The Klein-Alfvén cosmology revisited

Johan Hansson
Division of Physics Luleå University of Technology SE-971 87 Luleå, Sweden
E-mail: c.johan.hansson@ltu.se

Keywords: Klein-Alfven, cosmology, alternative

Abstract
The Klein-Alfvén model is based on the pragmatic belief that also cosmology, just like all other fields of physics, should be based on physical laws independently tested in the laboratory. It actually has a number of attractive features, described in this article. As almost all matter in the known universe is in the plasma state, the model is by necessity based on both gravity and electromagnetism, and as most cosmic plasmas are inhomogeneous and magnetized, it is automatically inhomogeneous (as is the real universe). It is not perfect (no models are), but many of the outstanding unsolved ‘problems’ of the contemporary standard big bang-model of cosmology are either solved/sidestepped by, or non-existent in, the Klein-Alfvén model. One should remember that the standard model of cosmology also is just that—a model, and highly idealized at that, with many ad hoc ingredients and a large number of free parameters and hypothetical ingredients that are fixed only through comparison with cosmological data in a global best-fit fashion. It is not, and should never be considered to be, sacrosanct. If a comparable number of man-hours had been invested in the direction of the Klein-Alfvén model it is plausible that it would describe the real observed universe as good as, or even better than, the big bang-model—with much fewer speculative additions to known physics.

1. Introduction
Roughly sixty years ago\textsuperscript{1}, two of the greatest Swedish physicists of all time, Oskar Klein and Hannes Alfvén, proposed a cosmology based on known laws of physics [1–4].

This has many positive aspects:

(i) It is highly advantageous to have several different models in order for the scientific method to work in the most efficient manner. Three well-known examples may show how wildly different descriptions can successfully describe (almost) the same data: 1. Newtonian Gravitation (gravitational forces) versus General Relativity (no gravitational forces, instead geodesic ‘free-falling’ motion in curved spacetime), 2. S-matrix Theory (only observable entities) versus Quantum Field Theory (unobservable fields) in elementary particle physics. 3. Orthodox ‘Copenhagen’ Quantum Mechanics (intrinsically probabilistic and observer subjective) versus Bohm’s Quantum Mechanics (deterministic and objective with non-local ‘hidden variables’).

(ii) Cosmology may be based on known physics, tested/testable in the laboratory and/or solar system without speculative contents.

(iii) There is a clear danger of ‘scientific inbreeding’ if everyone dances to the same tune single-mindedly. One should remember that all models are flawed, in some ways.

\textsuperscript{1} If that sounds ancient and irrelevant, one should remember that the standard model of cosmology, exclusively in use today, is almost one hundred years old.
In the highly speculative environment of much of theoretical/fundamental (or, rather, fantasy) ‘physics’ of today, with little or no connection to tested/testable reality, I believe it is time for a re-appraisal of the Klein-Alfvén model, and its attempt to base also cosmology on tested/testable physics, just like all its other sub-fields. Physics is, after all, supposed to be all about real phenomena in the real world - something which more often than not seems to have been forgotten in the ‘fundamental physics’ of today. This article is a small attempt in that direction.

2. The ‘standard’ model of cosmology—the ‘hot big bang’ model

Einstein’s equations of general relativity are a system of ten coupled, nonlinear partial differential equations that have to be solved simultaneously. To achieve analytical cosmological solutions to a physically realistic universe is out of the question. Therefore, early researchers made drastic approximations to make way forward. The ‘Cosmological Principle’ was decided upon as a reasonable approximation—at any epoch the (model) universe is exactly homogeneous and isotropic. With these extreme simplifying assumptions, and further assuming idealized perfect fluid for the matter content, Einstein’s original equations reduce to Friedmann’s equations—a system of only two ordinary differential equations that do allow analytical solutions.

The only dynamical degree of freedom that remains is the cosmic scale-factor, \( a(t) \), which describes the general expansion of space.

The parameter \( k \) encodes the spatial geometry of the model universe, and, as one is free to recalibrate the coordinates at will (general covariance), it is only the sign of \( k \) that matters: \( k = +1 \) describes a closed universe with positive spatial curvature (in this case \( a(t) \) is directly related to the physical radius of the model universe), \( k = -1 \) describes an open universe with negative spatial curvature, with \( k = 0 \) being the (unlikely) borderline case which describes a flat universe with Euclidean spatial geometry.

There is a ‘critical density’, \( \rho_{\text{crit}} \equiv 3H^2/8\pi G \), in the model which gives the flat \( (k = 0) \) case. The dimensionless parameter \( \Omega = \rho_{\text{obs}}/\rho_{\text{crit}} \) is commonly used to distinguish the three different cases, where \( \rho_{\text{obs}} \) is the observed physical density (assumed homogeneous).

One should however note that the whole idea of \( \rho_{\text{crit}} \), \( \Omega \), \( H \), etc., crucially depends on the assumption of complete and exact homogeneity and isotropy, which is simply not obeyed by the real, physical universe.

The cosmic scale-factor of the model is connected to the observable Hubble parameter, \( H(t) \), through \( H = \dot{a}/a \), where \( \dot{a} = da/dt \).

Through the absolute homogeneity and isotropy assumptions \( t \) is a universal ‘cosmic time’, the same everywhere throughout space. (Which is not the case in the real universe, due to both special and general relativistic effects.)

For a model universe without any gravitation \( H \) would be constant and the age of such a universe would simply be \( \text{age} = H^{-1} \). For a non-empty universe, gravitation decelerates the expansion, but as a fair approximation \( \text{age} \approx H_0^{-1} \), where \( H_0 = H(t_{\text{now}}) \). If extrapolated backwards in time, the temperature increases (hence the designation ‘hot’ big bang) and at \( t = 0 \) reaches a singular origin, where the density and temperature become infinite and the model fails.

3. Problems with the standard model of cosmology

Why there is ‘something rather than nothing’ is completely unanswered in the big bang-model. Everyone seems to agree that the Universe must have been matter–antimatter symmetric at the outset. However, in a homogeneous model, as the standard model of cosmology is by construction, there should be complete annihilation with no matter left. Although there is a known tiny asymmetry in the weak interaction between the behavior of matter and antimatter, it is far too small to explain the complete asymmetry (apparently) seen today. At the inception of the big bang-model in the 1920s, the existence of antimatter was still unknown, and it was naturally assumed that all matter must necessarily be of the ordinary kind.

The model itself is constructed to be exactly isotropic and homogeneous (=the Cosmological Principle). In the real universe this may have been a fair approximation when the cosmic background radiation (CBR), according to the model, was released (cosmological redshift \( z \sim a_{\text{now}}/a_{\text{decoupling}} \sim 1, 100 \)), but today is a very
poor approximation. Already in 1970, de Vaucouleurs [10] demonstrated that observations support a ‘hierarchical’, inhomogeneous cosmology. Since then, huge inhomogeneous regions of cosmic ‘voids’ and ‘filaments’ have been discovered [11, 12] and the largest known structure so far is $\sim 10^{10}$ lightyears [13], comparable to the entire observable universe.

The standard model of cosmology tries to treat the generation and evolution of structures, assumed generated solely by gravity, as small perturbations superposed on the idealized state = smooth background Friedmann-Robertson-Walker metric, but this breaks down when inhomogeneities become large and nonlinear effects overwhelm the linear ones. Furthermore, to work at all the process must be ‘doped’ by huge amounts of (hypothetical) dark matter in order to reproduce, statistically, the observed structure in the ‘mere’ 14 billion years available since the big bang in the model. Also, due to the highly nonlinear nature of general relativity, in a hierarchical (=real) universe, first averaging and then deducing the dynamics in not the same as first deducing the dynamics and then averaging. (But large N-body simulations have so far used only Newtonian gravitation, linear in the gravitational potential.).

The observed near-flatness ($\Omega_{tot} \sim 1$) is difficult to reconcile with the big bang-model. If $\Omega_{tot}$ differed from 1 by even the tiniest amount early in the history of the (model) universe it would not be near this value today. This ‘fine-tuning’ is a real problem when only gravity is at play; $\Omega > 1$ would mean that the Universe ‘should’ have collapsed in a big crunch long ago, $\Omega < 1$ that no structures (or humans) yet ‘should’ have formed. Another way of saying the same thing is that the case for Euclidean ($k = 0$) space in the model has probability density zero; there are infinitely many ways to have $\rho_{obs} > \rho_{crit}$ and $\rho_{obs} < \rho_{crit}$ but only exactly one way to have $\rho_{obs} = \rho_{crit}$. If the (model) universe started out with $\Omega_{tot} \equiv 1$ with exact mathematical precision it would stay $\Omega_{tot} \equiv 1$ forever, but as the real universe is physical this is unreasonable. This is attempted to be ‘amended’ by introducing a short (hypothetical) inflationary phase [14] supposed to (somehow) have happened in the very early universe, but there is still today not a mechanism for this that is based on known and tested physics, and inflation in turn introduces many new unsolved problems of its own, which require even more hypothetical ‘amendments’, and on and on... Furthermore, it seems that inflation cannot even solve the problems it was invoked for [15, 16].

A seldom discussed problem of the big bang-model is that the CBR must have been in equilibrium with the matter when the Universe (in the model), for the first time, became transparent at $t \approx 380,000$ years (using the presently preferred values of $\Omega_m \approx 0.3$ and $\Omega_\Lambda \approx 0.7$), hence the Universe must have been in a state of maximum entropy. However, since then the entropy has decreased (structure = order has increased) in apparent violation of the second law of thermodynamics. The real present universe is in a state of non-equilibrium; cold space between hot stars, structure formation, etc. One should also remember that, the generally covariant generalization/extension of (equilibrium) thermodynamics of the (homogeneous and isotropic model of the) universe [17] is distinct from general relativity, which only deals with the mechanical aspects of cosmology. Also, the pre-supposition of equilibrium, necessary for defining the state-variables of thermodynamics, is not strictly obeyed in the real universe—partly due to inhomogeneities, partly to horizons in the standard model of cosmology—and equilibrium is an assumption of the big bang-model underlying, not only decoupling and the CBR, but also, e.g., ‘primordial nucleosynthesis’.

Furthermore, as $t \to 0$ the big bang expansion rate $\to \infty$ (regardless of $k$)\footnote{a $\propto t^{-1/2}$, $a \to \infty$ as $t \to 0$. $H = \frac{1}{2}t^{-1}$, $H \to \infty$ as $t \to 0$.}, which, although intuitively ‘reasonable’ - as to ‘get out of’ the initial singular state the Universe must expand ‘infinitely fast’ - is physically meaningless. (Analogous to getting out of the singularity of a black hole.)

To quote Alfén himself, p. 106 in [4]: ‘The big bang theory postulates the existence of the high velocities in the singular point without any attempt to account for them as produced by any physical mechanism.’ In fact, in the big bang-model there is no clue at all as to why the Universe is expanding in the first place, it is simply postulated.

This also means that it is harder for different regions, within the model, to communicate the earlier the epoch - which leads directly to the isotropy problem of the big bang-model: There is no reason why different parts of the sky (> only a few degrees apart) should have the same CBR temperature, as those parts had never been in causal contact at the time for decoupling. Again, (hypothesis) inflation is supposed to come to the rescue, the whole presently observable universe supposed to be just a ‘pin-prick’ of the total universe, this tiny region supposed to have thermalized before inflation.

The present required values of the matter density ($\Omega_m \approx 0.3$) and the ‘dark’ (=invisible) energy density of, e.g., the cosmological constant $\Lambda$ ($\Omega_\Lambda \approx 0.7$) are at odds with the observed matter density ($\approx 0.04$). To reach $\Omega_m \approx 0.3$ means that $\sim 26\%$ of $\rho_{tot}$ must be ‘dark’ (=invisible) matter. But, we should remember that neither dark matter nor dark energy have any independent experimental support outside of cosmology and thus so far are completely hypothetical - ad hoc ‘add-ons’ to the big bang-model invented with the sole purpose to make it

\footnote{As the horizon distance grows $\propto t$ while the scale-factor expands $\propto t^{1/2}$ (for radiation dominated big bang universe before $t \approx 50,000$ years) or $\propto t^{1/3}$ (matter dominated big bang universe after $t \approx 50,000$ years) the model universe becomes more causally connected as it ages.}
comply with observation, with the normal matter (which is the only sort we know exists) being degraded to insignificant debris.

The standard model requires eleven (with additional simplifying assumptions, reducing to seven), a priori free parameters, painstakingly adjusted to provide the best global fit to cosmological observational data. In this connection there is reason to recall John von Neumann’s famous remark: ‘With four parameters I can fit an elephant, and with five I can make him wiggle his trunk’, i.e., one should not be overly impressed when a complex model fits the data set well—with enough parameters, you can fit any data”.

4. The Klein-Alfvén Cosmology

Oskar Klein, still today the internationally most widely known Swedish theoretical physicist, and Hannes Alfvén, one of only four Swedish Nobel Laureates in Physics and the pre-eminent plasma physicist of his time, in the early 1960s teamed together to construct an alternative cosmology. Their motivation was to use known basic laws controlled by laboratory results, instead of speculative theories and ‘divine creation’ à la Lemaître. Their model is based on general phenomena known to exist in the laboratory, making as few ad hoc assumptions as possible.

It is, for instance, known that most of the matter in the Universe is in the plasma state—and most space plasmas are highly inhomogeneous. Observations very often have demonstrated that homogeneous models, in the past generally relied upon in large parts of cosmic plasma physics, are misleading and not useful even as first approximations, but: ‘As homogeneous models are the simplest possible scientists usually have a tendency to assume homogeneity until there is clear evidence for inhomogeneity’, p. 123 in [4].

With this in mind, they postulate symmetry between matter and antimatter throughout the cosmos [1], with an initial state of contraction giving way to the expansion of the present observable universe (outside of which there may exist similar systems). The initial state is a plasma of the simplest stable particles with so low a density that annihilation is negligible. As all cosmical plasmas, it is magnetized. The change from gravitational contraction to expansion is achieved by a release of annihilation energy, when the particle density reached a critical (and maximum) value of \(10^{-2} \text{ cm}^{-3}\) (the present density being four-five orders of magnitude lower with annihilation time-scale \(\tau \geq 10^{12}\) years). This produced a radiation explosion about 10^{10} years ago, the size of the Universe in the model never being smaller than \(10^9\) lightyears \([2, 3]\). Annihilation is the only (known) source of energy large enough to cause the Hubble expansion. It cannot be created by the singular point of the big bang cosmology as that model is homogeneous (no pressure gradient) - instead, in the big bang-model, the Hubble velocities are postulated.

By the simultaneous actions of gravity and electromagnetism, the observable universe is divided into a large number of cells, half of which contain matter and half antimatter. Cells are separated by thin (\(10^{-8}\) lightyears) ‘Leidenfrost’ layers of discontinuity containing high energy \(e^+e^−\) produced by annihilation of \(p\bar{p}\) (or nuclei) at the interface, producing negligible \(\gamma\)-radiation [4]. The plasma pressure gradient is balanced by the force from electric plasma currents and magnetic fields. This pushes the cells away from each other, and as such does not contradict any observed phenomena.

The detailed theory for stellar nucleosynthesis was initiated by Hoyle [18], and its consequences later considerably elaborated in detail with various collaborators, as his own ‘Steady-State’-cosmology (of continuous creation) [19] contains, like the Klein-Alfvén cosmology, no extremely hot and dense initial phase [8]. Hoyle’s conclusions about elements not produced in a big bang [10] are valid also in the Klein-Alfvén model. The difference being that in the latter half of the elements, globally, will be antimatter.

5. Problems solved/sidestepped by the Klein-Alfvén model

Obviously, in the Klein-Alfvén model there is no need to explain how or why the matter–antimatter symmetry in the Universe is broken (unlike in the standard big bang-model) as it is assumed that the symmetry still exists today.

---

8 A case in point: it has been mathematically proven that with enough Ptolemaic epicycles one can reproduce, i.e., fit any motion whatsoever to arbitrary accuracy. This is what the standard ‘concordance cosmology’ is starting to resemble—an unfulfillable complicated dogma, waiting to be replaced by something simpler. The Ptolemaic theory had a wealth of adjustable parameters, Newton’s theory that superseded it has - none.

9 In the original big bang-model all elements were supposed to having been produced during the first few minutes—an idea later discredited. All elements heavier than Helium are now believed to be due to Hoyle’s stellar processes, also in the standard model of cosmology.

10 By combining these results with the earlier, much more detailed work of Burbidge et al. and of Cameron, we can finally conclude that all of the chemical elements were synthesized from hydrogen in stars’ [20].
Also, there is no singular creation of the Universe (where all known theories break down). The initial contraction and present expansion in the Klein–Alfvén cosmology are finite, less than $c$, which means that the whole (observable) universe in their model in principle is causally connected, whereas at $t = 0$ in the big bang-model the expansion is infinite, which surely is a sign that the big bang-model is flawed. The isotropy of the CBR is often cited as a problem for the Klein–Alfvén model, but as it has no horizon problem it is in fact much more serious for the big bang-model - there unsolvable without invoking hypothetical inflation, still ill-suited for the task [15]. The annihilation in the Klein–Alfvén model ($\sim 0.1 m c^2$), apart from explaining the Hubble expansion in terms of known processes, also produce different kinds of radiation (including x-ray background, etc.), and there are known possible mechanisms for isotropization of the resulting CBR [21–23].

Space automatically gets a ‘cellular’ structure [4] through gravity-enhanced plasma instability; inhomogeneous with filaments, sheets and voids (as much later observed in the real universe).

Furthermore, as there is no singular point, neither is there any need for the ‘quantum fluctuations’ in the very early big bang universe to seed structure formation as the Klein–Alfvén model is inherently inhomogeneous. So, there really is no need for a ‘quantum gravitational’ theory in order to describe all epochs of the Universe—and as there still is no such theory (despite 100 years of trying) this can only be seen as a boon for any cosmology based on physical laws known and tested in the laboratory\(^\text{11}\).

6. Conclusions

The Klein–Alfvén cosmology automatically resolves several of the outstanding unsolved problems of the standard hot big bang-model, notably, the matter-antimatter (a)symmetry, the ‘cellular’ structure of space (voids and filaments), and sidesteps several more: flatness problem, inflation, dark matter, dark energy, a singular origin of the Universe, quantum cosmology.

It seems plausible that if a comparable number of man-hours had been invested in the Klein–Alfvén model, it could describe the real, observed universe, as good as, or even better than, the almost universally accepted hot big bang-model—with much fewer speculative additions to known physics necessary. The standard model of cosmology can accommodate the observations only by the introduction of several hypothetical, ad hoc, additions to the model—additions furthermore assumed to dominate the dynamics of the Universe without any independent experimental support, and, to one more time quote Alfvén: ‘The credibility of big bang decreases with every ad hoc assumption which is needed’, p. 131 in [5].

It is also a danger when only one model is available (allowed?) in an intrinsically speculative subject such as cosmology. It is scientifically always much healthier when there are two, or more, competing models.

Acknowledgments

I have only recently appreciated the genius of Hannes Alfvén. This happened as I, by chance, read his novel ‘The Great Computer: A Vision’ [Gollancz London, 1968] (the original Swedish version, ‘Sagan om den stora datmaskinen’ [Bonnier Stockholm, 1966], is from my own year of birth). In it, he predicts the computer age up to the present (and beyond). If he could foresee that with such uncanny accuracy, why should he not have been able to predict cosmology in terms of (gravity-assisted) plasma physics—of which he was a true sage years ahead of his peers.

ORCID iDs

Johan Hansson  @ https://orcid.org/0000-0002-7200-4962

References

[1] Klein O 1962 in Recent Developments in General Relativity (Oxford Great Britain: Pergamon) pp 293–302
[2] Alfvén H and Klein O 1962 Arkiv for Fysik 23 187
[3] Alfvén H 1965 Rev. Mod. Phys. 37 652
[4] Alfvén H 1981 Cosmic Plasma (Dordrecht Holland: D. Reidel Publishing Company)
[5] Friedmann A 1922 Z. f. Phys. 10 377
Friedmann A 1924 Z. f. Phys. 21 326
[6] Lemaître G 1927 Ann. Soc. Sci. Bruxelles 47A 49

\(^{11}\) The ‘natural’ theoretical value, in any quantum theory of gravity, for the present cosmological constant is $\Lambda \sim \frac{m_{\text{Planck}}^4}{c^2}$ (in units $c = \hbar = 1$), or $\sim 10^{120}$ larger than the parameter needed in the standard model of cosmology to fit the observations—the biggest mismatch between theoretical prediction and observation ever encountered in any science.
[7] Robertson H P 1929 Proc. Nat. Acad. Sci. 15 822
[8] Feynman R P 1963 Chapter 12 in Lectures of Gravitation (Lecture Notes) ed F B Morinigo and W G Wagner (Pasadena USA: California Institute of Technology)
[9] Robertson H P 1933 Rev. Mod. Phys. 5 62
[10] de Vaucouleurs G 1970 Science 167 1203
[11] Geller M J and Huchra J P 1989 Science 246 897
[12] Einasto J et al 1997 Nature 385 139
[13] Horvath J et al 2015 Astron. & Astrophys. 584 A48
[14] Guth A H 1981 Phys. Rev. D 23 347
[15] Penrose R 1989 Ann. New York Acad. Sci. 271 249
[16] Ijjas A, Steinhardt P J and Loeb A 2013 Phys. Lett. B 723 261
[17] Tolman R C 1931 Phys. Rev. 37 1639
[18] Hoyle F 1946 Mont. Not. Roy. Astron. Soc. 106 343
Hoyle F 1954 Astrophys. J. Suppl. 1 121
[19] Hoyle F 1948 Mont. Not. Roy. Astron. Soc. 108 372
[20] Burbidge G and Hoyle F 1998 Astrophys. J. 509 L1
[21] Alfvén H and Mendis A 1977 Nature 266 698
[22] Rees M J 1978 Nature 275 35
[23] Wright E I 1982 Astrophys. J. 255 401