Abstract: A new model for the metric expansion of the universe is developed from basics. It is based on recent observational results and the model is established in the minimalist spirit of Occam’s razor. A detailed analysis shows that the principle of energy conservation simply does not hold in a universe undergoing spatially flat-metric accelerating expansion. Consequently, the non-inertial, accelerating expansion of the spatially flat universe is proposed to be driven by a non-conservative influx of new energy, in natural agreement with commonly accepted physics. (This source flux is fundamentally different from the one proposed in the Steady State Model.) A Big Bang beginning is predicted and the observed expansion features of the universe are readily explained, qualitatively as well as numerically. Dark energy is identified as the kinetic expansion energy of the universe; consequently its ‘exotic’ negative pressure in standard cosmology is replaced by more realistic positive pressure. A new, strong relationship between dark energy and other cosmic media is revealed. The theory yields singular and non-singular Big Bang solutions; the Planck unit system being closely linked to the non-singular primordial state of the universe. This new model is less restricted than standard cosmology and shows better predictive power.

Keywords: cosmology, Big Bang, expansion of the universe, Hubble’s law, dark energy, source flux, energy conservation, cosmological pressure, non-singular universe, Planck epoch

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, as expressed by Hubble’s law. 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. Standard cosmology is based on the curved-metric tensor formalism of General Relativity (GR) and its offspring $\Lambda CDM$. Recent spacecraft data (WMAP [4] and Planck [5]) indicate, however, that the universe is spatially flat-metric on a global scale even in a curved-metric $\Lambda CDM$ setting, suggesting that it could be handled within a much simpler but still rigorous mathematical framework – in the spirit of Occam’s razor. (Note: From now on, ‘flat universe’ always means ‘spatially flat universe’.)
There are several disturbing obscurities in the standard cosmology expansion model; not so surprising in view of the fact that it is essentially 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 standard 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, not in conflict with earlier or 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 numerically.

1.2 Global flat space postulate and the cosmological principle

We here apply the flat global space assumption at all stages of metric expansion, which in standard cosmology would correspond to curvature constant \( k = 0 \). As mentioned above, this assumption actually is in concord with WMAP and Planck data, indicating that observable space, at least as far back as the surface of last scattering, essentially is spatially flat on a global scale even in a ΛCDM framework. The size of the spatially flat universe is indeterminate, but we assume it to be effectively unlimited outside the observable part.

The model presented here is based on the notion of a homogeneous, isotropic (the cosmological principle) and spatially flat universe. As such, it can be seen as a post-inflationary model, possibly lacking validity in some early inflationary or pre-inflationary era. It should be held in mind, though, that there exist no direct, observational evidence from the era before photon decoupling some 380 000 years after the Big Bang singularity. In fact, direct observational evidence from this era cannot exist for obvious reasons. All we know is that the observable universe emerging from this era was essentially homogeneous, isotropic and spatially flat. We know what came out after photon decoupling, but we can only guess what happened prior to that.

Various inflation theories have been devised (conjectured), aiming at explaining how the very early universe became spatially flat-metric and physically equalized before it became observable. These theories are based on rather extreme conjectures (repulsive gravity etc) and assume – for no obvious reason – that the universe in primordial times must have been non-uniform and spatially warped on a global scale. This seems like unjustified assumptions. Extreme Big Bang inflation and nucleosynthesis could just as well have happened in a primeval, high density universe, being essentially homogeneous and flat-metric from the very beginning. In this case, so-called flatness and horizon problems do not occur. The mysterious disappearance of primordial magnetic monopoles may be explained by extreme dilution, but the simplest and by far most probable explanation is that these very hypothetical particles never existed.
Implementing Occam’s razor in this situation, the proper question is not: *Why* did the very early universe become so homogeneous, isotropic and spatially flat? Instead, the proper Occam’s razor question should be: *Why not flat-metric* at all times? Again: no observational evidence indicates anything else. Metric curvature of space on global scale is pure speculation, based on the premature idea that such curvature is necessary to explain the metric expansion. But spatial curvature on global scale is an unnecessary hypothesis if expansion can be explained without such curvature. This article proposes such an explanation.

Hence, we see good reason to apply our flat-metric theory all the way back to the Big Bang singularity (predicted by the same theory) and see what comes out. This is done in Sec 14, and the outcome is – in the author’s opinion – quite interesting.

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. In our *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 it is valid only in inertial reference frames, for isolated systems and in flat-metric theories like Newtonian mechanics, quantum mechanics or Special Relativity. Obviously, many real systems are not inertial or isolated and energy is not necessarily conserved in such cases.

2.2 Energy conservation or not in Newtonian and other flat-metric theories

Indeed, in flat-metric space there are strong reasons to question an unconditional implementation of energy conservation in a universe undergoing accelerating expansion in all linear directions, i.e. a system where 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-expanding 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 [7, 8]. 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 another 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 for some reason, 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. The ultimate free lunch, as Alan Guth puts it [9]. This is an attractive idea, but lacks scientific basis. The main reason is the fact that gravitational energy density cannot be unambiguously quantified on a global basis 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.

In agreement with this conclusion, the dark source flux theory presented below states that the non-inertial, accelerating expansion of the flat-metric 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).

The cosmological standard model postulates energy conservation, thus prohibiting source flux, while this is allowed by the model presented here. This is of crucial
importance: our theory cannot be comprehended unless the profound difference between energy conservation and non-conservative source flux is understood.

The source flux proposed here is fundamentally different from the one proposed by Hoyle [10] and Bondi & Gold [11] in their Steady State Model (SSM). Their model rejected the Big Bang idea – our model supports it – and their source flux furthermore included a baryonic component, not present in our source flux. The SSM has been convincingly dismissed in the literature [12]. The arguments against the SSM do not apply to our model.

3. The nature of dark energy and dark source flux (DSF)

3.1 The great conundrum of dark energy

The nature of dark energy has been a major conundrum within astrophysics for two decades now. In standard cosmology, 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 notion 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 also is 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. This is consistent with Einstein’s field equation, when a cosmological constant $\Lambda$ is included (postulated) on the spacetime side. Invariant dark energy – defining invariant flat space – is a basic postulate also in the theory presented here.

3.2 Dark source flux and the Hubble Puddle

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 – and 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, in analogy with the rain in the Hubble Puddle metaphor presented below. 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.
The expansive effect of the dark source flux is vividly illustrated by 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.

Of course, all metaphors are incomplete and of 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.

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 space invariant and the dark energy density everywhere constant 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).

### 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 in all linear directions. The only influx of energy we have in our universal system is the DSF. Thus we conclude that 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.)

The action of DSF can be visualized in the following way. The boundless sea of dark energy is everywhere ‘seething’ with newly created kinetic energy, displaying the spherically symmetric momentum distribution that drives the expansion (‘blows up space’). At any selected point in space, new-born momentum immediately escapes radially, as determined by Hubble’s law; continuously and never endingly being replaced by new, spherical distributions of momentum at the observed point.

3.4 Kinetic expansion energy in local and global perspectives

Hubble’s law (\(v = Hr\); 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 \(r\) and the velocity vector \(v\). 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 and non-localized metric of flat 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, an embedded particle has no kinetic energy relative to the metric. In this picture, expanding flat space possesses a kinetic energy density of its own, and particles embedded in the metric just drift along without resistance in the expanding dark energy, just like the leaves in the Hubble Puddle.

The local and global perspectives are both correct and compatible.

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). DSF theory predicts that the sum of all energy in the universe, dark energy exempted, is conserved (see Secs 5.6 and 7). Hence, in cases where only photons and dark energy are present, energies of photons stay conserved as they travel through dark energy. DSF theory thus predicts optical transparency of dark energy.

Lack of interaction between photons and dark energy means that a light source travelling through pure dark energy does not experience an ‘ether wind’, i.e. the speed of emitted light is equal in all directions, in agreement with Michelson and Morley’s famous experiment in 1887.
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 compared with the dark energy density, and the expansive effect of DSF on these matters is completely negligible compared with their huge gravitational cohesion. So DSF does not make a galaxy expand noticeably.

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; all pressures are positive relative to classical absolute vacuum. 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. Still, for completeness, pressure in DSF theory is discussed separately in an Appendix.

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 (the cosmological principle). 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.

However, in standard cosmology the evolutionary history is divided into different eras, where different cosmic media were dominant. This is not the case in DSF theory, where all media are present at all times, even though their relative density levels vary drastically over time.

4.2 Dark source flux and cosmic metric expansion

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 $\Lambda CDM$ model.
The main ‘non-standard’ feature of the new model concerns the expansion mechanism. In the \( \Lambda \text{CDM} \) model the expansive effect in flat space occurs under the constraint of energy conservation, and is said to be caused by a physically dubious negative pressure induced by a cosmological constant \( \Lambda \) 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. Moreover, in contrast to \( \Lambda \), the source flux is definitely not constant over time (see Fig. 3). Hence, these two expansion hypotheses are of fundamentally different nature, and should not be mistaken for synonymous or similar concepts.

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 just like everything else.

During expansion, the source flux creates new space without action of forces (cp. the forceless drift of the leaves in the Hubble Puddle). No net gravitational (or inertial) forces act on individual mass elements. 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. It is easily shown that Hubble’s law is a purely geometric effect in a uniformly expanding system (Sec. 5.3), i.e. no physics is involved (a fact rarely – if ever – mentioned in the literature). But physics determines the value of the Hubble parameter.

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 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. Perhaps a connection with matter/antimatter unbalance and the CPT theorem exists?

4.4 The DSF model compared with the standard model

Our new expansion theory is free-standing from GR and its offspring $\Lambda CDM$, 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 parts of the new theory. Hubble’s law is an observed fact that actually is a simple geometric effect in a uniformly expanding system (Sec 5.3). A non-vanishing ground state energy density is a natural consequence of the source flux assumption. 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 $\Lambda CDM$ 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 is justified in some detail in Sec 2. (It is 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. Pressure in DSF theory is discussed separately in the Appendix.

Differences between the standard and DSF models are further discussed in Sec 6.

4.5 New achievements by the DSF model

What are the added values of our new theory? 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 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 $\Lambda CDM$ model, are:

- Non-relativistic simplicity
- Tangible driving agent behind the metric expansion
- Dark energy identified as the kinetic expansion energy of the universe
- Initial deceleration and later acceleration of expansion become logical consequences
- Negative pressure of dark energy replaced by more realistic positive pressure
- 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 evaluated from merely two experimental parameters
- No best-fit procedures (in contrast to the $\Lambda CDM$ evaluation of WMAP and Planck)
- Seamless connection between the Big Bang singularity and the ultimate state
- New intimate relation between dark energy and other cosmic media revealed
- Comprehensible cosmological arrow of time defined by the dark source flux
- Non-singular primordial state of the universe 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: $\rho(t) = \rho_g + \rho_{\text{bdr}}(t)$, where $\rho_g$ is the ground state (dark energy) density and $\rho_{\text{bdr}}(t)$ 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 Secs 5.6 and 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 $\rho_{\text{bdr}}$ therefore dilutes in inverse proportion to the volume expansion. The composition of $\rho_{\text{bdr}}$ changes over time though, due to energy conversion. For instance, the early, rapid drop of the radiation-to-matter ratio is discussed in Sec 11.
5.2 Hubble’s law

Hubble’s law was first derived in 1927 by Lemaître [13] 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 and in next section an even more fundamental derivation is presented. In any chosen local frame of reference, metric expansion is given by Hubble’s law:

\[ v(r,t) = H(t)r. \] (1)

\(v\) is the recession velocity of the Hubble flow at the radial position \(r\) 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 features 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 deviation from flat space or to the non-linearity of the scale factor. But in flat space Hubble’s law always is linear in \(r\); see below.)

5.3 Purely geometric derivation of Hubble’s law

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

A very simple 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 is spatial uniformity in an expanding space (i.e. homogeneity and isotropy implying non-centricity). Hence it is shown here that Hubble’s law is a simple consequence of the geometrical non-centricity criterion (the Copernican principle) in a uniformly expanding universe.

We define a function \(f(t)\) being the relative volume growth rate during expansion:

\[ f(t) \equiv \left[ \frac{d}{dt}V(t)/V(t) \right]. \] (2)

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

\[ \frac{d}{dt}r(t) = (f(t)/3)r(t). \] (3)

The radial velocity is: \(v(t) = \frac{d}{dt}r(t)\) and we define a new function: \(H(t) \equiv f(t)/3\).
Eq. (3) becomes:

\[ v(t) = H(t)r(t) , \]  

(4)

which is *Hubble’s law* derived from a simple geometric argument. Eq. (4) is a mathematical given fact, lacking physical content. A mathematical relationship of this type *always* is valid for uniform expansion. But of course, the \( H(t) \) function may assume different forms. This is where physics enters the picture. In Sec 5.7, this law is derived from a dynamic energy balance argument that includes gravity. 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. We shall here use a different approach to derive the same equation.

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 *change of mass per time unit and volume unit*:

\[ s(t) = \frac{d}{dt} [\frac{M(t)}{V(t)}] \]  

(5)

Note that this definition of source flux does not rely on any physical effect; it is pure differential geometry. The time derivative of \( M(t) = \rho(t)V(t) \) is:

\[ \frac{d}{dt} M(t) = V(t) \frac{d}{dt} \rho(t) + \rho(t) \frac{d}{dt} V(t) . \]  

(6)

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

\[ s(t) = \frac{\frac{d}{dt} M(t)}{V(t)} = \frac{d}{dt} \rho(t) + \rho(t) \frac{d}{dt} V(t) / V(t) . \]  

(7)

In previous section we showed that the relative volume growth rate is:

\[ [\frac{d}{dt} V]/V = 3H \]  

and Eq. (7) now becomes:

\[ s(t) = \frac{d}{dt} \rho(t) + 3H(t) \rho(t) , \]  

(8)

which is the continuity equation for source flux driven expansion.
For vanishing source flux, i.e. \( s(t) = 0 \), Eq. (8) 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 \( \left( s = 0, H = 0 \text{ and } \frac{d}{dt} \rho = 0 \right) \). A non-vanishing source flux in Eq. (8), 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

If the expanding volume is filled with dark energy of constant mass density \( \rho_g \), and nothing else, Eq. (8) reduces to:

\[
s(t) = 3H(t)\rho_g,
\]

(9)

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 \( t \) (corresponding to the rain in the Hubble Puddle metaphor). The source flux \( s(t) \) expands space and maintains constant \( \rho_g \) level at all expansion rates \( H(t) \). In principle, the model allows for \( \rho_g \) being exactly zero, but in that case our model is reduced to a degenerate state of the universe (verified in Sec 5.8).

Eq. (9) 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. (9) is reduced to a simple and fundamental relationship between three universal constants (subscript \( g \) indicates ground state values at \( t \to \infty \)):

\[
s_g = 3H_g\rho_g.
\]

(10)

### 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 (possibly intrinsic) 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:

\[
s(r,t) = \frac{\partial}{\partial t} \rho(r,t) + \nabla \cdot \mathbf{\sigma}(r,t),
\]

(11)

where \( \rho \) is the total mass density (including \( \rho_g \)), \( s \) 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 \( \mathbf{\sigma} \) 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 $\nabla \cdot \sigma$ through its surface (due to Hubble flow). Note that this equation does not imply mass or energy conservation, since $s$ and $\nabla \cdot \sigma$ may assume any values and the corresponding value of $\frac{d}{dt} \rho$ 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: $\sigma(r, t) = \rho(t) v(r, t)$, where the velocity field is the Hubble velocity $v(r, t) = H(t)r$. Remembering that $\nabla \cdot r = 3$, Eq. (11) becomes:

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

(12)

where the $r$-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. (8), derived in Sec 5.4. We repeat that the effects of pressure and gravity are implicit in this equation.

Eq. (12) 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. (12) 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 expansion (inflation). This epoch and our contemporary epoch of slower metric expansion are seamlessly linked by the common equation of continuity (12). In the ultimate limit $t \to \infty$, Eq. (12) reduces to Eq. (10), as expected.

If we use Eq. (9): $s(t) = 3H(t)\rho_g$ to eliminate $s(t)$ from Eq. (12) we obtain:

$$\frac{d}{dt} \rho(t) + 3H(t)(\rho(t) - \rho_g) = 0.$$  

(13)

Inserting the defining relationship $\rho(t) = \rho_g + \rho_{bdr}(t)$ into Eq. (13), we obtain:

$$\frac{d}{dt} \rho_{bdr}(t) + 3H(t)\rho_{bdr}(t) = 0,$$

(14)

expressing local conservation of $\rho_{bdr}(t)$. This feature is not an explicit initial postulate; it follows from the theory. Note that $\rho(t)$ in Eq. (12) is not locally conserved if $s(t) \neq 0$.

### 5.7 Dynamic balance and Hubble’s law

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

$$\varepsilon_{\text{dyn}}(\mathbf{r},t) = \varepsilon_{\text{kin}}(\mathbf{r},t) + \varepsilon_{\text{grav}}(\mathbf{r},t) = \rho(t)\left|\mathbf{v}(\mathbf{r},t)\right|^2 / 2 - 4\pi G \rho(t)^2 \left|\mathbf{r}\right|^2 / 3. \quad (15)$$

$\mathbf{v}(\mathbf{r},t)$ 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. The $\varepsilon_{\text{kin}}$ term is non-relativistic, seemingly excluding relativistic media. But the space averaged density of relativistic media is embedded and expands at the same rate as the density of non-relativistic media; hence both types of media are included in the density $\rho$. (Note: The rest mass density $\rho_{\text{rest}}$ is included in $\rho$, but the corresponding energy density $\rho_{\text{rest}} c^2$ is not included in $\varepsilon_{\text{dyn}}$. Hence $\varepsilon_{\text{dyn}} = 0$ does not express energy conservation, nor is it a ‘zero energy universe’ criterion.)

In Eq. (15) we make no assumption about the velocity field other than spherical symmetry (i.e. Hubble’s law is not presupposed). A state of dynamic balance implies $\varepsilon_{\text{dyn}} = 0$, and Eq. (15) now reduces to the scalar version of Hubble’s law:

$$\left|\mathbf{v}(\mathbf{r},t)\right| = H(t)\left|\mathbf{r}\right|, \quad (16)$$

with Hubble parameter:

$$H(t) = \pm \sqrt{8\pi G \rho(t) / 3}. \quad (17)$$

In this derivation, metric expansion according to Hubble’s law is related to 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 or contracting. It is also clear that Hubble’s law according to Eqs (16) and (17) is valid for expansion or contraction only in dynamic balance ($\varepsilon_{\text{dyn}} = 0$). Hence the astronomical observation of this law is an experimental verification of the principle of dynamic balance in expansion.

Eq. (17) can be expressed in a more familiar form:

$$\rho(t) = 3H^2(t) / (8\pi G). \quad (18)$$

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 $\Lambda$CDM theory (for $k = 0$ and $\Lambda = 0$). The fact that experimental present-day values of $\rho$ and $H$ satisfy Eq. (18) quite well is by no means a coincidence; Eq. (18) 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:

\[
\rho_g = \frac{3H_g^2}{8\pi G}.
\]  

(19)

5.8 Expansion parameters as functions of cosmic time

The three equations (9), (12) and (18) relate the three functions \(\rho(t), s(t)\) and \(H(t)\) to each other, and Eq. (19) relates \(\rho_g\) to \(H_g\). Eliminating \(s(t), \rho(t)\) and \(\rho_g\) from this equation system, we obtain a cosmological expansion equation:

\[
2 \frac{d}{dt} H(t) + 3H^2(t) = 3H_g^2.
\]  

(20)

This equation is based on the dark source flux hypothesis embodied by Eq. (9) and is of central importance in our theory. It is a first order, non-linear differential equation, which can be solved analytically for \(H_g \neq 0\) by separation of variables. The solution is a hyperbolic function:

\[
H(t) = H_g \coth(3H_g t / 2),
\]  

(21)

displaying a singularity \(H(0) = \infty\) at \(t = 0\) as expected, and \(H(\infty) = H_g\), also as expected. (Notes: Strictly, Eq. (21) 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 14.2). Mathematically, there is an alternative solution of Eq. (20) 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 \(H_g = 0\), Eq. (20) only has the degenerate solution \(H(t) \equiv 0\), whereby \(\rho(t) \equiv 0\) follows from Eq. (18). Non-degenerate states require non-zero ground state constants \((H_g > 0, \text{implying } \rho_g > 0)\). 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. (21) into Eqs (9) and (18), we obtain source flux and density as functions of cosmic time \(t\):

\[
s(t) = 3H_g \rho_g \coth(3H_g t / 2),
\]  

(22)

\[
\rho(t) = \rho_g \coth^2(3H_g t / 2).
\]  

(23)

Dividing the scalar version of Hubble’s law: \(\frac{d}{dt} a = H a\) 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. (21), we obtain:

\[
a(t) = \sinh^{2/3} \left(3H_g t / 2\right),
\]  

(24)
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 this arbitrary normalization constant does not affect the other expansion parameters in Eqs (21) – (23); more about this arbitrary constant in Sec 7, Eq. (37).

All four expansion parameters in Eqs (21) to (23) can be expressed as compact functions of one single variable (cosmic time) and two universal constants (\( \rho_g \) and \( H_g \)), which in turn can be determined from experimental data (see Sec 9).

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 mathematical formulation of the metric expansion in terms of one single variable (cosmic time \( t \)) and two measurable universal constants (\( H_g \) and \( \rho_g \)). 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:

\[
\frac{d}{dt} H(t) = \frac{a(t)}{a(t)} |H(t)| \qquad \text{(metric expansion rate function)} \quad (25)
\]

\[
s(t) = 3H(t)\rho_g \qquad \text{(basic expression for source flux-driven expansion)} \quad (26)
\]

\[
s(t) = \frac{d}{dt} \rho(t) + 3H(t)\rho(t) \qquad \text{(basic equation of continuity)} \quad (27)
\]

\[
\rho(t) = 3H(t)^2 / (8\pi G) \qquad \text{(criterion for expansion in dynamic balance)} \quad (28)
\]

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 \( \Lambda CDM \) 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 \( \rho, s \) and \( H \). Eqs (26) to (28) can be combined into a cosmological expansion equation:

\[
2 \frac{d}{dt} H(t) + 3H^2(t) = 3H_g^2. \quad (29)
\]

The solution of this equation yields the expansion parameters as hyperbolic functions:

\[
H(t) = H_g \coth(3H_g t / 2), \quad (30)
\]

\[
\rho(t) = \rho_g \coth^2(3H_g t / 2), \quad (31)
\]

\[
s(t) = 3H_g \rho_g \coth(3H_g t / 2), \quad (32)
\]

\[
a(t) = \sinh^{2/3}(3H_g t / 2). \quad (33)
\]
The three first functions (the physical parameters) display Big Bang singularities at \( t = 0 \). Their ultimate values \( (t \to \infty) \) are: \( H(\infty) = H_s, \rho(\infty) = \rho_s \) and 
\[ s(\infty) = s_s = 3H_s\rho_s, \]
respectively. The scale factor (the metric parameter) in the last equation increases with time monotonously (but not linearly) from 0 to \( \infty \).

6. Comparison with Friedmann’s equation

The fundamental difference between expansion caused by a cosmological constant \( \Lambda \) in standard cosmology, and our dark source flux \( s(t) \), is discussed in Sec 4.2.

Friedmann’s equation, derived under an adiabatic perfect fluid constraint (see e.g. [7] or [14]), is:
\[ \frac{d}{dt} \rho_e(t) + 3H(t)(\rho_e(t) + P(t)) = 0, \tag{34} \]
where \( \rho_e(t) \) is the energy density defined by the Friedmann formalism and \( P(t) \) is the pressure (which also is an energy density). If divided by \( c^2 \), it has some formal similarities with our continuity equation (12) for mass:
\[ s(t) = \frac{d}{dt} \rho(t) + 3H(t)\rho(t). \tag{35} \]

Direct comparison of (34) with (35) may lead to the misconception that \( s(t) \) somehow corresponds to negative pressure. These two equations cannot be straight off compared, however, since they are based on differing initial conditions and the energy densities are defined in different ways. In Eq. (34), energy is locally conserved, which is not the case in Eq. (35) due to the non-conservative influx \( s(t) \). Also, the energy density of pressure is included in the \( \rho(t) \) of Eq. (35) – this has been repeatedly pointed out in previous sections – while pressure is explicit in Eq. (34). Let us delve a bit on this difference, since it is a major source of misinterpretation.

In standard literature, Friedmann’s equation (34) is derived from the GR expression for vanishing covariant divergence of the energy-momentum tensor, which is taken to be a diagonal tensor of 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.

Furthermore, in the thermodynamics derivation of Eq. (34), 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 (35), 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.
Obviously, Eq. (34) is not straight off comparable with our equation (35), and \( s(t) \)
does certainly not correspond to negative pressure. Negative pressure of dark energy
is replaced by positive pressure by DSF theory (see the Appendix).

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. Obvious omissions made in our model are nucleogenesis
processes and the link to modern particle physics. At this stage, however, our
expansion theory can be developed without these connections.

7. New relationship between dark energy and other cosmic media

The expansion parameters (30) – (33) are related in the following simple manner:

\[
\rho / \rho_g = (H / H_g)^2 = (s / s_g)^2 = (1 + a^3) / a^3. \tag{37}
\]

(Note: If an arbitrary normalization multiplier \( \kappa \) is included in Eqs (24) and (33), i.e. \( a \to \kappa a \), the
last member of Eq. (37) becomes: \((\kappa^3 + \kappa^2 a^3) / \kappa^3 a^5 = (1 + a^3) / a^5\). Hence the arbitrary choice of
\( \kappa \) does not affect Eq. (37) or the following two equations.)

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

\[
\rho(t) = \rho_g + \rho_{\bar{\rho}} / a^3(t). \tag{38}
\]

Comparing with the defining expression \( \rho(t) = \rho_g + \rho_{\text{obr}}(t) \) we find:

\[
\rho_{\text{obr}}(t) = \rho_g / a^3(t). \tag{39}
\]

This result is of profound importance. The density \( \rho_{\text{obr}} \) dilutes with time in inverse
proportion to an expanding volume, again showing that the sum of non-dark energy
species is conserved in an expanding volume (cp. Eq. (14)).

It is seen that space (\( \rho_g \)) and its matter contents (\( \rho_{\text{obr}} \)) are intimately related. They
resemble the two faces of a coin; if one face vanishes both must vanish. In Eq. (39),
\( \rho_{\text{obr}}(t) = 0 \) implies \( \rho_g = 0 \), and vice versa. Empty space is as non-existent as a
faceless coin.
But Eq. (39) reveals an even more far-reaching physical duality of space. Not only is the mass density \( \rho_b \) of dark energy a physical manifestation of space; at every point of time in the expansion process there must be a superposed matter density \( \rho_{bdr} \) amounting to a rescaled \( \rho_g \) value according to Eq. (39). 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. To the knowledge of the author, this duality is not predicted by any other cosmological model.

The two universal constants \( H_g \) and \( \rho_g \) are related to \( G \) by Eq. (19). 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 \( \rho_g \) as the determining constant, close to the primordial singularity (\( a \) close to zero) the initial density \( \rho(0^+) \) 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. (38) for small \( a \) values.

8. Transition from deceleration to acceleration (the ‘jerk’)

The time derivative of \( H = (\frac{\ddot{a}}{a})/a \) yields: \( (\frac{\dddot{a}}{a^2})/a = \frac{\dddot{a}}{a} H + H^2 \). Combined with Eq. (20) we obtain:

\[
(\frac{\ddot{a}}{a(t)})/a(t) = -(H^2(t) - 3H_g^2)/2.
\]

This equation shows that an inflection point \( t_i \) – a jerk – between deceleration and acceleration (i.e. \( (\frac{\ddot{a}}{a^2})/a = 0 \) occurred at rate of expansion: \( H(t_i) = \sqrt[3]{3} H \). From Eq. (37) 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 \( \rho_g \) 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. (30) gives an exact relationship:

\[
t(H) = \frac{1}{3H_g} \ln \left( \frac{H + H_g}{H - H_g} \right).
\]

This equation expresses the ‘cosmological arrow of time’, i.e. how time develops toward the future as a function of the metric expansion rate \( H \). We shall return to this expression in Sec 12. Inserting the inflection condition \( H(t_i) = \sqrt[3]{3} H \) into Eq. (41),
we obtain the time of inflection (a numerical estimate in good agreement with observations is found in next section):

\[
t_i = \frac{1}{3H_g} \ln \left( \frac{\sqrt{3} + 1}{\sqrt{3} - 1} \right) \approx \frac{0.439}{H_g}.
\]  

(42)

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 \(\Lambda CDM\) 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 [15]: \(H_0 = 74.2 \pm 3.6\) 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 [16]: \(t_0 = 14.46 \pm 0.80\) 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 \(\Lambda CDM\) 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 those of the \(\Lambda CDM\) model. Likewise, we feel that our own evaluation model in no way falls short of the standard \(\Lambda CDM\) 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. (28) to evaluate \(\rho_0\). Insert \(H_0\) and \(t_0\) into Eq. (30) to evaluate \(H_g\). Insert \(\rho_0\), \(t_0\) and \(H_g\) into Eq. (31) to evaluate \(\rho_g\). Now all expansion functions (30) – (33) are known functions of one single variable \(t\) in a flat-metric, non-perfect fluid model. Finally, insert \(\rho_g\) and \(H_0\) (or \(H_g\)) into Eq. (26) to evaluate \(s_0\) (or \(s_g\)). In summary, the results are:

<table>
<thead>
<tr>
<th>Input:</th>
<th>Output:</th>
</tr>
</thead>
<tbody>
<tr>
<td>(H_0 = 2.40 \pm 0.12 \ 10^{-18}) s(^{-1}) [15]</td>
<td>(H_g = 2.16 \pm 0.11 \ 10^{-18}) s(^{-1}) ((H_g = 0.90\ H_0))</td>
</tr>
<tr>
<td>(t_0 = 14.46 \pm 0.80) Gyr [16]</td>
<td>(\rho_0 = 1.03 \pm 0.11 \ 10^{-26}) kg m(^{-3})</td>
</tr>
<tr>
<td></td>
<td>(\rho_g = 0.84 \pm 0.10 \ 10^{-26}) kg m(^{-3}) ((\rho_g = 0.81\ \rho_0))</td>
</tr>
<tr>
<td></td>
<td>(s_0 = 6.02 \pm 0.81 \ 10^{-44}) kg m(^{-3}) s(^{-1})</td>
</tr>
<tr>
<td></td>
<td>(s_g = 5.42 \pm 0.73 \ 10^{-44}) kg m(^{-3}) s(^{-1}) ((s_g = 0.90\ s_0))</td>
</tr>
</tbody>
</table>
The evaluated total density $\rho_0$ of today is close to the corresponding WMAP and Planck values. The dark energy density $\rho_g$ 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 (30) – (33) are plotted in Figs 1 - 4, using the ground state values $H_g$ and $\rho_g$ listed above. Note that we are today ($t_0 \approx 14 \text{ Gyr}$) close to the ultimate ground state.

![Fig. 1. Hubble parameter $H$ $(10^{16} \text{ s}^{-1})$ versus cosmic time $t$ (Gyr).](image1)

![Fig. 2. Total density $\rho$ $(10^{25} \text{ kg m}^{-3})$ versus cosmic time $t$ (Gyr).](image2)
Fig. 3. Dark source flux $s \, (10^{-42} \, \text{kg m}^{-3} \, \text{s}^{-1})$ 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 even more prominent in a diagram relating $(\frac{a'}{a^2})/a$ to time, see Eq. (40).)

A possibility to check our theory is given by Hubble Space Telescope observations made by Riess et al. [17] indicating that the present-day accelerating expansion was preceded by a stage of decelerating expansion. The experimentally estimated
inflection point \( \left( \frac{d^2 a}{dt^2} \right) / a = 0 \) 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. (42), 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 (20), and graphically illustrated by Figs 1-4.

The results of 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 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 (but no 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 (energy equivalent to rest mass is not included in this balance). This is in complete accord with Hubble’s law; in fact, it is a compelling consequence of it – see Sec 5.7. 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. In DSF theory 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 standard cosmology picture is that the universe from the earliest beginning consisted of a fixed, huge amount of energy, which then was diluted by metric inflation/expansion (in an energy conserving process) into the low energy density we experience today. Hence, in this picture, earliest creation happened at or before the beginning of our time, and no new creation happened after that. Our leap of thought is that a huge amount of energy actually existed from the earliest beginning, subsequently being diluted by metric expansion of space (in agreement with the standard picture). At the same time, however, new vacuum energy continuously was and is created in pace with the increasing volume of space. Hence, creation was not ready at the beginning of expansion, but in our view it still continues as the expansion of space progresses.

11. 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 and the Appendix.)

In standard cosmology, non-relativistic matter (baryonic and dark matter) 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 energy annihilation mechanism corresponding to the ‘extra’ declination factor $a^{-1}$.

Our theory predicts that the sum $\rho_{\text{br}}(t)$ 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 this case, radiation diluted faster than $\propto a^{-3}$, and non-relativistic matter slower than that, resulting in a summed-up decline: $\rho_{\text{br}} \propto a^{-3}$. Hence, an early dilution rate $\propto a^{-4}$ of radiation alone – in agreement with standard cosmology – is not excluded by DSF theory. 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.

12. The cosmological arrow of time

To highlight how the source flux inflates space, the last equality of Eq. (37) can be expressed:

$$a(s)^3 = \frac{1}{(s/s_g)^3 - 1}. \quad (43)$$

In Eq. (41), 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 (9) and (10), we can reformulate this cosmological arrow of time in terms of an actively driving agent:

$$t(s) = \frac{\rho_g}{s_g} \ln \left( \frac{s + s_g}{s - s_g} \right). \quad (44)$$

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. (43) and of time according to Eq. (44). 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 [18], 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 extensive measure lacking clear meaning in a metrically expanding universe of indeterminate size, whereas source flux is a well defined intensive quantity, locally as well as globally.

Eq. (44) shows how the source flux introduces time in the theory. But the time coordinate is not independent of the space coordinates; taken together, Eqs (43) and (44) 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.

13. Limited size of the ultimate observable universe

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.

The Hubble sphere does not co-expand with the metric. But at the surface of the Hubble sphere, the speed \( c \) of radiation travelling inwards toward the observer always equals the outwards oriented metric expansion speed (this is the definition of the Hubble horizon). 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:

\[
c = H(t)r_{Hu}(t),
\]

where \( r_{Hu} \) is the radius of the Hubble sphere. Using the \( H(t) \) function derived in Eq. (21) we have:

\[
r_{Hu}(t) = c / H(t) = (c / H_g) \tanh(3H_g t / 2).
\]

In the ultimate limit \( t \to \infty \) we have:

\[
r_{Hu}(\infty) = c / H_g = 1.39 \times 10^{26} \text{ m} = 14.7 \text{ Gly},
\]

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:

\[
v_{Hu}(t) = \frac{dr_{Hu}(t)}{dt} = (3c / 2) \left[ 1 - \tanh^2(3H_g t / 2) \right].
\]

This speed begins with $3c/2$ at $t = 0$ and approaches zero asymptotically for $t \to \infty$. 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).

Normally, we have $v_{\text{lin}}(t) \neq c$, but there was a moment of time in the evolution process when the Hubble horizon speed actually equalled $c$. Solving the equation $v_{\text{lin}}(t) = c$, 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:

$$M = V \rho_g = 0.93 \times 10^{53} \text{ kg}, \quad (49)$$

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

14. Primordial non-singular universe

14.1 The primordial singularity

In Sec 1.2, we discussed the lack of direct observational data from the era close after the Big Bang singularity, which in an Occam’s razor perspective provides sound reason to extrapolate our flat-metric DSF theory back into this singularity, and see what comes out. This section pursues this line of thought.

Expand the expressions (30) – (33) in Maclaurin series about $t = 0$. Let $\tau$ 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:

$$H(\tau) = \frac{2}{3\tau} \quad (50)$$

$$\rho(\tau) = \frac{1}{6\pi G \tau^2} \quad (51)$$

$$s(\tau) = 2 \rho_g / \tau \quad (52)$$

$$a(\tau) = \left(3H_g \tau / 2\right)^{2/3} \quad (53)$$

Observe that these relationships are only valid for very small $\tau$ values, i.e. very close to the singularity. Farther out, Eqs (30) – (33) are valid.
14.2 Time shifted DSF theory

The expansion functions (21) – (24) 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 $\Delta t$, i.e. the time parameter $t$ in Eqs (21) – (24) should be replaced by $t + \Delta t$. A positive integration constant $\Delta t$ corresponds to a shift $\Delta t$ 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 $\Delta t$, the $H$, $\rho$ and $s$ graphs will intersect the vertical axes at very high yet limited primordial cut-off values: $H_p$, $\rho_p$ 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 $\Delta t$ does not affect the ultimate levels of $H$, $\rho$ and $s$, 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 $\Delta t$ value we have $\tau = \Delta t$ and Eqs (50) – (53) yield:

\begin{align*}
H_p &= 2/(3\Delta t). \\
\rho_p &= 1/(6\pi G \Delta t^2) \\
s_p &= 2 \rho_g / \Delta t \\
a_p &= (3H_g \Delta t / 2)^{2/3}
\end{align*}

In this primordial limit of the time-shifted DSF model, $s_p$ is the active agent while $H_p$, $\rho_p$, and $a_p$ are reactive. It is seen that $s_p$ is directly proportional to $\rho_g$.

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, $\rho_g$ is primarily linked to the primordial source flux and, as a later consequence, to the ultimate ground state.

The primordial dark source flux determines $\rho_g$, which in turn determines $H_g$ via Eq. (19), and then $H(t)$, $\rho(t)$, $s(t)$, and $a(t)$ via Eqs (21) – (24).

Thus, in the time-shifted DSF model, the whole evolution process is completely determined by the primordial dark source flux $s_p$, which determines the dark energy density $\rho_g$ and all other expansion parameters.
14.3 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 \( \Delta t \) relates to the primordial Planck epoch, and that the primordial values defined by Eqs
(54) – (57) are Planck epoch values, a natural conjecture is that \( \Delta t \) is of the order of
one Planck time unit: \( \Delta t = \hat{t} = (\hbar G / c^5)^{1/2} = 5.39 \times 10^{-44} \) sec. We can now express \( H_p \)
and \( \rho_p \) in terms of Planck units. From Eqs (54) and (55) we obtain:

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

(58)

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

(59)

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:

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

(60)

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 \( \rho_p \) the mass content of the primordial Hubble sphere
can be calculated:

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

(61)

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 still were merged.

In summary, the primordial Planck state parameters, based on the time-shifted DSF
theory and the conjecture \( \Delta t = \hat{t} \), are:
\[ H_p = 1.24 \times 10^{43} \text{ s}^{-1} = 2/(3\dot{t}) \]
\[ \rho_p = 0.274 \times 10^9 \text{ kg m}^{-3} = \dot{\rho}/(6\pi) \]
\[ r_p = 2.43 \times 10^{-35} \text{ m} = 3\dot{t}/2 \]
\[ M_p = 1.65 \times 10^{-4} \text{ kg} = 3\dot{M}/4 \]
\[ s_p = 3.12 \times 10^{17} \text{ kg m}^{-3} \text{ s}^{-1} \]
\[ a_p = 0.312 \times 10^{-40} \]

14.4 ‘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: \( \hbar \dot{t} = h \), which is twice the Heisenberg limit. Our primordial values \( E_p = M_p c^2 = 3\dot{M}c^2 / 4 \) and \( \Delta t = \dot{t} \) satisfy: \( E_p \Delta t = 3\hbar / 4 \), i.e. 1.5 times the limit. The close vicinity to the Heisenberg limit suggests that the primordial universe, where the three fundamental theories of physics still were merged, actually was in a quantum ground state.

This would explain the well known, puzzling ratio, estimated in the range \( 10^{120} – 10^{122} \), between \( \Lambda \) values (or, equivalently, dark energy density values) based on quantum field theory on one hand, and experimental values derived from \( \Lambda CDM \) (or DSF) on the other. The ratio \( \rho_p / \rho_g \), derived in this article is of the order \( 10^{121} \), suggesting that the extremely high \( \Lambda \) value derived from quantum field theory may relate to a primordial quantum state density \( \rho_p \), not to the ultimate value \( \rho_g \).

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.

Appendix: Pressure in dark source flux cosmology

In Sec 3.5 it is pointed out that pressure is an implicit property in DSF cosmology, so an explicit definition of pressure is not really necessary in that theory. Neither positive nor negative pressures appear in explicit form. Hence precarious conjectures about pressures, or about equations of state that explicitly relate pressure to energy density in different cosmic fluids, can be avoided in DSF theory.

In GR and standard cosmology the pressure concept is of central importance to the expansion theory. It is ill defined, though, and therefore confusing, and it stands in conflict with the Occam’s razor philosophy implemented in the present article on DSF.

However, since DSF theory unavoidably will be compared with standard cosmology, the DSF pressure concept is discussed in detail in a separate article [19]. It must be emphasized, though, that DSF cosmology is completely independent of standard
cosmology and GR. The pressure issue only arises when DSF cosmology is compared with standard cosmology, and the problem lies entirely on the standard cosmology side. In standard cosmology, pressure is defined by a Friedmann equation, which is a strongly simplified version of Einstein’s field equation and therefore subject to several problematic limiting constraints. In [19], on the other hand, a cosmological pressure concept is defined from a more general and unconstrained virial equation for open systems.

Comparing the pressures thus derived with corresponding pressures derived from the Friedmann equation, the pressures are found to agree for non-relativistic matter and relativistic radiation, but differ for dark energy. The ‘exotic’ negative pressure of dark energy in standard cosmology is replaced by more down-to-earth positive pressure, amounting to one third of the dark energy density \( P_{de} = \rho_{de} / 3 \). This is the same type of equation of state as that of a photon gas, which is not surprising since both fluids consist of pure kinetic energy with no rest mass-energy.

Another interesting finding is that the dilution of radiation density (caused by expansion) influences the pressure, as expected, but more surprisingly the influence of the redshift of photons on pressure is eliminated by the energy balance criterion.

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References


