. The resulting expansion parameters are hyperbolic functions:

$$H(t)=H_{\mathrm{g}}\coth(3H_{\mathrm{g}}t/2), \tag{31}$$

$$\rho(t)=\rho_{\mathrm{g}}\coth^2(3H_{\mathrm{g}}t/2), \tag{32}$$

$$s(t)=3H_{\mathrm{g}}\rho_{\mathrm{g}}\coth(3H_{\mathrm{g}}t/2), \tag{33}$$

$$a(t)=\sinh^{2/3}(3H_{\mathrm{g}}t/2). \tag{34}$$

The three first functions (the physical parameters) display Big Bang singularities at $t=0$. Their ultimate values ($t\to\infty$) are: $H(\infty)=H_{\mathrm{g}}$, $\rho(\infty)=\rho_{\mathrm{g}}$ and $s(\infty)=s_{\mathrm{g}}=3H_{\mathrm{g}}\rho_{\mathrm{g}}$, respectively. The scale factor (the metric parameter) in the last equation increases with time monotonously (but not linearly) from 0 to ∞.

6. Comparison with the Friedmann equation

Friedmann's equation, derived under an adiabatic perfect fluid constraint (see e.g. [10] and [11]), is:

$$\tfrac{d}{dt}\rho(t)+3H(t)(\rho(t)+P(t)/c^2)=0, \tag{35}$$

where $P(t)$ is the pressure. It has some formal similarities with our continuity equation:

$$s(t)=\tfrac{d}{dt}\rho(t)+3H(t)\rho(t), \tag{36}$$

especially if we use Eq. (27): $s(t)=3H(t)\rho_g$ to eliminate $s(t)$ from Eq. (36):

$$\tfrac{d}{dt}\rho(t)+3H(t)(\rho(t)-\rho_{\mathrm{g}})=0. \tag{37}$$

Comparing (35) with (37), it is tempting to infer constant negative pressure: $P(t)=-\rho_{\mathrm{g}}c^2$. However, that would be too rash. For instance, positive time-dependent radiation pressure cannot be included in this constant negative pressure. Direct comparison of (35) with (37) is misleading, since these equations are based on differing initial conditions. The effect of pressure (in whatever form that is manifested) is implicitly included in $\rho(t)$, $H(t)$, and $s(t)$, as is repeatedly pointed out in connection with Eqs (1) , (15) and (26) – (29). Let us delve a bit on the difference between Eqs (35) and (36), since this is a major source of misinterpretation.

In standard literature, Friedmann's equation (35) is derived from the GR expression for vanishing covariant divergence of the energy-momentum tensor, which is taken to be a diagonal tensor for a perfect fluid (which in itself is a very dubious constraint on a system undergoing accelerating expansion). The same equation can also be derived from the classical thermodynamics equation of state: $dU = -PdV$. In both derivations, a state of thermal quasi-equilibrium in an isolated system is assumed, which is questionable, especially in the early, rapidly expanding, rapidly cooling, high-energy phase. Other debatable assumptions are energy conservation and an unorthodox interpretation of the pressure concept.

In the thermodynamics derivation of Eq. (35), the equation of state: $dU = -PdV$ implies entropy change $dS = 0$ at all temperatures, which in turn implies that every increment of the expansion process is thermally reversible. This certainly seems like an overly bold presumption, considering the dramatic thermal development of the universe from Big Bang and forward.

The derivation of our continuity equation (36), on the other hand, is much more general. *No energy conservation, no reversible expansion process, no quasi-equilibrium state, no perfect fluids, no strange pressure concepts are assumed.* Hence, Eq. (35) is not straight off comparable with our equation (36).

There are, of course, assumptions and omissions also in our expansion model that might be disputed. For instance: our initial assumptions about flat-metric space, large-scale homogeneity and isotropy, and constant dark energy density permeating all of space. But these are assumptions present also in the standard model, so our model doesn't fall short of this model for these reasons. The major assumption in our model, not present in other models, is the existence of dark source flux. There is only one way this assumption can win credibility: agreement with astrophysical observations, today and tomorrow. Admittedly, one obvious omission is made in our model: the link to modern particle physics. At this stage, however, our expansion theory can be developed mostly on a macro level.

7. New relationship between dark energy and other cosmic media

The expansion parameters (31) – (34) are related in the following simple manner:

$$\rho / \rho_{\mathrm{g}} = (H / H_{\mathrm{g}})^2 = (s / s_{\mathrm{g}})^2 = (1 + a^3) / a^3 . \tag{38}$$

This expression relates ρ , H and s to the scale factor a . For instance, the total density declines with increasing a according to:

$$\rho(t) = \rho_{\mathrm{g}} + \rho_{\mathrm{g}} / a^3(t) \; . \tag{39}$$

Comparing with the defining expression $\rho(t) = \rho_{\mathrm{g}} + \rho_{\mathrm{bdr}}(t)$ we find:

$$\rho_{\mathrm{bdr}}(t) = \rho_{\mathrm{g}} / a^3(t) . \tag{40}$$

This result is of profound importance. The density ρ_{bdr} dilutes with time in inverse proportion to an expanding volume, *implying that the sum of non-dark energy species is conserved in an expanding volume*. This feature is not an explicit initial postulate; it follows from the theory.

It is seen that space (ρ_g) and its matter contents (ρ_{bdr}) are intimately related. They resemble the two faces of a coin; if one face vanishes both must vanish. In Eq. (40), $\rho_{bdr}(t) \equiv 0$ implies $\rho_g = 0$, and *vice versa*. Empty space is as non-existent as a faceless coin.

But Eq. (40) reveals an even more far-reaching physical duality of space. Not only is the mass density ρ_g of dark energy a physical manifestation of space; at every point of time in the expansion process there must be a superposed matter density ρ_{bdr} *amounting to a rescaled* ρ_g *value according to Eq.* (40). Hence both densities are inseparable manifestations of the expanding space; one expressing the invariant ground state, the other expressing a time-dependent, compelling amount of superposed matter closely related to the ground state density.

The two universal constants H_g and ρ_g are related to G by Eq. (20). Thus – given the value of G – a remarkable and highly deterministic feature of our expansion model is that just one of the ultimate expansion constants actually determines the whole evolution of the universe from Big Bang to eternity. At any point of time along the road of evolution, all expansion parameters are completely fixed by this single ultimate constant. For example, selecting ρ_g as the determining constant, close to the primordial singularity (a close to zero) the initial density $\rho(t)$ was not just any old density that happened to be around from the start; in our model it must have been exactly the one determined by Eq. (39) for small a values.

8. Transition from deceleration to acceleration (the 'jerk')

The time derivative of $H = (\frac{d}{dt}a)/a$ yields: $(\frac{d^2}{dt^2}a)/a = \frac{d}{dt}H + H^2$. Combined with Eq. (21) we obtain:

$$(\tfrac{d^2}{dt^2}a(t))/a(t) = -(H^2(t) - 3H_g^2)/2\,. \tag{41}$$

This equation shows that an inflection point t_i – a jerk – between deceleration and acceleration (i.e. $(\frac{d^2}{dt^2}a)/a = 0$) occurred at rate of expansion: $H(t_i) = \sqrt{3}\,H_g$. From Eq. (38) we obtain: $\rho = \rho_g (H/H_g)^2$. Inserting the inflection condition, we get the jerk density: $\rho_i = 3\rho_g$, i.e. at the jerk the dark energy density ρ_g was 1/3 of the total density and $\rho_{bdr} = 2\rho_g$ was 2/3 of it.

In the literature, the relationship $t \approx 1/H$ commonly is used as an estimate of cosmic time at a certain rate of expansion. In our theory, the inverted function $H(t)$ in Eq. (31) gives an exact relationship:

$$t(H) = \frac{1}{3H_g}\ln\left(\frac{H + H_g}{H - H_g}\right). \tag{42}$$

This equation expresses the 'cosmological arrow of time', i.e. how time develops toward the future as a function of the metric expansion rate. We shall return to this expression in

Sec 13. Inserting the inflection condition $H(t_\mathrm{i}) = \sqrt{3}\,H_\mathrm{g}$ into Eq. (42), we obtain the time of inflection (a numerical estimate in general agreement with observations is found in next section):

$$t_\mathrm{i} = \frac{1}{3H_\mathrm{g}} \ln\left(\frac{\sqrt{3}+1}{\sqrt{3}-1}\right) \approx \frac{0.439}{H_\mathrm{g}}. \tag{43}$$

9. Numerical estimates

The dark source flux model developed here does not rely on the perfect fluid assumption, but we wish to compare our results with *WMAP* and *Planck* results based on that assumption. Therefore, we will here use input values evaluated by techniques *not* relying on the perfect fluid assumption, and then compare with ΛCDM results. *We need merely two input values in our evaluation model, which is extremely 'economic' compared with other expansion models.* Best-fit procedures are not necessary; another advantage over *WMAP* and *Planck*.

Our input values will be an H_0 value (subscript 0 means today's value) obtained by means of a differential distance ladder technique [12]: $H_0 = 74.2 \pm 3.6$ km s^{-1} Mpc^{-1} = $2.40 \pm 0.12\ 10^{-18}$ s^{-1}, and a t_0 value based on the age of a star born shortly after the Big Bang [13]: $t_0 = 14.46 \pm 0.80$ Gyr. (Corresponding *WMAP 9 yr* values are: 2.25 $\pm$ 0.03 10^{-18} s^{-1} and 13.77 $\pm$ 0.06 Gyr, respectively, and the *Planck* values are: 2.17 $\pm$ 0.04 10^{-18} s^{-1} and 13.81 $\pm$ 0.06 Gyr, respectively.)

Our choice of experimental H_0 and t_0 input values differs numerically somewhat from the generally accepted *WMAP* and *Planck* results, which are evaluated by means of the ΛCDM model. But we see no reason to believe that the evaluation models behind the experimental H_0 and t_0 values used here are inferior to that of the ΛCDM model. Likewise, we feel that our own evaluation model in no way falls short of the standard ΛCDM model – quite the opposite; see the discussion on initial approximations in Secs 4.4 and 6. For these reasons, we believe that our numerical results, presented below, are at least as credible as the *WMAP* and *Planck* results.

Our evaluation procedure is straightforward. Insert H_0 into Eq. (29) to evaluate ρ_0. Insert H_0 and t_0 into Eq. (31) to evaluate H_g. Insert ρ_0, t_0 and H_g into Eq. (32) to evaluate ρ_g. Now all expansion functions (31) – (34) are known functions of one single variable t in a flat-metric, non-perfect fluid model. Finally, insert ρ_g and H_0 (or H_g) into Eq. (27) to evaluate s_0 (or s_g). In summary, the results are:

Input:
$H_0 = 2.40 \pm 0.12\ 10^{-18}$ s^{-1} [12]
$t_0 = 14.46 \pm 0.80$ Gyr [13]

Output:
$H_\mathrm{g} = 2.16 \pm 0.11\ 10^{-18}$ s^{-1} ($H_\mathrm{g} = 0.90\, H_0$)
$\rho_0 = 1.03 \pm 0.11\ 10^{-26}$ kg m^{-3}
$\rho_\mathrm{g} = 0.84 \pm 0.10\ 10^{-26}$ kg m^{-3} ($\rho_\mathrm{g} = 0.81\, \rho_0$)
$s_0 = 6.02 \pm 0.81\ 10^{-44}$ kg m^{-3} s^{-1}
$s_\mathrm{g} = 5.42 \pm 0.73\ 10^{-44}$ kg m^{-3} s^{-1} ($s_\mathrm{g} = 0.90\, s_0$)

The evaluated total density ρ_0 is close to the corresponding *WMAP* and *Planck* values. The dark energy density ρ_g is roughly 20% higher. This difference is surprisingly small though, considering the fact that the expansion models are based on different theoretical frameworks (non-GR and GR, respectively) and very differing sets of initial postulates and experimental input parameters. Again, our notion that the metric expansion is an effect in the classical limit of relativity is supported by this correspondence.

The four expansion functions given by Eqs (31) – (34) are plotted in Figs 1 - 4, using the ground state values H_g and ρ_g listed above. Note that we are today ($t_0 \approx 14\,$Gyr) close to the ultimate ground state.

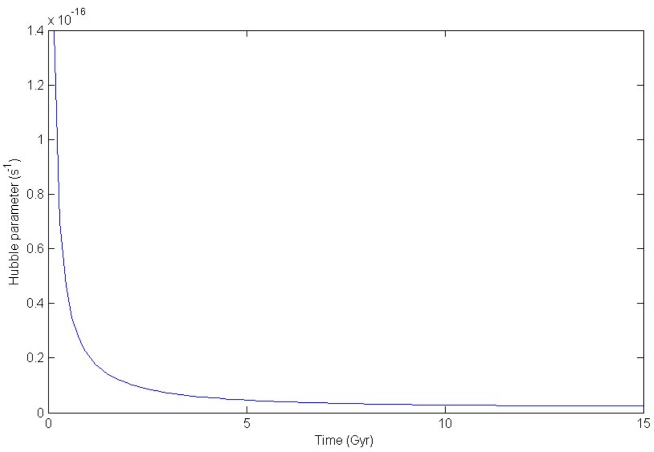

Fig. 1. Hubble parameter H (10^{-16} s^{-1}) versus cosmic time t (Gyr).

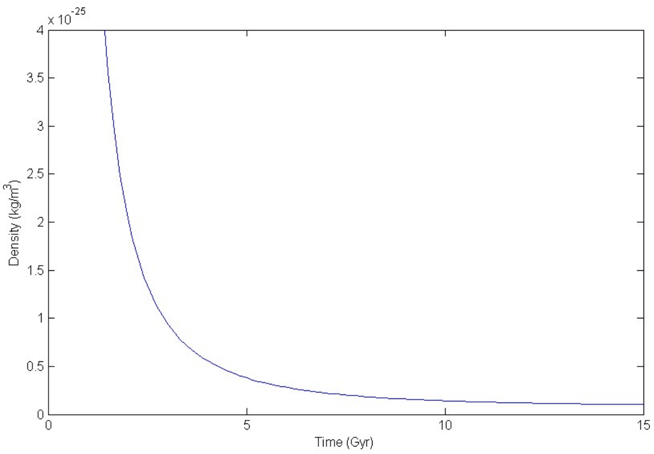

Fig. 2. Total density ρ (10^{-25} kg m^{-3}) versus cosmic time t (Gyr).

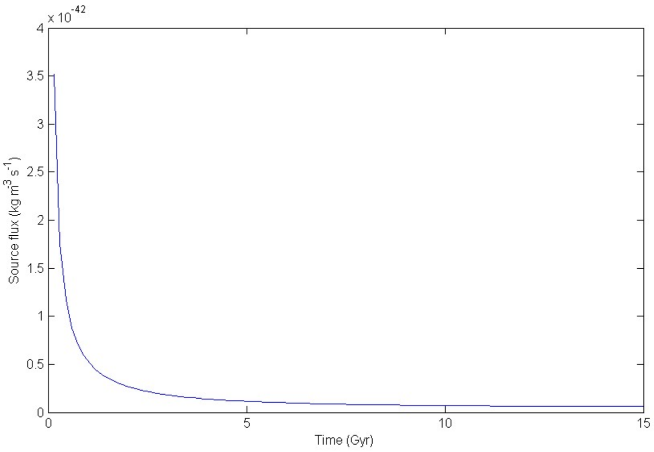

Fig. 3. Dark source flux s (10^{-42} kg $m^{-3}s^{-1}$) versus cosmic time t (Gyr)

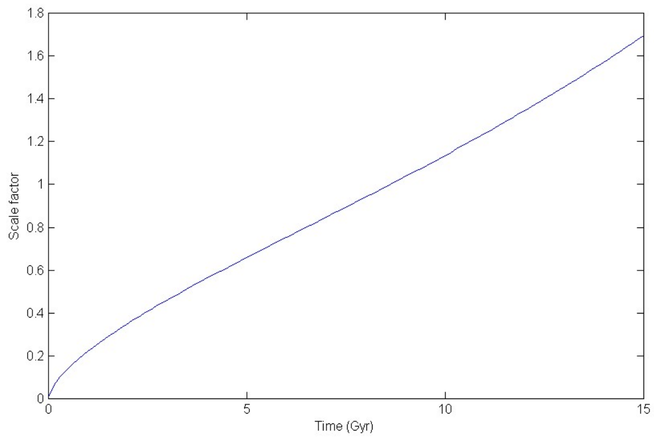

Fig. 4. Scale factor a versus cosmic time t (Gyr).

If the normalization $a(t_0) = 1$ is preferred; divide the scale factor in Fig. 4 by 1.63. The inflection from deceleration to acceleration is visible in the scale factor diagram. (This effect would be more prominent in a diagram relating $(\frac{d^2}{dt^2}a)/a$ to time, see Eq. (41).)

A possibility to check our theory is given by Hubble Space Telescope observations made by Riess et al. [14] indicating that the present-day accelerating expansion was preceded by a stage of decelerating expansion. The experimentally estimated inflection point ($(\frac{d^2}{dt^2}a)/a = 0$) occurred at redshift $z_i = 0.46 \pm 0.13$. Depending on choice of equation of state, in standard cosmology the corresponding interval of inflection usually is estimated at $t_i \approx$ 7-9 Gyr, in fair agreement with Fig. 4. Inserting our H_g value into Eq. (43), we find the corresponding DSF cosmology value: $t_i = 6.4$ Gyr. The facts that the DSF model features a transition from deceleration to acceleration in agreement with observation, as well as a credible time t_i of transition, seem like trustworthy indications of validity.

10. Simple evolution narrative based on DSF

At this point, it is time to summarize the evolution story of the DSF theory.

The expanding universe, as we perceive it, began with a dramatic Big Bang event some 14 billion years ago. The deepest cause of this event is a philosophical question, but in the DSF theory this event and the subsequent evolution are mathematically defined by the solution of the cosmological expansion equation (21), and graphically illustrated by Figs 1-4.

The DSF theory supports the idea that dark energy is a physical manifestation of invariant space, and consequently concludes that the metric expansion of space is driven by a source flux of dark energy – a dark source flux (DSF) – of unknown physical origin. The dark source flux is a non-conservative process.

The accelerating expansion of the physical universe requires an influx of kinetic energy, so it is concluded that the DSF constitutes this influx (DSF is the power density driving the expansion of the universe). The dark energy density is identified as the kinetic expansion energy density of the universe. (We will keep the denomination 'dark energy', even though we know what it is.) The dark energy is a *non-localized basic background density*, being continuously 'refilled' by the source flux to stay constant during expansion. This is an irrefutable consequence of the assumption that dark energy is a physical manifestation of invariant space, and can be intuitively understood by means of the Hubble Puddle metaphor.

The spatial extension of the entire primordial universe was indeterminate but colossal – perhaps unlimited – and the DSF operated with equal strength *everywhere and simultaneously* in this extended universe. The strength of the DSF varied over time though, from the Big Bang moment and forward. The initial flux was enormous – perhaps singular – but declined with time to the very low level of today and will asymptotically approach a slightly lower but still non-zero ultimate ground state level. The DSF varies over time, but is always non-localized in space. The metric expansion driven by the source flux occurs simultaneously and uniformly everywhere in the extended universe, but from *a local viewpoint* it appears as if the observable universe expands radially from that point, in accordance with Hubble's law.

The source flux provides pure kinetic energy, which – according to the mass-energy equivalence principle – possesses gravitational mass (without rest mass). Thus, at all stages of evolution, the cosmic medium (dark energy and everything else) possesses kinetic energy and gravitational interaction energy. The dynamics of the universe features two opposing energy densities: one expansive kinetic energy density and one contractive gravitational energy density.

The DSF theory states that these two energy components locally are in exact dynamic balance at all times, i.e. the positive kinetic term and the negative gravitational term always add up to zero. This is in complete accord with Hubble's law. Thus, in this theory the expansion of the universe is *not* due to the expansive kinetic energy of matter overcoming the contractive gravitational energy – they are always in balance. Instead, the expansion is due to the ever ongoing dark source flux that generates a resistance-less expansion of all matter embedded in the metric, vividly illustrated by the resistance-less drift of the leaves in the Hubble Puddle metaphor. The DSF theory shows that the source flux in the dynamically balanced universe drives a metric expansion *exactly* as described by Hubble's law and relates the expansion rate to the source flux rate.

The DSF provides enough dark energy to cover the cost of new space during expansion. But the *initial* cost of all universal energy is not covered. Thus, a huge amount of energy existed from the start in this picture.

This implies the existence of an extremely dense and hot *pre*-Big Bang universe. The DSF was 'turned on' at the Big Bang moment and expansion commenced. *Hence Big Bang was not the beginning of everything; it was just the beginning of the expansion of everything.* The expansion caused the universe to cool down, which initiated energy conversion processes within the non-dark energy part that eventually resulted in particles and matter existing today: photons, neutrinos, baryons, free electrons, dark matter…

The possibility of a cyclically expanding/contracting universe is discussed in Sec 17. The following eight sections address special issues that often are discussed in the context of metric expansion of space.

11. No coincidence, horizon or flatness problems

In Sec 5.7, it is explained why a so-called coincidence problem does not arise in the DSF theory. Neither do two other standard cosmology problems: the horizon and flatness problems.

The source is an agent acting uniformly and simultaneously everywhere in the entire universe. This puts the causal connection issue – the horizon problem – into a new perspective. Figuratively, if it is raining way beyond our horizon, it is no surprise that strangers out of sight get just as wet as we do. Hence, in the DSF model we do not need rapid early inflation to explain the causal connection, and we do not need it to flatten the universe – it was always flat. Inflation simply marks the 'explosive' initiation of metric expansion, which occurred simultaneously everywhere in an initially extended – even limitless – flat universe. In this picture, it still is a viable idea that primordial stochastic fluctuations were the seeds of present-day large-scale structures. These issues are further discussed in Sec 16: 'Inflationary phase'.

12. Early rapid decline of radiation density

In standard cosmology, the dilution rates of the various cosmic fluids due to expansion are based on assumed, incoherent equations of state, relating pressures to energy densities. (In the DSF theory, such assumptions are avoided – see Sec 3.5.)

Non-relativistic matter (baryonic and dark matter) in standard cosmology is attributed zero pressure and therefore declines with increasing scale factor as $\propto a^{-3}$, i.e. in inverse proportion to the volume expansion. Relativistic radiation, on the other hand, is attributed the pressure $\rho_{\text{rad}}/3$ and therefore, according to the Friedmann theory, declines more rapidly: $\propto a^{-4}$. This behaviour usually is explained by a combined effect of the decreasing number density of photons ($\propto a^{-3}$) and the redshift of each photon ($\propto a^{-1}$), resulting in a combined effect $\propto a^{-4}$. Apparently, this result requires some kind of photon annihilation mechanism corresponding to the 'extra' declination factor a^{-1}. (Conversion of relativistic radiation into non-relativistic matter is no alternative in this theory, unless the declination rate $\propto a^{-3}$ and the related zero pressure assumption are abandoned for non-relativistic matter.)

Our theory predicts that *the sum* $\rho_{\mathrm{bdr}}(t)$ of non-relativistic matter and relativistic radiation densities dilutes as $\propto a^{-3}$, thus leaving room for energy conversion *within* this summed-up density. Hence we assume that the rapid drop in the radiation-to-matter ratio, which occurred at early times, was due to conversion of relativistic radiation into non-relativistic media during an early phase of rapid cooling, rather than unexplained annihilation of radiation energy. In DSF expansion theory, the individual declination rates of non-relativistic matter and relativistic radiation are unimportant; only the declination rate of their summed-up density is of interest.

13. The cosmological arrow of time

To highlight how the source flux inflates space, the last equality of Eq. (38) can be expressed:

$$a(s)^3 = \frac{1}{(s/s_{\mathrm{g}})^2 - 1}. \tag{44}$$

In Eq. (42), the 'cosmological arrow of time' expresses how the flow of time toward the future is related to the expansion rate H of the universe. Using Eqs (12) and (13), we can reformulate this cosmological arrow of time in terms of an actively driving agent:

$$t(s) = \frac{\rho_{\mathrm{g}}}{s_{\mathrm{g}}} \ln\left(\frac{s + s_{\mathrm{g}}}{s - s_{\mathrm{g}}}\right). \tag{45}$$

This expression shows how the action of dark source flux s drives the flow of time toward the future. Hence the source of dark energy also can be seen as the source of space according to Eq. (44) and of time according to Eq. (45). The dark source flux not only drives the expansion of space but also makes the cosmic clock tick.

Several alternative definitions of the arrow of time have been suggested, the most popular being the 'thermodynamic arrow of time', where the ever-increasing entropy of the universe is thought to define an irreversible arrow toward the future. In principle, this is not in conflict with our model, where the source flux perpetually feeds new energy and related new entropy into the system. In practice, however, 'entropy of the universe' is a global measure lacking clear meaning in a metrically expanding universe of indeterminate size, whereas source flux is a well defined quantity, locally as well as globally.

Eq. (45) shows how the source flux introduces time in the theory. But the time coordinate is not independent of the space coordinates; taken together, Eqs (44) and (45) indicate how dark source flux connects space and time. DSF thus provides a physical interpretation of all four spacetime dimensions, and our normal, mentally tangible 3+1 dimensional spacetime accommodates DSF without need for higher dimensions. In a sense, DSF generates spacetime and expands it in all four dimensions.

14. Limited size of the ultimate observable universe

There are some issues concerning the term 'observable universe' and its size. Looking out into space means looking back in time. The oldest photons that meet our eyes were emitted by cosmic stuff at the time of photon decoupling, shortly after Big Bang. For simplicity, we shall here disregard this small time difference, and consider the oldest photons to be 'Big Bang photons'.

Hence our observable universe is not a snapshot of the universe of today, but rather depicts the evolution from the time of Big Bang some 14 billion years ago until today.

Thus the Big Bang photons have been travelling for 14 billion years through space before they reach us. Space is expanding, so they have been travelling upstream the Hubble flow, and a piece of cosmic stuff that emitted a Big Bang photon in our direction has been travelling downstream the Hubble flow for 14 billion years when the photon meets our eye.

So what do we see? We do not see what the emitting stuff looks like today, since it has receded out of sight long ago. Anyway, even if we could see it, it would have evolved for 14 billion years into something else that most likely looks like our closest cosmic surroundings today. What we do see at the horizon is a picture of what the emitting stuff looked like 14 billion years ago, at the time of the Big Bang (almost), *before* the emitting stuff receded out of sight. The Hubble sphere is a reasonable definition of the size of the observable universe, even if the oldest photons we see today were emitted by cosmic stuff that now is far beyond the Hubble horizon and has changed appearance.

The fact that a particle embedded in the expanding metric always is receding at the speed of light when it is located at the Hubble horizon (i.e. at the surface of the expanding Hubble sphere) has sometimes led to the misconception that the Hubble horizon itself always recedes at the speed of light. But a particle located at this horizon at cosmic time t is not the same particle that was located there before or after that time. If we follow a *specific* embedded particle, it will feature subluminal speed before it reaches the Hubble horizon and superluminal speed after passing it. The recession speed of the horizon obviously is lower than that of the embedded particle when the horizon is overtaken by the particle. Hence, the Hubble sphere does not co-expand with the metric.

At the surface of the Hubble sphere, the co-moving speed c of radiation travelling inwards toward the observer equals the outwards oriented metric expansion speed; thus radiation emitted from the surface or from points beyond it will not ever reach the observer (an exception is mentioned below). For this case, Hubble's law is:

$$c = H(t) r_{\mathrm{Hu}}(t)\,, \tag{46}$$

where r_{Hu} is the radius of the Hubble sphere. Using the $H(t)$ function derived in Eq. (22) we have:

$$r_{\mathrm{Hu}}(t) = c / H(t) = (c / H_{\mathrm{g}}) \tanh(3H_{\mathrm{g}} t / 2)\,. \tag{47}$$

In the ultimate limit $t \to \infty$ we have:

$$r_{\mathrm{Hu}}(\infty) = c / H_{\mathrm{g}} = 1.39\ 10^{26}\ \mathrm{m} = 14.7\ \mathrm{Gly}\,, \tag{48}$$

which is not much larger than our present-day sphere. This stands to reason, since the H value of today is quite close to the ultimate H_{g} value.

Hence, even if we live forever, we will not be able to see much more of the universe than we see today.

The recession speed of the Hubble horizon is:

$$\mathrm{v}_{\mathrm{Hu}}(t) = \tfrac{d}{dt} r_{\mathrm{Hu}}(t) = (3c/2)\left[1 - \tanh^2(3H_{\mathrm{g}}t/2)\right] \ . \quad (49)$$

This speed begins with $3c/2$ at $t = 0$ and approaches zero asymptotically for $t \to \infty$. Again, note that the superluminal recession speed $3c/2$ of the primordial Hubble horizon refers to the speed of the *immaterial* Hubble front; not to the recession speed of a material particle embedded in the expanding metric (which always equals *c* at the Hubble horizon). The initial recession speed $3c/2$ of the Hubble horizon is consistent with the radius of the primordial Hubble sphere, as derived in the time-shifted DSF theory in Sec 15.3.

Normally, we have $\mathrm{v}_{\mathrm{Hu}}(t) \neq c$, but there was a moment of time in the evolution process when the Hubble horizon speed actually equalled c. Solving the equation $\mathrm{v}_{\mathrm{Hu}}(t) = c$, we find that this point of time coincides with the time of inflection from decelerating to accelerating expansion (the 'jerk'), as derived in Sec 8. Thus, in the early interval of decelerating metric expansion, the Hubble sphere expanded faster than the metric and light emitted from points outside the Hubble sphere may eventually have been observed at the centre of the sphere. (This is the exception mentioned above.)

The mass of the *ultimately observable* part of the universe is:

$$M = V\rho_{\mathrm{g}} = 0.93\ 10^{53}\ \mathrm{kg}\,, \quad (50)$$

where $V = 4\pi r_{\mathrm{Hu}}(\infty)^3/3$. The mass of the *entire* universe is indeterminate but colossal.

15. Primordial non-singular universe

15.1 The primordial singularity

Expand the expressions (31) – (34) in Maclaurin series about $t = 0$. Let τ be a non-zero t value small enough to make all terms of the Maclaurin series, except the first one, negligible. Then the *primordial singularity* is defined by the expansion functions below:

$$H(\tau) = \frac{2}{3\tau} \quad (51)$$

$$\rho(\tau) = \frac{1}{6\pi G\tau^2} \quad (52)$$

$$s(\tau) = \frac{2\rho_{\mathrm{g}}}{\tau} \quad (53)$$

$$a(\tau) = \left(3H_{\mathrm{g}}\tau/2\right)^{2/3} . \quad (54)$$

15.2 Time shifted DSF theory

The expansion functions (31) – (34) actually should include an integration constant, which for simplicity was disregarded in Sec 5.8. It is easily shown that this integration constant can be expressed in terms of a shift in time Δt, i.e. the time parameter t in Eqs (31) – (34) should be replaced by $t+\Delta t$. A positive integration constant Δt corresponds to a shift Δt to the left along the time axes in Figs 1 - 4, meaning that all graphs will intersect the vertical axes at *limited, non-zero values*. For a very small value of Δt, the H, ρ and s graphs will intersect the vertical axes at very high yet limited primordial cut-off values: H_{p}, ρ_{p} and s_{p}, respectively. The a graph will intersect the vertical axis at a very small yet non-zero value a_{p}. It is also clear from the diagrams that the time shift Δt does not affect the ultimate levels of H_{g}, ρ_{g} and s_{g}, and that $H(t)$, $\rho(t)$ and $s(t)$ values are negligibly affected for $t \gg \Delta t$.

Hence this time shift transforms the mathematical singularity at $t=0$ into a finite-density, initial state of a huge and spatially indeterminate universe. To a *local* observer, whose range of vision is limited by the expanding Hubble horizon, it would seem as if everything started from a small, initial kernel of non-zero spatial radius and huge but limited density, reminding of Lemaître's 'primeval atom'.

Assuming an extremely small Δt value we have $\tau = \Delta t$ and Eqs (51) – (54) yield:

$$H_{\mathrm{p}} = 2/(3\Delta t). \tag{55}$$
$$\rho_{\mathrm{p}} = 1/(6\pi G \Delta t^2) \tag{56}$$
$$s_{\mathrm{p}} = 2\rho_{\mathrm{g}} / \Delta t \tag{57}$$
$$a_{\mathrm{p}} = (3H_{\mathrm{g}}\Delta t/2)^{2/3} \tag{58}$$

In this primordial limit of the time-shifted DSF model, s_{p} is the active agent while H_{p}, ρ_{p}, and a_{p} are reactive. It is seen that s_{p} is directly proportional to ρ_{g}. Considering the time line of causality, the primordial source flux must be what determines the ultimate ground state density; not the other way around. Therefore, ρ_{g} is primarily linked to the primordial source flux and, as a later consequence, to the ultimate ground state.

The primordial dark source flux determines ρ_{g}, which in turn determines H_{g} via Eq. (20), and then $H(t)$, $\rho(t)$, $s(t)$, and $a(t)$ via Eqs (31) – (34).

Thus, in the time-shifted DSF model, the whole evolution process is completely determined by the primordial dark source flux s_{p}.

15.3 Non-singular primordial Planck state

The Planck unit system is based on dimensional considerations linking together the fundamental constants of Nature of the three great basic theories of physics: classical Newtonian theory (G); theory of relativity (c); and quantum theory ($\hbar$). Although elegant in theory, the Planck unit system hitherto lacks commonly accepted physical significance.

Let the circumflex symbol above a letter ($\hat{x}$) denote a Planck unit. Assuming that Δt relates to the primordial Planck epoch, and that the primordial values defined by Eqs (55) – (58) are

Planck epoch values, a natural conjecture is that Δt is of the order of one Planck time unit:
$\Delta t = \hat{t} = (\hbar G / c^5)^{1/2}$ = 5.39 10^{-44} sec.

We can now express H_p and ρ_p in terms of Planck units. From Eqs (55) and (56) we obtain:

$$H_p = \frac{2}{3\Delta t} = \frac{2}{3}\left(\frac{c^5}{\hbar G}\right)^{1/2} = \frac{2}{3\hat{t}} = 1.24\ 10^{43}\ \text{s}^{-1}. \tag{59}$$

$$\rho_p = \frac{1}{6\pi}\left(\frac{c^5}{\hbar G^2}\right) = \frac{1}{6\pi}\hat{\rho} = 0.274\ 10^{96}\ \text{kg m}^{-3}. \tag{60}$$

On a global scale, the size of the universe was indeterminate even in the primordial Planck epoch. However, using Hubble's law it is possible to associate a *primordial Hubble sphere radius* r_p with the Planck scale parameters discussed above:

$$r_p = c / H_p = \frac{3}{2}\left(\frac{\hbar G}{c^3}\right)^{1/2} = \frac{3}{2}\hat{r} = 2.43\ 10^{-35}\ \text{m}. \tag{61}$$

It is important to realize that $r_p = 3\hat{r}/2$ neither is the radius of the entire primordial universe, nor is the Hubble sphere thus defined a co-expanding volume (the Hubble radius is not co-expanding with the metric). From the primordial Hubble volume $V_p = 4\pi r_p^3/3$ and the density ρ_p the mass content of the primordial Hubble sphere can be calculated:

$$M_p = V_p \rho_p = \frac{3}{4}\left(\frac{\hbar c}{G}\right)^{1/2} = \frac{3}{4}\hat{M} = 1.64\ 10^{-8}\text{kg} \tag{62}$$

The small mass M_p contained in the primordial Hubble sphere is a vanishingly small fraction of the total mass of the entire primordial universe, which was indeterminate but enormous.

If our conjecture is correct, the Planck unit system may have found an attractive physical significance: it relates to the primordial Planck state of the universe where the three fundamental theories of physics were merged.

In summary, the primordial Planck state parameters, based on the time-shifted DSF theory *and* the conjecture $\Delta t = \hat{t}$, are:

$H_p = 1.24\ 10^{43}\ \text{s}^{-1} = 2/(3\hat{t})$
$\rho_p = 0.274\ 10^{96}\ \text{kg m}^{-3} = \hat{\rho}/(6\pi)$
$r_p = 2.43\ 10^{-35}\ \text{m} = 3\hat{r}/2$
$M_p = 1.65\ 10^{-8}\text{kg} = 3\hat{M}/4$
$s_p = 3.12\ 10^{17}\ \text{kg m}^{-3}\ \text{s}^{-1}$
$a_p = 0.312\ 10^{-40}$

15.4 'Worst theoretical prediction the in history of science' explained?

One observation of interest concerns Heisenberg's uncertainty relation. The saturation limit of this relation (the 'Kennard bound') usually is expressed: $\Delta E \Delta t = \hbar / 2$. It is well known that the Planck units for energy and time satisfy: $\hat{E}\hat{t} = \hbar$, which is twice the Heisenberg limit. Our primordial values $E_\text{p} = M_\text{p}c^2 = 3\hat{M}c^2/4$ and $\Delta t = \hat{t}$ satisfy: $E_\text{p}\Delta t = 3\hbar/4$, i.e. 1.5 times the limit. The close vicinity to the Heisenberg limit suggests that the primordial universe actually was in a quantum ground state.

This would explain the well known, puzzling ratio, estimated in the range $10^{120} - 10^{122}$, between Λ values (or, equivalently, dark energy density values) based on quantum field theory on one hand, and experimental values derived from ΛCDM (or DSF) on the other. The ratio $\rho_\text{p} / \rho_\text{g}$ derived in this article is of the order 10^{121}, suggesting that the extremely high Λ value derived from quantum field theory may relate to a primordial quantum state density ρ_p, rather than to the ultimate value ρ_g.

Thus, the enormous discrepancy by a factor $10^{120} - 10^{122}$, which has been called the worst theoretical prediction in the history of science, may have found an explanation here.

16. Inflationary phase

16.1 Some initial problems with the standard and DSF models

The standard Big Bang cosmological model is not considered valid in the very early universe, where instead a Grand Unified Theory (GUT) is assumed to have prevailed at extremely high energy levels. The point of cosmic time when the transition from GUT to the standard cosmology realm occurred is guesswork; it is sometimes assumed to have happened somewhere in the Planck unit range, or later, depending on more guesswork about an intermediate inflationary time period.

GUT predicts early creation of a very high density of *magnetic monopoles*. These should be detectable today, since the expansion rate of standard cosmology is considered not to have been high enough to 'dilute them away' completely. However, no such particle has been found.

The *flatness problem* concerns the observed spatial flatness of today's universe. According to standard cosmology, our contemporary flatness would require a really extreme flatness of the primordial universe, which cannot be explained by the standard model itself. Primordial flatness is instead introduced as an initial condition in this model, but the proponents of the inflationary model find that insufficient.

The *horizon problem* concerns the causal connection within the remarkably uniform universe we can see today. How can parts at the horizon of the observable universe and our neighbouring parts display such uniformity, when the distance between these parts at the onset of standard model expansion was too large (within the limits given by the speed of light and time available) for thermal or other equalizing processes to occur?

16.2 Inflation theory

The expansion rates predicted by standard cosmology are considered to be too low by many orders of magnitude to explain these issues. But the *inflation theory* offers solutions, and also provides an explanation to how large-scale structures in today's universe could evolve from quantum fluctuations in the hot 'primordial soup'. The fundamental idea of the inflation theory is to construct a model with expansion rates high enough to dilute away the monopoles, flatten the universe, and spread out the observable universe over huge distances in an extremely short period of time. Numbers mentioned in the literature are amplification factors of 10^{30} in 10^{-35} seconds [8]. Standard cosmology, as well as our DSF cosmology, comes nowhere near such an expansion rate at 10^{-35} seconds after Big Bang (but, of course, closer to the Big Bang singularity the rate was unlimited).

The inflation theory involves hypotheses, speculations and conjectures, tied together in a dramatic story delivering the desired result: extreme exponential expansion rates at very small scale factors. The story involves highly imaginative elements like metastable repulsive gravitational matter, supercooled phase transitions, zero energy universe, temporary false vacuum with enormous mass density and negative pressure, expanding 'bubbles' of ordinary vacuum, and pocket universes making up a multiverse. Of course, direct experimental evidence cannot exist from such early times, so nothing can be falsified, but a few indirect indications of validity may possibly exist. The main reason for the widespread acceptance of this exciting but really speculative narrative seems to be that no theory presenting better explanations – hypothetical or not – of the issues discussed above has been presented as yet.

16.3 How does DSF theory relate to inflation theory?

Our question now is: what implications can our new source flux concept have on this well-established inflation theory? Let's deal with the monopole problem first. Magnetic monopoles are hypothetical particles which have never been detected, and are not even expected to be detected in the future. Inflation theory is very hypothetical. So, what we have here is a very hypothetical theory offering a solution to a very hypothetical problem. It doesn't seem necessary to involve DSF theory in this discussion.

What about the flatness and horizon problems? In DSF theory, spatial flatness is postulated at all times from Big Bang to eternity, corresponding to curvature constant $k = 0$ in standard cosmology. For $k \neq 0$, the enormous initial expansion rate of inflation theory is devised to 'straighten out' any spatial curvature in the early inflationary interval, and hand over flat space to post-inflationary standard cosmology or DSF cosmology. Hence both DSF theory and standard theory must either postulate flat space at all times, or leave it to some inflation theory to do the job at very early times. However, nothing really indicates that the global flatness postulate is unjustified; on the contrary, it may well be true at all times. Perhaps the hypothetical inflation theory again is offering a solution to a hypothetical problem (and Occam's razor proves useful once again).

The horizon problem (the causal connection problem) is no problem in the DSF theory. The dark source flux varies strongly over time, but is always uniformly distributed in space. There is absolutely no reason to assume that the distribution of the source flux is non-uniform, as long as we consider the dark energy to be non-localized in space. If the initial Big Bang distribution of non-dark energy also was uniformly distributed in space – again there is no reason to assume anything else – this uniformity will just be preserved during DSF expansion, and a horizon problem does not arise.

The origin of today's large-scale structures in space (galaxies etc.) is a more intricate problem. Inflation theory explains their origin by enormous amplification of primordial density perturbations, assumed to have arisen in the Heisenberg uncertainty realm. Some experimental support of this is indicated by non-uniformities in the CMBR spectrum. But such primordial perturbations are amplified by expansion also in the standard and DSF theories; in fact, in their Big Bang singular solutions the initial expansion rates are unlimited, and in the non-singular, time-shifted DSF solution the initial expansion rate is limited but still tremendous. In this picture, enormous amplification may have occurred without a separate, hypothetical inflation theory.

One objection to this reasoning could be that the standard and DSF theories possibly are not valid close to the Big Bang singularity. But even if our known theories of physics break down in some uncertain neighbourhood of the Big Bang singularity, and are replaced by unknown physics, it is still reasonable to believe that expansion in dynamic balance is maintained straight through the break-down limit, irrespective of what unknown physics comes in to play. This is probable, since Hubble's law is a consequence of the geometric non-centricity criterion – the Copernican principle – in an expanding universe (see Sec 5.3). Thus, DSF-driven metric expansion is more of a geometric effect than a physical effect, and the break down of known physics may not have influenced the primordial expansion rate much.

The main conclusion of this section is that the widely accepted inflation theory may come close to some future truth, but today inflation theory does not really seem like a compelling complement to standard or DSF theory; especially not to DSF theory.

17. Metric inversion and cosmic oscillation

A plethora of hypotheses about the possible existence of a pre-Big Bang universe and cyclically expanding/contracting universes is found in the literature. We shall now contribute with yet another hypothesis, here based on our dark source flux concept.

In Sec 10, an evolution narrative is sketched in which an enormous density of primordial energy is suggested to have existed already from the start of expansion. This implies an extremely dense and hot *pre*-Big Bang universe. Of course, one might speculate on the origin of such a pre-Big Bang universe. A commonly occurring conjecture is that our expanding universe was preceded by a contracting universe. In some extreme limit of contraction, this pre-Big Bang universe became critically dense and hot and 'flipped over' from metric contraction to metric expansion, as some unknown physical mechanism was triggered. Perhaps non-centric pre-Big Bang space contracted at tremendous rate towards a non-centric 'focal space', and dynamically 'shot through' this focal state into an expanding state as it emerged 'on the other side'. This dramatic metric inversion thus is thought to define the Big Bang event.

After this event, expansion commenced and non-dark energy (but not dark energy) was diluted over time. But dilution was not the only process going on. In parallel, nucleogenesis happened, and stars, galaxies and black holes were formed. In the future, after an extreme period of time, all stars will have burned out and the black holes evaporated away. All non-dark energy then has turned into an extremely diluted density of radiation, superposing the ever unchanging dark energy density.

At some future point of time, the energy density will become critically low and for unknown reason the source flux flips over into drain flux. Maybe this flip-over is a stochastic event, happening somewhere in the Heisenberg uncertainty realm and spreading throughout the universe. Now a 'rebound' event occurs, i.e. reverse metric inversion, this time from expansion to contraction. The blow-up effect of the source flux is replaced by a suck-in effect of the drain flux, and contraction commences. This proceeds until a new, high density Big Bang event occurs as described above. Drain flux then flips back to source flux, contraction to expansion, and a new cycle begins.

Mathematically, this picture actually is consistent with negative time values in Eqs (31) – (34). Following the usual sign rules for hyperbolic functions with negative argument we have:

$$H(-t) = -H(t) \qquad s(-t) = -s(t) \qquad \rho(-t) = +\rho(t) \qquad a(-t) = +a(t) \tag{63}$$

In the expanding phase (positive time), a positive dark source flux maintains constant dark energy density $+\rho_{\mathrm{g}}$. In the contracting phase (negative time), a negative dark drain flux still maintains constant dark energy density $+\rho_{\mathrm{g}}$. Hence the dark energy density level is unaffected by the Big Bang and 'rebound' events. Before as well as after these events, the dark energy density is the kinetic energy density of expansion *or* contraction (always positive and constant). This is consistent with our assumption that dark energy is a physical manifestation of invariant flat space.

This is an attractive hypothesis. Of course, two important things are missing: detailed mechanisms behind the two metric inversions – provided they really occur.

18. Pocket universes and a multiverse

In inflation theory, a pre-Big Bang universe is conjectured to have been in a state of 'false' vacuum, featuring negative pressure and an extremely high density of a hypothetical, 'repulsive-gravity' matter. The repulsive gravitational property of this matter made it expand at tremendous rate. This pre-Big Bang universe was short-lived, though, since the repulsive-gravity matter was metastable and rapidly decayed into 'bubbles' or 'patches' of ordinary vacuum. These bubbles appeared randomly, and each bubble experienced its own Big Bang as it emerged from the false vacuum. The bubbles continued to expand at much lower rates, determined by the dark energy level of ordinary vacuum (perhaps different for different bubbles). In this picture, each bubble constitutes a 'pocket universe' and together they make up a multiverse. Our own universe is just one pocket universe among an indefinite number of other such universes.

This fantastic narrative may seem like science fiction at high level. But from our DSF viewpoint, it has a couple of virtues. It provides our pocket universe with a surrounding environment, from which the dark source flux entering our universe possibly could emanate. Maybe our universe is immersed in a much vaster, residual pre-Big Bang universe – a background universe, still present everywhere but not easily perceived, except for the expansion caused by the dark source flux. That would also ease our discomfort with non-conservation of energy, since our universe in this picture is just a small part of something bigger.

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