On the Origin of Cosmic Structures By Means of Einstein's Original General Relativity (Without Dark Energy) And The Standard Model of Elementary Particles (Without Dark Matter)[1]

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SUMMARY

Early reports from the James Webb Space Telescope (JWST) support growing evidence that galaxies in the very early universe were 'surprisingly mature.' We predict that JWST and other instruments will keep detecting well-developed galaxies as well as mature galactic clusters, as early as they can reach. The New-Old Cosmology we propose is founded in Einstein's original ('old') General Relativity (GR) without the cosmological constant. The agent that, instead of dark energy, drives the accelerated expansion of the universe must be a component of the ordinary stress-energy tensor of the original GR, caused by an ordinary Standard-Model interaction. There is only one possibility: electrostatic repulsion. We show that with the proposition of an asymmetrically charged universe, Einstein's original GR provides a comprehensive and coherent explanation for the origin of cosmic structures. Our studies indicate that at the onset of the electromagnetic plasma phase, the universe must have been approximately extremally charged ($8.6 \cdot 10^{-11}\ C\ kg^{-1}$), i.e. suspended in a local equilibrium between gravitational attraction and electrostatic repulsion. In the electrically conducting plasma, a fraction of the net charge migrated away from the initially overlapping charge- and mass-density peaks, making the mass-density peaks subextremal, and the surrounding shells superextremal. The repulsive electro-gravitational potential barriers formed by superextremal shells caused the prolapse of the surrounded highest-biased subextremal mass-density peaks into charged supermassive black holes, a process completed already during the first year. These black holes are the origin of all other structures, starting with galaxies, which formed around them by an equivalent electro-gravitational process already during the recombination period. Quasars are powered by the energy of their black holes' charge, and they become dormant after that charge has been expended (partly through relativistic jets of electrons). The mechanism behind the formation of these and other major cosmic structures is universal: its key is the interplay between the gravitationally attractive subextremal matter and the gravitationally repulsive superextremal matter. The latter gradually gains net charge at the expense of the former, so it can exert increasingly more pressure on the former, as well as within the entire universe. The present-day state of void matter is ~1.6 times the extremal. This universal push-pull structure-formation mechanism is inherent in Einstein's original GR, as exemplified by its Reissner–Nordström solution. In contrast, traditional cosmologies have embraced GR with neutral matter, which provides only the pull component and thus necessitates dark matter. We elaborate how this push-pull mechanism has formed progenitor black holes and galaxies, why black-hole clusters and the corresponding early galactic clusters are flash-photos of the one-year old universe, and how the superextremal void matter drives the accelerated expansion of the universe, inflates bubbles in the cosmic foam, and confines exceedingly fast ordinary matter into extra-massive galaxies and galactic clusters (all without dark matter).

[1] Keywords: dark matter, dark energy, accelerated expansion, general relativity, electric charge, extremal, Coulomb repulsion, gravitational collapse, black hole, galaxy, quasar, void, galactic cluster, cosmic foam

Contents

1. Introduction

Albert Einstein's General Theory of Relativity (GR) has been indispensable to cosmology since its completion in 1915 [1]. Yet, in two notable instances, it was transmuted to comply with certain common beliefs. In the first instance, which predated Edwin Hubble's 1929 discovery of the expansion of the universe, Einstein tried to bring his manifestly non-static GR theory into compliance with his belief in a static universe. Unable to determine a known force that could compensate for the absence of a static solution in his theory, he introduced a Deus ex machina by inserting the 'cosmological constant' term into his field equations [2]. However, in 1930 Arthur Edington discovered that Einstein's enforced equilibrium was unstable against perturbations [3] and could not serve its intended purpose. Eventually, Hubble's discovery dispelled belief in a static universe, and thus put the cosmological constant to rest. Einstein famously expressed regret for trying to tame his prophetic theory in favor of a common belief [4].

Despite this historic lesson, the original GR has been tamed again, this time to compensate for the alleged absence of a known force that could be responsible for the accelerated expansion of the universe, a phenomenon discovered in 1998 [5,6]. This new Deus ex machina was named 'dark energy,' apparently echoing Fritz Zwicky's 1933 term 'dark matter.' This term, in contrast, denotes a gravitating Deus ex machina that grants the theory of galaxies and galactic clusters an additional source of cohesion, needed to make the models of these structures stable against the observed 'excessive' velocities of their luminous constituents. With the introduction of dark energy, cosmology has thus tamed GR once again, and now balances on as many as two Dei ex machina, neither of them detected or understood so far.

Our proposition is that neither dark energy nor dark matter exists. An entirely new framework is necessary to successfully address these and other related unexplained phenomena – a framework firmly rooted in the untamed Einstein's GR. The unique beauty and simplicity of Einstein's GR beg against any tempering with its inner coherence. We have followed this moral to the letter.

Our radical approach (with respect to status quo ante) must necessarily lead to the rejection of yet another deeply entrenched idea. Which one? In the absence of a Deus ex machina, the agent that accelerates the universe must be hiding in plain sight - within the original field equations of GR,

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}, \qquad (1.1)$$

where $G_{\mu\nu}$ is a four-dimensional tensor representing the curvature of spacetime, $T_{\mu\nu}$ is the stress-energy tensor, G is the gravitational constant, and c is the velocity of light.

Only one among the Standard-Model interactions represented by $T_{\mu\nu}$ is capable of accelerating the expansion of the universe – electrostatic repulsion. Therefore, what we need to sacrifice is nothing less than the common belief in the general electric neutrality of the universe. In other words, what we introduce here is one simple novelty – the universe is s not electrically neutral. The universe is asymmetrically charged.

We will elaborate how the net electric charge drives the accelerated expansion of the universe, inflates bubbles in the cosmic foam, compresses exceedingly fast luminous matter into extra-massive galaxies and galactic clusters, and gives rise to most of the mass in the universe.

The proposition of the asymmetrically charged universe is in absolutely no conflict with the experimentally verified neutrality of the structure-forming matter close to our planet. On the contrary, we elaborate why the existence of the familiar neutral forms of matter within galaxies comes precisely because of the initial universal charge asymmetry.

After realizing that quasars and relativistic jets are consistent with the physics of charged black holes, we expanded our research to other important phenomena. We found not only promising interpretations of the different individual phenomena, but also significant coherence among these interpretations. In this introductory manuscript, we wish to illustrate the broad scope of relevance and overall internal consistency of our new cosmology, while detailed studies of the individual topics will follow later in full-blown chapters and dedicated articles.

The manuscript is organized in the following way. In Sections 2-5, we briefly discuss the role of the electric charge in GR and in our new cosmology. In Section 6, we show that the physics of charged supermassive black holes provides a unique explanation for the high power of quasars and the limited duration of their active phase. Sections 7-11 explain how the electric current led to the formation of charged supermassive black holes during the first year of the plasma phase. Sections 12-19 explain how the charged supermassive black holes generated galaxies within a short period during the recombination phase, and how galaxies are structured as compact, 'anomalously' massive structures. Sections 20-23 discuss the structure of galactic clusters and the cosmic foam. Section 24 summarizes the contributions of three charge migrations into the void space, and Section 25 discusses reversed migration and the possible roles of charge in galaxies with dis-charged supermassive black holes. In Section 27, we discuss predictions of our new cosmology, ranging from the nonexistence of dark matter and dark energy, to the detection of galaxies and their structured clusters as early as the observations can reach.

2. General Relativity with net electric charge

Cosmologies that hypothesize the existence of dark energy parametrize the observed pace of accelerated expansion of the universe by adding a fudge term with the cosmological constant Λ to the original GR field equations

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} - \Lambda g_{\mu\nu}. \quad (2.1)$$

In contrast, our new cosmology explains the accelerated expansion of the universe with the electromagnetic term $T_{\mu\nu}^{EM}$ that is part of the familiar stress-energy tensor $T_{\mu\nu}$. We can rewrite the original GR equations by splitting the full stress-energy tensor into its 'traditional,' non-electromagnetic component, $T_{\mu\nu}^{NON-EM}$, and the electromagnetic component $T_{\mu\nu}^{EM}$

$$G_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu}^{NON-EM} + \frac{8\pi G}{c^4} T_{\mu\nu}^{EM} \tag{2.2}$$

The original GR has thus gained its antigravitating term merely by our recognition that it was already present within the stress-energy tensor.

One can express the electromagnetic stress-energy tensor $T_{\mu\nu}^{EM}$ in terms of the electromagnetic field tensor $F_{\mu\alpha}$,

$$T_{\mu\nu}^{EM} = \frac{1}{\mu_0}\left[F_{\mu\alpha}F^{\alpha}_{\ \nu} - \frac{1}{4}\eta_{\mu\nu}F_{\alpha\beta}F^{\alpha\beta}\right]. \tag{2.3}$$

The electromagnetic field tensor is in our case determined by the distribution of the net electric charge. An analytic solution to this problem exists for a non-rotating, spherically symmetric system of mass M, and electric charge Q. The solution is the Reissner–Nordström line element [7-9],

$$ds^2 = g_{tt}c^2dt^2 - g_{tt}^{-1}dr^2 - r^2d\theta^2 - r^2 sin^2\theta d\emptyset^2 \ ,$$

with the metric element, or the relativistic gravitational potential

$$g_{RN} \equiv g_{tt} = \left(1 - \frac{2GM}{c^2r} + \frac{Q^2G}{4\pi\epsilon_0 c^4 r^2}\right), \tag{2.4}$$

where r is the radial spatial coordinate, and ϵ_0 is the dielectric constant of vacuum. The equivalent solution to the field equations (2.1) [10] yields the gravitational potential

$$g_{DM} \equiv \left(1 - \frac{2GM}{c^2r} + \frac{\Lambda}{3}r^2\right), \tag{2.5}$$

which has the same form as (2.4). Both potentials have a positive-definite term - the agent that drives the acceleration of the expansion of the universe. Still, at first glance, the positive-definite terms in (2.4) and (2.5) seem to have a different radial dependence. This is because Q^2 does not directly correspond to Λ. After multiplying and dividing the third term in (2.4) by $4\pi\epsilon_0 r^2$, we obtain the expression

$$g_{RN} = \left(1 - \frac{2GM}{c^2r} + 4\pi\epsilon_0 G\frac{\left|\vec{E}\right|^2}{c^4}r^2\right), \tag{2.6}$$

where $\vec{E}$ is the electric field of charge Q. The square of the electric field is related to the energy density, which confirms the equivalence of the two potentials.

In the limit of vanishing charge in g_{RN}, and vanishing cosmological constant in g_{DM}, the positive-definite terms vanish, and both potentials converge to the Schwarzschild potential

$$g_S \equiv \left(1 - \frac{2GM}{c^2 r}\right), \tag{2.7}$$

which exclusively represents gravitational attraction (it is always lower than unity). The Schwarzschild potential has one event horizon at the Schwarzschild radius

$$r_S = \frac{2GM}{c^2}. \tag{2.8}$$

Since all forms of energy contribute to the attraction, they are all part of the mass in the negative-definite term, in addition to the rest mass.

The mass in the negative-definite term of the Reissner–Nordström potential (2.4) also includes the energy due to the electric field, which makes the negative-definite term in the potential more attractive with more charge. Likewise, the mass in (2.5) includes the energy due to the cosmological constant (presumably, dark energy).

However, in both cases the entire potential can exceed unity if the magnitude of the positive-definite term in (2.4) or (2.5) exceeds the negative-definite term. With sufficiently high charge, the Reissner–Nordström potential is repulsive at small distances from the source, and still attractive at larger distances.

Because of the $1/r^2$-dependence of the positive-definite term in (2.4), the entire Reissner–Nordström gravitational potential is manifestly non-conservative. The conservative gravitational force of neutral matter[2] can only attract, but it can never repel objects. However, the gravitational force of charged matter can also repel massive objects.

A continuous, sufficiently charged medium can form net gravitational pressure everywhere within. In addition, the mass of such a charged medium can significantly exceed the mass of its material constituents.

We argue that the electrically charged void matter in the universe (i.e. the matter void of structures) is precisely such a medium. It drives the accelerated expansion of the universe – without dark energy – and inflates bubbles in the cosmic foam. The same charged matter exerts inward gravitational pressure that balances the momenta of the ‘excessively fast’ luminous constituents of galaxies, keeping them confined within the compact and massive observed structures of seemingly ‘anomalously’ high mass (in fact, energy) – without dark matter. Simultaneously, the charged void matter gives rise to most of the mass in the universe.

Our studies indicate that the omnipotent electrically charged matter in the universe was initially balanced between gravitational attraction and electrostatic repulsion. The void matter became increasingly electrically charged and repulsive with the migration of net charge from localized structure-forming regions. This process started with the formation of charged supermassive black holes right at the onset of

[2] Even the Schwarzschild solution of General Relativity is non-conservative, but the effects are weak (e.g. the anomalous precession of Mercury's orbit).

the electromagnetic plasma phase. This peculiar black-hole formation process is based on the spontaneous displacement of the electric charge away from the high energy-density peaks in the plasma. Two more charge migrations followed: the first during the galaxy formation, triggered by the recombination process, and the second during the billions of years long process of charge emission from the supermassive black holes.

The balance between the attractive and repulsive terms in the Reissner–Nordström potential determines the conditions for the formation of charged black holes. The solution to the quadratic equation $g_{RN} = 0$ is a pair of radii representing two event horizons. The upper limit on the charge-to-mass ratio of a charged black hole corresponds to the unique solution when the two event horizons coincide. This limit is called the 'extremal' charge-to-mass ratio (or charge concentration), and it is defined by nothing else than two fundamental constants, ϵ_0 and G,

$$\Xi \equiv \left(\frac{Q}{M}\right)_{extr} = \sqrt{4\pi\epsilon_0 G} = 8.617 \cdot 10^{-11} \frac{C}{kg}. \tag{2.9}$$

In classical physics, the simple balance between the forces of Coulomb repulsion and gravitational attraction of two charged massive particles

$$\frac{Q^2}{4\pi\epsilon_0 r^2} = \frac{GM^2}{r^2}, \tag{2.10}$$

leads to the same extremal limit. In a locally flat space, this is the upper limit on charge in a gravitationally bound system. Superextremal matter can neither collapse into a black hole, nor can it form a structure that would be gravitationally bound solely by its own constituents.

To put the magnitude of the extremal charge concentration into perspective, we can express it in terms of the number of excess electrons over protons,

$$\Xi = 9 \cdot 10^{-19} \frac{e}{proton}.$$

This figure is nine more orders of magnitude lower than the matter-antimatter asymmetry, which is already by all means notoriously low (the former is approximately the square of the latter – could this be of any significance for the underlying theory of Baryogenesis and more?). A very small excess of charge can create a number of effects that shape the structure of the universe.

One can define the relative extremality (or the level of extremality) as the ratio of the actual charge concentration and the extremal concentration,

$$\epsilon \equiv \frac{\left(\frac{Q}{M}\right)}{\Xi}\ . \tag{2.11}$$

With the definition of another dimensionless quantity, the relative radius

$$\rho \equiv \frac{r}{r_S} \, , \tag{2.12}$$

one can rewrite the Reissner–Nordström potential as

$$g_{RN}(\rho) = \left(1 - \frac{1}{\rho} + \frac{\epsilon^2}{4\rho^2}\right). \tag{2.13}$$

The dependence of the Reissner–Nordström gravitational potential on the relative radius is presented in Fig.1, for different levels of extremality. The Schwarzschild potential ($\epsilon = 0$) always flips its sign, but it never exceeds unity. In contrast, the Reissner–Nordström potential always exceeds unity, and it flips its sign twice for $\epsilon < 1$, and never for $\epsilon > 1$. As discussed above, in the extremal case, i.e. for $\epsilon = 1$, the potential (2.13) has a single solution at $\rho = 0.5$. The event horizon of a maximally charged black hole is exactly one-half the Schwarzschild radius. In addition, a charged black hole cannot have a negative-infinite singularity at $\rho = 0$, unlike an exactly neutral black hole.

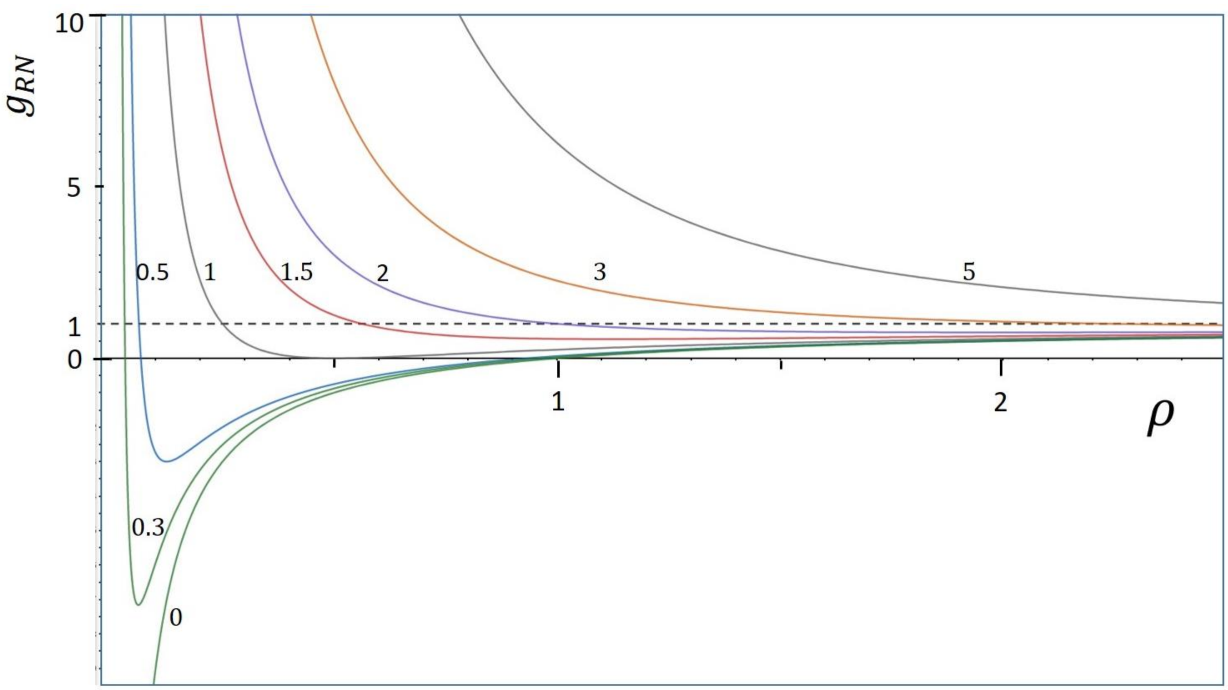

Fig. 1 Reissner–Nordström potential (2.13) for extremality levels from 0 to 5.

3. The electric charge that accelerates the expansion of the universe

The cosmological constant in the GR field equations parametrizes the observed acceleration of the present-day expansion of the universe (by the present day we mean approximately the last two billion years). Since in Section 2, we have established the equivalence between the net electric charge and the cosmological constant, we can find the amount of charge in the universe that would cause the same acceleration rate as the cosmological constant.

By equating g_{RN} and g_{DM} ((2.4) and (2.5)), and assuming that the contributions of Λ and Q to mass due to the equivalence principle are equal, it follows:

$$Q_{VOID} = c^2 r^2 \sqrt{\frac{4\pi\epsilon_0}{3G}\Lambda}. \tag{3.1}$$

With a commonly quoted result for the cosmological constant, $\Lambda \cong 1.1 \cdot 10^{-52} m^{-2}$, and the radius of the causally connected universe, $r_0 = c \cdot 13.8 \cdot 10^9 y = 1.3 \cdot 10^{26} m$, our estimate for the net charge in the void matter is

$$Q_{VOID} = 1.2 \cdot 10^{43} C. \tag{3.2}$$

To find the charge-to-mass ratio of void matter, we use the critical energy density of 'empty' space, 5.6 $m_p c^2/m^3$ (m_p is proton mass). The resulting mass of void matter within a sphere of radius r_0 is

$$M_{VOID} = 8.6 \cdot 10^{52} kg, \tag{3.3}$$

which leads to the concentration of charge in the void matter,

$$\epsilon_{VOID} \equiv \frac{\frac{Q_{VOID}}{M_{VOID}}}{\Xi} = 1.6. \tag{3.4}$$

Void matter is thus indeed highly superextremal, as expected for an agent that is capable of driving the accelerated expansion of the universe and providing most of the mass in the universe.

In a more nuanced approach, one should recognize that not all of the charge has migrated from the structured matter into the void matter, and that the void matter occupies not all of the volume.

4. What was the initial concentration of net charge?

In the previous Section, we determined that the charge concentration in void matter is superextremal at the level of $\epsilon \approx 1.6$. As elaborated in detail in Sections 6-11, the key ansatz of our cosmology is that the initial state of the universe at the onset of the electromagnetic plasma phase should have been nearly extremal. We will test the validity of this ansatz, using yet another empirical measure. This measure is the present-day division of total mass in the universe, between the component that drives the expansion of the universe (active matter), and its complement (passive matter).

In our new cosmology, the former is the superextremal void matter, and the latter includes luminous matter and the energy that balances galaxies and clusters against the inward pressure of the very same, active void matter. In traditional cosmologies, the former is dark energy, and the latter is all matter, dominated by dark matter.

To calculate the ratio between the mass of void matter and the total mass, we first need to find the total mass. The key ansatz of our new cosmology can be expressed as

$$\epsilon_{INIT} = \frac{\frac{Q_{TOT}}{M_{TOT}}}{\Xi} = 1. \tag{4.1}$$

Since we assume that nearly all of the net charge in the universe has already migrated from (what thus became) passive matter into the active void matter, it follows that

$$Q_{TOT} \gtrsim Q_{VOID} = 1.2 \cdot 10^{43} C, \text{ and}$$

$$\frac{Q_{VOID}}{M_{TOT}} \lesssim \Xi. \tag{4.2}$$

The total mass of the universe is thus

$$M_{TOT} \gtrsim \frac{Q_{VOID}}{\Xi} = 1.4\ 10^{53} kg. \tag{4.3}$$

Consequently, the fraction that void matter takes in the total mass is

$$\Omega_{VOID} = \frac{M_{VOID}}{M_{TOT}} \lesssim 0.62. \tag{4.4}$$

The division of mass between the active void matter and its passive complement is thus $\Omega_{VOID} \approx 0.62$, vs. $\Omega_{PASSIVE} \approx 0.38$, which falls remarkably close to the commonly accepted figure of $\Omega_{\Lambda} \approx 0.68$ vs. $\Omega_M \approx 0.32$. The latter is the result of observations and their robust interpretations, based mainly on conservation laws. This is why we assume that it is indeed an accurate property of the present-day universe, and thus relevant for the verification of the extremal initial condition. To conclude, the key ansatz of our new cosmology, (4.1), is indeed consistent with the empirical observations. (Another way of reaching this conclusion would be the reverse: to postulate the accepted mass division and calculate the initial charge concentration).

5. What if the initial state was *exactly* extremal?

The previous section provided evidence for our ansatz that the initial state of the universe was nearly extremal. The possibility that the initial charge density could be exactly extremal is exciting for a number of reasons:

- The extremal state is a fundamental state.

  The extremal charge concentration (2.7) is the product of only two fundamental constants, ϵ_0 and G, and it could thus itself be considered a fundamental constant, a cornerstone between electrostatics and gravitation.

  (Likewise, the speed of light is a composite of two fundamental constants, ϵ_0 and μ_0 (μ_0 is vacuum permeability), and it could be viewed as the link between electrostatics and magnetism.)

- The path to creation of the universe as we know it is extremely narrow (the anthropic principle).

  The extremal condition presents the threshold for the formation of charged black holes, which, in turn, is the key to the formation of all structures in the universe. The exact extremality of the initial state could thus join those other events in the history of the universe that narrowly provided the actual outcome, including the existence of the ^{12}C resonance in the nuclear fusion chain which, as Fred Hoyle correctly predicted, explains the very existence of carbon and heavier elements in the universe.

- Charge asymmetry must have implications on Baryogenesis, particle-antiparticle asymmetry, the nonexistence of dark matter, the possibility of non-zero photon mass, and more.

  The extremal condition presents a new constraint that could be revolutionary for the physics of the 'earlier' universe, perhaps even quantum gravity.

6. Quasars are powered by extremal supermassive black holes

By embracing charge asymmetry as a necessity required by the original GR, we can explain the two most puzzling aspects of the quasar phenomenon - the extreme power, and the limited duration of quasars' active phase. In the framework of the Christodoulou-Ruffini theory of charged Reissner–Nordström black holes [12], black holes emit charged particles (in our case electrons) using the energy converted from their reducible mass (up to one-half of the initial mass).

The particle emission process benefits from the surrounding active galactic nucleus. Once the black hole's charge and the reducible mass have been expended, a Reissner–Nordström black hole becomes a neutral and dormant Schwarzschild black hole. For instance, the average power of an extremal Christodoulou-Ruffini black hole of $10^{10} M_{\odot}$ (where $M_{\odot}$ is a solar mass), whose active period lasts for 10 Gy, can exceed $10^{40} W$ [12]. This result is indeed consistent with the observations of the quasar phenomenon.

7. The early formation of charged supermassive black holes

When and how were the quasars' charged black holes created? This could have happened only at the onset of the electromagnetic plasma phase. During this period, the density of the radiation-dominated plasma was still high enough to provide the mass needed for black-hole formation. Narrow peaks in the density landscape were still not dispersed, and the density of net charge – a necessary ingredient for the formation of a supermassive black hole – was still high.

Black holes of the lowest mass ($\sim 10^7 M_\odot$) were created first, because they needed the highest possible density to form. Black holes of $\sim 10^{11} M_\odot$ could form in a plasma diluted to the density of water, which took place approximately one year after the Big Bang. We estimate that black holes of masses lower than $\sim 10^6 - 10^7 M_\odot$ simply cannot be formed, because the formation process (described below) would have to be superluminal in order to compete against the expansion of the universe, i.e. the falling mass-energy density.

How could black holes form out of charged matter? A short answer is - precisely because of the net electric charge, not in spite of it. We explain why in the next section.

8. The Electro-Gravitational Sinkhole Prolapse

Based on the analysis elaborated in Section 4, we assume that before the onset of the electromagnetic plasma phase, all matter in the universe was nearly extremal. Since the processes that previously formed matter were local, and there was no time for significant adjustments before the plasma phase, it is plausible that the distribution of net charge initially followed the distribution of mass. Once the universe entered the electromagnetic plasma phase, the electric current could carry the net electric charge (electrons) away from the high-density peaks. The electrostatic instability due to uneven distribution of net charge could thus be relaxed on a significantly shorter timescale than the gravitational instability due to variations in the mass-energy distribution. Initially overlapping, these two distributions thus parted for good.

We propose a mechanism for the creation of charged black holes within the extremally charged plasma, which we call the Electro-Gravitational Sinkhole Prolapse. Note that the black-hole formation process takes place in a rapidly expanding matter rather than in a gradually collapsing system – thus we refer to this process as 'prolapse' rather than 'collapse.'

The radial electric currents, driven by local field gradients in this out-of-equilibrium plasma, rapidly carry part of the charge away from the high-density peaks within the universally extremal matter. All electrons in the plasma conduct the current, not only the net charge. The relaxation process is most likely chaotic and fast, driven by massive percolation. As illustrated in Fig. 2, the widening of the charge-density distribution with respect to the mass-density distribution makes the peaks significantly sub-extremal, a necessary but not sufficient condition for the formation of a Reissner–Nordström black hole. On their way, electrons necessarily pass through the low mass-density tails of the high mass-density peak, which leads to the increase of the extremality above the previous extremal level. The shell that surrounds the subextremal high-density peak thus becomes superextremal.

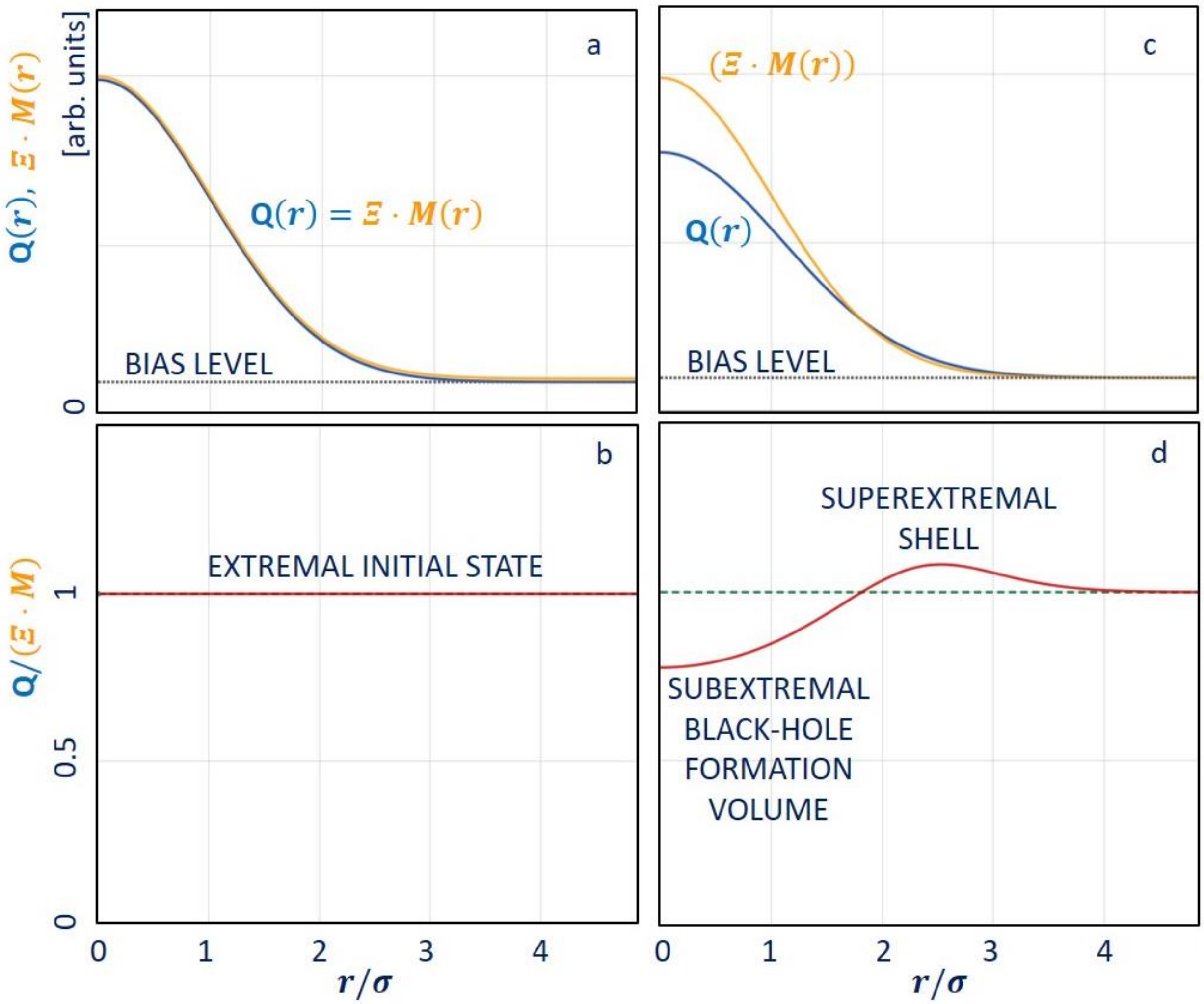

Fig. 2 Radial distribution of densities of charge (Q) and the normalized mass ($\Xi \cdot M$) (top), and the corresponding extremality ($\epsilon = Q/(\Xi \cdot M)$, (bottom). We focus on a single peak that can potentially lead to the formation of a supermassive charged black hole (approximated by a normal distribution). The initial state is extremal (a, b). The two density distributions split when the radial electric current displaces electrons. The volume within the peak becomes subextremal, while the displaced charge around it creates a superextremal shell, (c, d). A snapshot is shown at the time when $\sigma' = 1.1\sigma$. (The expansion of the universe and the displacement of mass during the presented timeframe are neglected).

The superextremal shell forms a repulsive gravitational barrier that encloses the subextremal high-density peak, and it can exceed unity by a significant margin (see Fig. 1). This condition more than satisfies the second and last requirement for the formation of a charged Reissner–Nordström black hole, namely that the gravitational potential asymptotically levels off at unity. With the depressed potential baseline, and with the absence of asymptotic freedom, this requirement could not be satisfied within the dense early plasma.

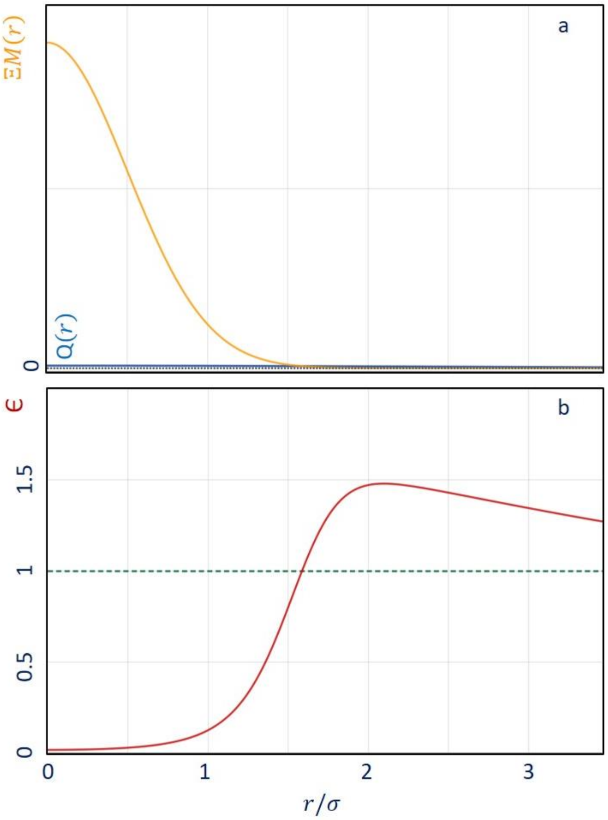

Fig. 3 The same as in Fig. 2, but for a wider, large-scale biasing peak ('hill') in the density distribution. This snapshot corresponds to a later time, when the charge-density peak widened to $\sigma' = 5\sigma$. The mass-density peak is deeply subextremal and surrounded by a wide shell of highly superextremal matter.

However, the potential barrier effectively isolates the black hole-formation volume from the rest of the universe during a brief period, within a deep potential-sinkhole whose walls rise above unity. This way, the potential eventually reaches (and even breaches) the asymptotic unity level, but, quite conveniently, this takes place immediately outside the subextremal volume. If the density within the formation volume is still high enough for the formation of a black hole, a black hole is formed and locked in its existence.

Fluctuations in the density of mass and charge that are wider than those that can lead to black hole formation experience similar electro-gravitational dynamics, but on correspondingly larger space-time scales, and without prolapse. The electric current keeps driving electrons away from the high-density peaks and creating subextremal islands and superextremal shells around them, as shown in Fig. 3. The wide and very high inward and outward repulsive barriers created within these superextremal shells are likely to create large-scale electro-gravito-acoustic waves. This violent disturbance is probably the real source of the acoustic waves, indirectly observed in the cosmic microwave background.

The newly created charged black holes remain Debye-screened within plasma until the recombination process. This pulsating configuration, which hides charged supermassive black holes within, suddenly becomes electrostatically unstable because the electric field becomes unscreened.

To summarize, the key ansatz of our new cosmology is that the initial charge concentration at the onset of the electromagnetic plasma phase must have been nearly extremal. This is because the extremal concentration is low enough for the radial electric current to quickly reduce the concentration in the core of the black-hole formation density-peak to a subextremal level, which is a necessary condition for black hole formation. At the same time, the initial extremal concentration is high enough for the same radial electric current to rapidly form a superextremal potential barrier in the tails of the black-hole formation density-peak (the second necessary condition). Both processes of the Electro-Gravitational Sinkhole Prolapse mechanism compete against the rapid reduction in the mass density due to the expansion of the universe. In addition, they can both take advantage of (or be inhibited by) the biasing mechanism, as discussed in the following section.

9. The key role of biasing during universe's first year

The offset or biasing of the black hole-formation peaks in the density distribution by wider underlying peaks or 'hills' of various heights, directly influences the success of a black-hole formation attempt. To illustrate how, we discuss three different configurations.

First, if a potential black-hole formation peak is centered at the bottom of a broad potential valley, the electron current flows down the hills, toward the bottom of the valley and the formation peak. This inward current thus counters the outward electron current from the peak. In conjunction with the low mass-density at the bottom of the valley, this current inhibition results in a low probability for a black-hole formation.

In another configuration, the formation peak resides at the steepest descent on a broad biasing potential hill. In this case, the field gradient down the hill's slope is high. The resulting electron current counters the radial current from the formation peak on its uphill side, but enhances the current on the downhill side. The combined action can shorten the black-hole formation period and lead to a black hole of a low mass, or to the failure of a formation attempt.

Lastly, in a singular configuration, the formation peak is centered at the top of a broad biasing hill in the density distribution. The gradient of the electric field around the formation peak is relatively weak, but due to the highly biased density, more time is available for the electron current than in any other configuration. A black hole formed at the top of a biasing hill is thus likely to be at the high end of the mass spectrum, and it is not likely to have any similarly massive neighbors. If no formation peak is centered close to the top of the biasing hill, there will be no ultra-massive black holes in the cluster.

When charge-density distributions expand by the same amount in a low-biased and a high-biased case, the resulting variation in the extremality level will be weaker in the latter case. Consequently, a higher biased distribution needs to expand more in order to provide the same contrast in extremality, i.e. it will need more time to form a black hole. Therefore, the same argument applies like for the previous case - since the overall density is high due to biasing, more time is available for the black-hole formation and the black hole is likely to become relatively massive.

The overall landscape is therefore dominated by clusters of supermassive black holes, with (or without) an ultra-massive black hole in the middle of a cluster, a high population of massive black holes around the center, then a lower population of low-mass black holes, and none far outside. The mass of the central black hole reflects the level of biasing, and thus also the probable width of the biasing potential hill, as well as the total number of black holes within a cluster. The aspect ratio of the biasing peak determines the distribution of black-hole masses within a cluster. One should naturally expect to see irregular clusters of various kinds.

As further discussed below, there is no reason for the black-hole pattern within the clusters and the large-scale pattern of clusters, to change significantly until the recombination phase, or even shortly after the galaxies have been formed around the black holes (black holes are Debye-screened until recombination, and it takes a long time for their galaxies to interact magneto-gravitationally afterwards). Therefore, by observing the early galactic clusters (within the first billion years after recombination), one actually observes a strongly magnified flash-photo of the peaks in the density landscape of the universe during the very first year of its radiation-dominated electromagnetic plasma phase.

10. The first migration of net charge – from the black-hole forming matter into voids

The net charge that was removed from the high-density peaks during the Electro-Gravitational Sinkhole Prolapse spreads throughout the electromagnetic plasma. Assuming that the initial state of the plasma was nearly extremal (as demonstrated above), the plasma that remained void of black holes after this migration must have become slightly superextremal, probably not more than 1.1 Ξ.

11. Why the hypothetical "bridging" black holes are missing?

An additional problem that finds a simple answer in the framework of our new cosmology is the presence of the wide gap in the distribution of black hole masses, between the masses of black holes formed within galaxies ($M \lesssim 10^2 M_\odot$), and masses of supermassive black holes in the galactic centers ($M \gtrsim 10^6 M_\odot$). The underlying belief behind this alleged puzzle has been that the supermassive black holes must have formed through gradual mergers of smaller black holes and other matter, which must have left a trace of black holes of intermediate masses. Our explanation for the absence of evidence for such 'bridging' black holes is straightforward – they do not exist. The two groups of black holes were generated by utterly different mechanisms and at completely different cosmological times. Mergers play no role in the formation of supermassive black holes.

12. How progenitor charged black holes form galaxies during recombination

After charged, supermassive black holes were formed at the beginning of the electromagnetic plasma phase; they were Debye-screened within expanding plasma until the onset of the recombination process. With recombination, the charged plasma around a black hole turned gradually into a gas consisting of neutral atoms and unpaired net electrons. This medium thus for the first time became transparent to the electromagnetic waves, including those that carried the information about the existence of a virtually point-like black-hole charge. The configuration of a charged black hole within a charged and recombined gas is unstable, and the relaxation process started as soon as the electromagnetic waves started spreading. This led to the immediate formation of galaxies.

In a schematic model, a charged black hole is initially surrounded by an imaginary large sphere of fully recombined, but still charged matter, which contains an equal amount of charge like the central black hole itself, see Fig. 4. This sphere thus contains two times more charge than any nearby sphere of equal volume. To reach the equilibrium with the environment, the electric field within the double-charged sphere repels roughly all of its free electrons into void matter. Following this massive charge migration, the charged black hole finds itself surrounded with gravitating neutral gas – its galaxy is created, and it is followed by a number of processes illustrated below.

Since the mass of the double-charged sphere is also roughly twice the mass of any nearby sphere without a black hole, the newly forming galaxy gravitationally attracts more matter from the neighborhood. The influx of charged matter is regulated by the repulsion from the central charged black hole. There are no sharp boundaries between the neutral galactic core and the superextremal galactic halo, or the superextremal void matter, but we nevertheless suspect that superextremal matter may segregate from structure-forming matter in bubbles.

During its migration into the void matter, the extra charge must have passed through the slightly superextremal shell around the emptied sphere. This makes the surrounding shell temporarily highly superextremal. Just like during the black-hole creation process by the Electro-Gravitational Sinkhole Prolapse, the superextremal shell around the newly forming galaxy creates a strong, short-range, inward-repulsive electro-gravitational potential barrier. This sinkhole funnels the gravitating neutral matter and the surrounding charged matter (galactic halo) toward the center, causing rapid convergence of matter into the core of a new galaxy.

As the freshly neutralized matter and the charged halo slide into the sinkhole, they acquire angular momentum, and the latter develops a dipole magnetic field. The interplay of extremal and neutral matter within a rotating galactic environment can induce deformation and structure within the galaxies.

The star formation process should have started as soon as the compressed and gravitating recombined matter became locally subextremal (not necessarily neutral). The initial and subsequent variations in the electric field induce turbulent magnetic fields that could also have contributed to rapid star formation.

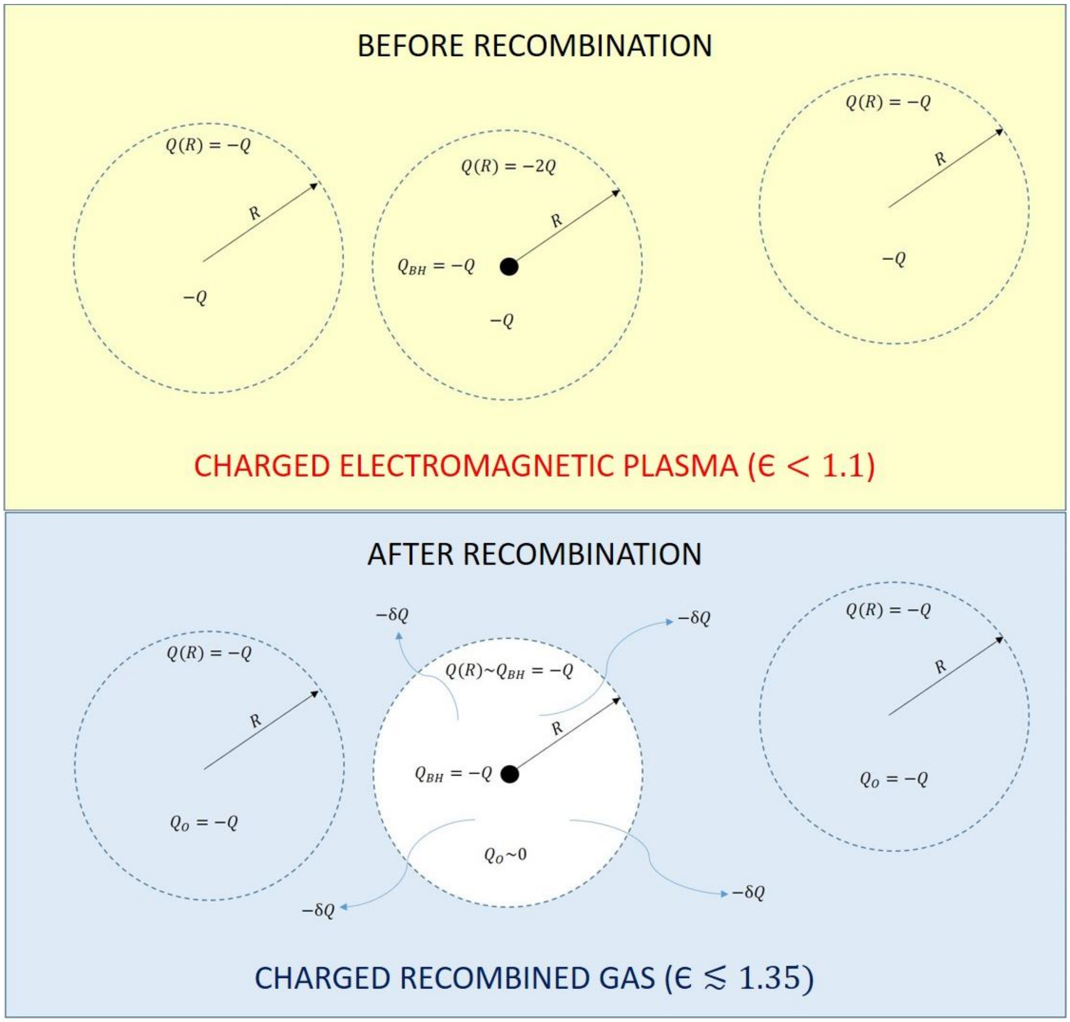

Fig. 4 Schematic view of charge migration during galaxy formation by a charged progenitor black hole (the black dot in the middle sphere). See text for explanation.

The radiation from the early star formation, as well as the outward electron drift that works against the inspiralling of gravitating and compressed matter, can cause partial reionization. The remnants of the electric field established by the central black hole, which initially spread through the recombined matter, can remain 'frozen' after reionization within the non-equilibrium plasma. The migration of the net charge from the forming galaxy can thus continue through the ionized matter. We estimate that the galaxy-formation process (defined as outlined above) should have taken no more than a quarter of a billion years.

13. The second migration of net charge – from the galaxy-forming matter into voids

The void matter is further enriched by the charge expelled from all of the newly formed galaxies. As elaborated below, our estimate for the resulting concentration is ~1.35 Ξ. This process shifted the pressure that drives the accelerated expansion of the universe into a higher, but still not its highest, gear. The actual acceleration of the ‘massive’ universe will pick up its pace only billions of years later.

14. Why the masses of galaxies and their progenitor black holes are correlated?

Since the mass of neutral matter within a galaxy is related to the lost charge, which is nearly equal to the charge of the black hole, and since the mass of the black hole is related to its own charge, it follows that the mass of neutral matter within the galaxy must be correlated with the mass of its central black hole.

15. The Galactic Bag Model

The superextremal void matter is not only responsible for the accelerated expansion of the universe, but also for the seemingly anomalous high kinetic energy of galactic constituents. The observed ‘excessively’ high kinetic energy of the galactic matter merely balances the inward pressure exerted by the superextremal void matter.

To explain this important effect in the simplest possible terms, we have introduced the Galactic Bag Model, inspired by the MIT Bag Model of hadrons [11], in which the kinetic energy of nearly massless quarks within the hadron bags of perturbative QCD vacuum balances the inward pressure of the non-perturbative QCD vacuum that occupies the outside space. The total mass of a hadron is thus two orders of magnitude higher than the mass of its quark constituents. Likewise, the total mass of a Galactic Bag, compressed within the superextremal void matter, must be significantly higher (though not that much) than the mass of its luminous constituents.

As discussed in the previous Section, the matter within a galaxy can pick up rotation early on during its formation, which can deform (flatten) the Galactic Bag. The central charged black hole keeps the outside charge at bay. The spinning charged galactic halo introduces the magneto-gravitational energy. This is a very complex non-linear problem, but the Christodoulou-Ruffini predictions [12] for a subextremal charged and/or spinning system provide the respective lower limits for the extra mass of a superextremal system, i.e. the electro-gravitational energy other than the mass of the material, luminous constituents. As discussed below, these limits fall surprisingly close to the observed extra mass in older galaxies, which means that already a mild compression by void matter can explain the existence of Galactic Bags.

Christodoulou and Ruffini divide the mass of a free, unconstrained, subextremal system, into its irreducible and reducible components. The former corresponds to the mass in an electrically neutral and spinless system. The latter represents the electro-gyro-gravitational energy that the net charge and/or angular momentum cause. The reducible mass of a free (uncompressed), spinless, extremally charged system can constitute 50% of the total mass. The reducible mass of a free, spinning, but electrically neutral system, can give rise to as much as 29% of the total mass. The combination of net charge and angular momentum leads to reducible masses between these two limits [12]. These limits, as well as the concept of reducible mass, are valid only for a free and subextremal system.

However, when the constituents of a system are prevented from spinning out by an external potential barrier, the electro-gyro-gravitational energy can exceed the upper limits on the reducible mass of a free system. Consequently, the state of a bound system can be superextremal, either due to excessive net charge or due to high angular momentum, or both. Moreover, the contributions of the charge and the angular momentum to the extra mass are independent: net charge and angular momentum can simultaneously contribute more than 50%, and more than 29%, respectively. An extremally charged and spinning system, such as the galactic halo, can thus contribute more than 79% to the extra mass. A superextremal galactic halo can contribute even more.

We find it remarkable that such a simple estimate corresponds to the extra mass observed within galactic haloes around disc galaxies. Furthermore, also consistent with the observations, a neutral galactic core should have less extra mass, because the angular momentum component is the sole contributor. However, this contribution should exceed 29% because galactic cores are bound by superextremal haloes, and the surrounding superextremal voids.

In conclusion, already a mild compression by void matter on a Galactic Bag can explain its existence. We expect this pressure to increases over time, as voids receive more charge from the structure-forming matter. This influences the dynamic balance, and thus the size, shape, and the angular velocity of a galaxy. As we discuss later, the reversed migration of charge into the old galaxies with discharged central black holes can result in penetration of bubbles of superextremal matter into the galactic plane. This would increase the average charge concentration of the cores, and should thus increase their contribution to the extra mass.

The extra mass is not a mass of matter, but rather the electro-gyro-magneto-gravitational energy of ordinary matter. Ironically, our new cosmology effectively replaces dark matter with ordinary energy (after it has already replaced dark energy with ordinary matter).

16. What is the true size of a galaxy?

What is the size of all the galactic components that are both necessary and sufficient for the sustained existence of a galaxy? Imagine that the superextremal void matter everywhere around a galaxy is removed. The balance that keeps the Galactic Bag stable would thus disappear, and most of the constituent matter of that galaxy would instantaneously spray out into empty space. The real size of each galaxy in the universe should therefore be considered not any smaller than the size of the entire causally connected universe.

This conclusion comes in stark contrast to the status-quo-ante cosmologies, which assume that the matter within galaxies (and similarly in galactic clusters) should be solely responsible for its balance in a passive space.

One should recognize that the conditions within the local neighborhoods of galaxies play a disproportionate role. The internal configuration of a galaxy can be influenced by the size of the surrounding cluster, by its position within the cluster, the distance, size and the orientation of the magnetic fields of next neighbors, the level of magnetic concatenation among the galaxies, and more.

17. Galaxies are magnetic dipoles

Circular motion of a superextremal galactic halo forms a magnetic field that stretches far into space. The energy of the generated magnetic field gives rise to an increase in the mass of the galaxy, as well as of the local void space through which the field spreads. The additional mass further enhances the cohesion within the galactic cluster. The dipole nature of the magnetic field is crucial, because it provides directional dependence, something that the attractive gravitational potential cannot provide. While one can easily estimate the magnetic flux generated by a highly charged, rotating galactic halo (modeled e.g. on our galaxy), the quantification of the magneto-gravitational effect, which indeed is necessary in this case, is a very complex task. This task is under way, and we are not sharing any quantitative estimates at this point.

The dipole-dipole and more complex interactions among galaxies within clusters naturally lead to the formation of concatenated strings of galaxies and galactic collisions. The orientation of the rotational axis and the sense of rotation of each galaxy in a string become aligned with time. Since the magnetic dipoles are directly coupled to charged haloes as their generators, and only indirectly to neutral cores, internal galaxy distortions (warps) can occur at a significant distance between the interacting galaxies. Internal galaxy warps can occur even through the process of concatenation, in which the charged haloes align first, and the galactic cores try to follow the suit. Various forms of temporary or permanent ‘injuries’ may happen to galaxies, including some of those that have presented a challenge to traditional explanations.

18. Relativistic jets, cosmic gamma rays, and ultra-high energy neutrinos

Our new cosmology provides an explanation for the collimation of relativistic jets emitted by active galactic nuclei. The charged supermassive black hole in the center of each galactic nucleus is not only the quasar’s source of energy, but also the source of particles that end up in the jets. Since these particles are electrons, the content of the jets is charged. Beams of relativistic electrons emerge at the only two places around the black hole that provide clear passage – the two ‘polar’ orifices in the accretion system. The electrostatic potential energy of a unit charge can exceed $10^{26} eV$ close to the innermost stable orbit. The electrons can thus escape through the orifices with very high energies (even after redshift). The initially beamed electron flow is effectively an electric current that induces a circular magnetic field around itself.

This field, in turn, selects electrons of higher energies and filters out low-energy electrons, as well as hadrons and their charged decay products. The selected high-energy beam generates a higher magnetic field, and the self-collimation process continues. However, this is not all.

Although the electron beam is charged, the gravitational potential within a jet is dominated by the attractive, mass-driven component of the gravitational potential. For instance, if we assume that the average power of a jet from a quasar that hosts a $10^{10} M_{\odot}$ black hole is $\sim 10^{38} W$ (two orders of magnitude lower than the total power) during $10\ Gy$, then the linear mass density of the jet would be a staggering $\sim 10^{12} kg/m$.

The attractive gravitational potential within this subextremal beam could thus sink below the repulsive gravitational potential of the surrounding superextremal void matter. Just like in our Galactic Bag Model, the inward compression by the void matter could be balanced by the 'excessive' energy of trapped electrons and photons. This consideration gives rise to the Jet Tunnel Model.

Our model of relativistic jets is fundamentally different from most traditional models, which assume acceleration of neutral matter (or plasma). A general problem in this field has been how to explain the weak presence of hadrons (i.e. neutrinos as their only survivable products) in relativistic jets of active galactic nuclei. In our model, however, this result is a natural consequence of the fact that jets conduct almost exclusively electrons. Electrons and gamma rays generated close to the orifices dissipate most of their original energy in cascades and thus have no chance of directly reaching our detectors with their original energies. However, we regularly detect high-energy gamma rays generated within the jets in great abundance, when jets are pointing towards us. In contrast, hadronic processes are strongly suppressed in leptonic jets, so neutrinos are not nearly as abundant as gamma rays. Neutrinos of highest energies are mainly generated close to the event horizon, and they are not narrowly beamed. They can carry an extraordinary amount of energy, possibly exceeding $10^{20} eV$ (even after redshift), and right into our detectors. This expectation is consistent with the observations.

Relativistic jets have also been observed in small black holes that were created within structure-forming matter in galaxies. The corresponding jet formation mechanism could be different from the mechanism outlined above. However, since the structure-forming matter within galaxies does not need to be completely neutral when structure is formed, but rather only subextremal, it is possible that even these small black holes could contain some charge, and could thus be Christodoulou-Ruffini black holes whose jets are powered by the same mechanism as the quasar jets. Since the Electro-Gravitational Sinkhole Prolapse can take place only during the first year after the Big Bang, we do not expect galactic black holes to be charged anywhere near the extremal level.

19. The third migration of net charge – from black holes into voids

Immediately after their formation, extremal supermassive black holes start losing charge through Christodoulou-Ruffini radiation [12]. The probability of particle emission is apparently very low because of the narrow phase space, a result of kinematic constraints. However, the vast size of a black hole can compensate for this low probability, similarly as the mass of a star compensates for the extremely low probability of nuclear fusion. This is why the active period of active galactic nuclei lasts for billions of years, and during this time, their power is relatively low, but much higher than the power of any other source in the universe.

Most of the electron emission and charge migration from quasars into the voids takes place after the formation of galaxies. While receiving this charge from the black holes, the void matter gradually becomes more superextremal. The pressure that accelerates the expansion of the universe thus grows further, until all black holes have discharged. However, the acceleration of the 'massive' universe by the increased pressure comes again with a delay.

20. Galactic clusters

The gravitational and magnetic cohesion of galaxies within clusters reduces the internal repulsive gravitational potential within the cluster below the level that is present within the surrounding superextremal void matter. Nevertheless, the medium around the galaxies in a cluster remains superextremal, and it keeps galaxies properly compressed, but it is less superextremal than the void matter that surrounds the cluster. This gives rise to inward pressure on a cluster by void matter, and thus to 'excessive' velocities of its constituents, as well as to 'anomalous' but real mass, detectable e.g. by gravitational lensing.

The initial distribution of galaxies within a cluster should be closely related to the initial distribution of their supermassive black holes. As discussed above, the initial black-hole distribution was influenced by biasing. After galaxies formed, the initial pattern was gradually modified by gravitational and magnetic interactions among the galaxies.

While it takes a very short time for freshly formed galaxies to generate a dipole magnetic field through the rotation of the initially infalling charged haloes, it takes much longer for the galactic dipole magnetic fields to reach other galaxies and connect with their fields to form concatenated strings, and to start moving each other. The initial cluster configuration should thus probably persists for at least a billion years.

Concatenated structures come because of spontaneous magnetic and gravitational interactions, rather than due to dark matter. Magnetic interactions are dominant, because they are concentrated, mutually enforced, and transported to long distances through multi-galactic concatenation. The elongated magnetic flux tubes are themselves massive due to their energy, so they do themselves gravitate.

21. Early galactic clusters – a flash-photo of universe at its first birthday

As discussed above, there is no reason for the black-hole pattern within the clusters and the large-scale pattern of black-hole clusters, to change significantly until the recombination phase, or even until shortly after the galaxies have formed around these black holes. We cannot stress enough that by observing the early galactic clusters (within the first billion years), one actually observes a strongly magnified flash-photo of the peaks in the universe's density landscape when it was only one year old.

This conclusion certainly applies to the currently awaited results of the observations by the James Webb Space Telescope (JWST), but it could already apply to some existing observations of early galactic clusters, such as the large-scale structure around the $z = 6.31$ quasar SDSS J1030+0524. The existence of clusters of galaxies that surround fully developed ultra-massive galaxies comes as a necessary outcome of our new cosmology. In contrast, the very same phenomenon presents a puzzle to the cosmologies that assume gradual structure formation around dark-matter structures, a process that would start only after recombination. It is simply hard for these models to find enough time for the collapse of recombined gas into stars and mergers of collapsed stars, among many other phenomena.

We predict that JWST will soon confirm the early formation of complete galaxies and their clusters - one of the key predictions of our new cosmology. These results will leave zero time for the mergers of gas and smaller objects into larger ones, all the way to the supermassive black holes.

22. Late galactic clusters – the liquid in the cosmic foam

Luminous constituents of young Galactic Bags act to a certain extent like a compressed ideal gas with weak internal cohesion. The galactic clusters act more like a liquid, thanks to their long-range magneto-gravitational cohesion. The inward pressure of the superextremal void matter on a galactic cluster therefore does not lead to a galaxy-like confinement, but rather to a foam structure. Galactic clusters are themselves superextremal, but their overall gravitational pressure is lower than that of the truly void matter.

In general, the active, compressing component in any foam appears in the form of bubbles that are trying to assume a spherical shape. In the cosmic foam, this role belongs to the superextremal void matter. The other component of a foam is usually a liquid, and in our case, this is the cohesive galactic-cluster matter. It balances bubbles' pressure by caving in to them.

The rich variety of bubble configurations in this foam results in diverse galactic cluster shapes, masses, and volumes, whose particular appearances have no real meaning or physical significance, other than for classification of the phase[3] of a foam.

One of the earliest conclusive surveys of the large-scale structure of the universe is shown in Fig. 5. The authors could clearly see spherical voids and galactic clusters compressed among them, in what they

[3] In a critical state, bubbles are completely spherical and only touch each other at one point. In a supercritical state, bubbles are not anymore fully spherical.

named a foam. Many systematic surveys have followed this pioneering study, with exceedingly high precision (as exemplified in Fig. 6), and reinforcing the same conclusion.

Nevertheless, an excessively descriptive taxonomy has been established by the status-quo-ante cosmologies in order to assign certain dynamic roles to the individual configurations, such as a 'cosmic wall,' a 'great wall,' a 'string,' a 'supercluster,' or 'the cosmic web.'

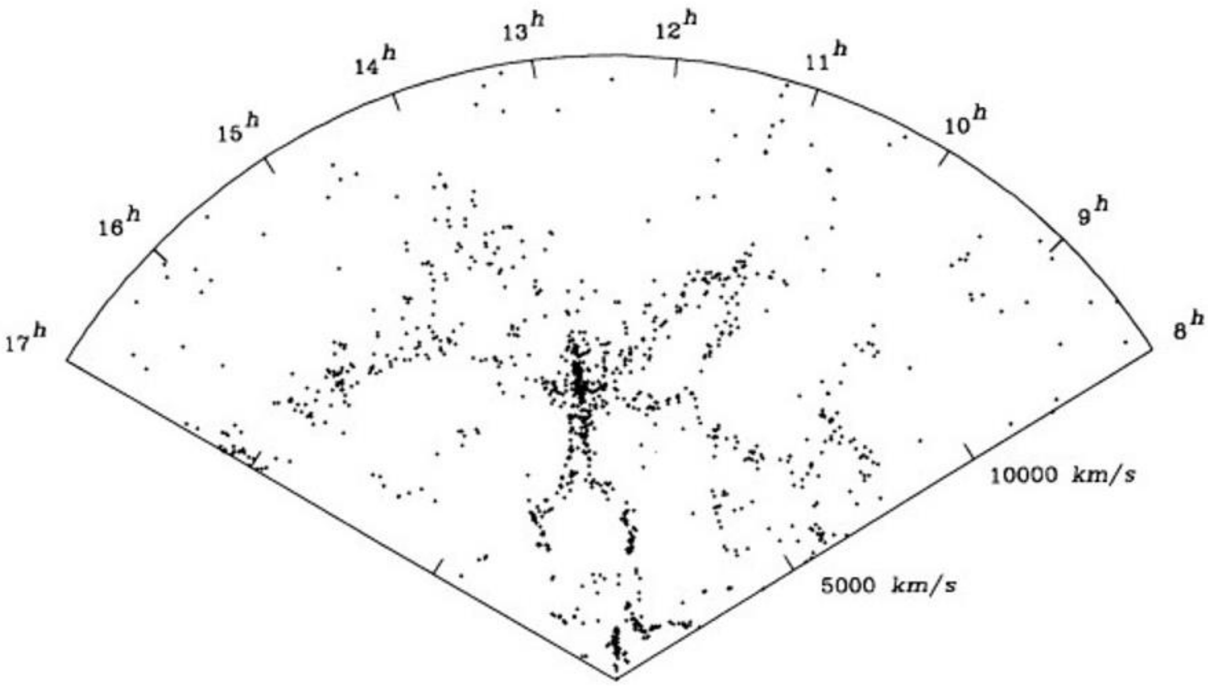

Fig. 5 An early survey showing the large-scale structure of the universe, from the publication titled "A Slice of The Universe" [13]. It shows the map of the observed velocity, which in our context means the distance, plotted vs. right ascension in the declination wedge from 26°.5 to 32°.5; 1061 objects are included.

For the physics of foams, a 'wall' is merely a 'membrane' between two touching bubbles, a 'string' is a 'plateau border' common to two flat sheets with a concave triangular cross section, and a 'supercluster' is a volume of liquid cornered by four bubbles into a 'vertex' in which four plateau borders meet, i.e. a tetrahedron with concave surfaces, and a 'web' is an interconnected network, formed by all plateau borders. None of these elements of the foam has any particular function; they are just random outcomes of a single, spontaneous process in a foaming two-component system.

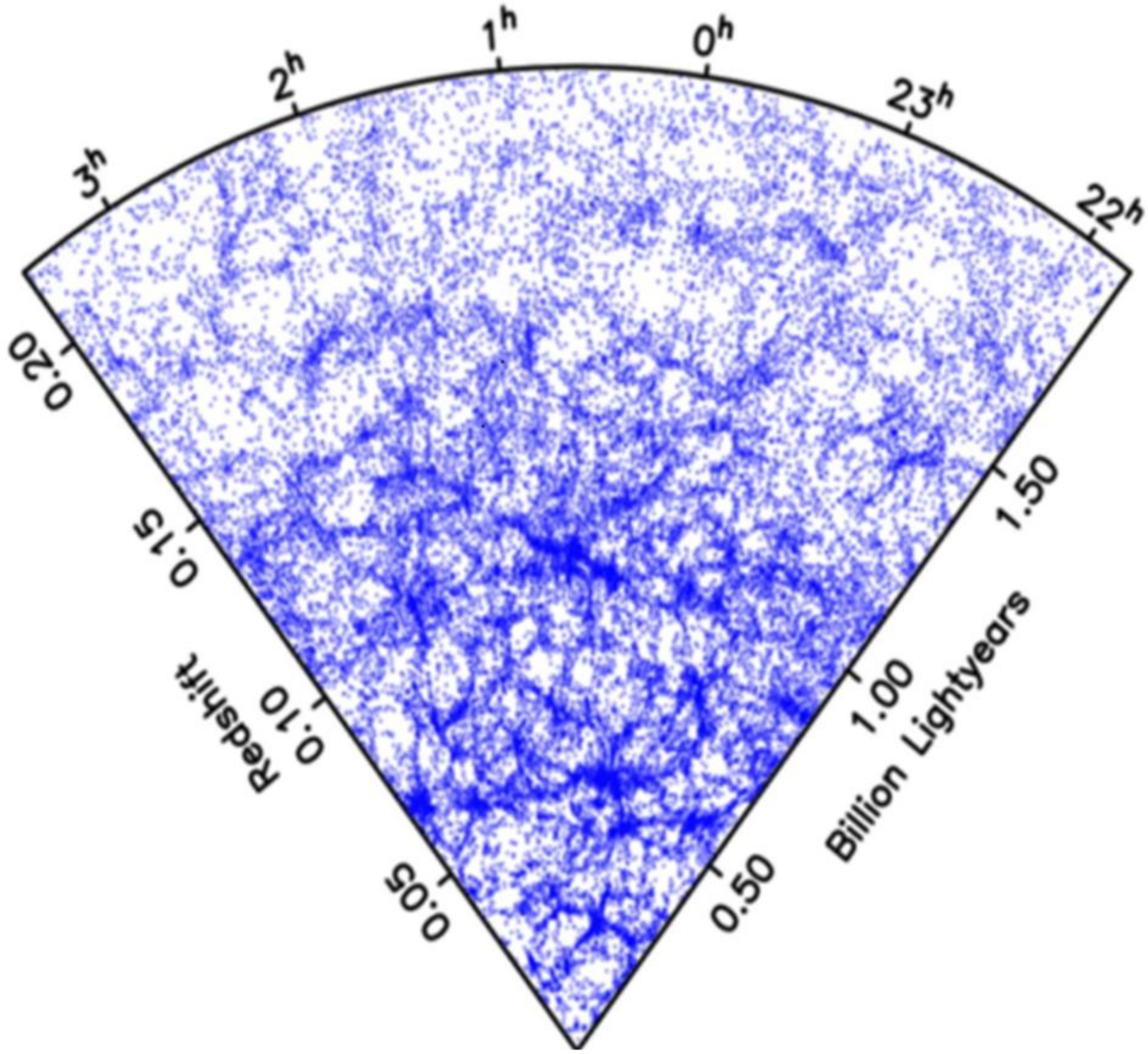

Fig. 6 An example of a modern survey of the large-scale cosmic structure. This map covers a significantly larger and thicker 'slice of the universe' than the one shown in Fig. 5. Despite the overlap of many layers of the foam, the spherical bubble shapes are still visible. (Credit: 2dF Galaxy Redshift Survey Team, Public Domain Dedication (CC0)).

In contrast, one could assign dynamic and functional properties to such elements under the hypothesis that the total network, i.e. the 'cosmic web,' should have grown as a result of particular actions of its elements. Since galactic clusters would never be able to create a cosmic web by themselves, a Deus ex machina (dark matter) was added to the mix. The result of such numerical exercises (which may seem increasingly realistic with ever-improving computer imagery) is not at all a foam, but rather a sort of a sponge – a living organism with complex DNA instructions for the growth, whose specialized organs are indeed made of different tissues, and assume different forms to perform their functions - walls, strings, and superclusters.

In stark contrast, our new cosmology predicts a true foam, spontaneously created by two phases of ordinary, Standard-Model matter: the superextremal void matter and the superextremal galactic-cluster matter.

The void matter inflates bubbles within the galactic-cluster matter in a similar way that gas inflates bubbles in a foam of beer. Recall that the pressure within superextremal matter comes from the repulsive, short-range, non-conservative gravitational potential, caused by the superextremal concentration of electric charge. In addition, recall that superextremal matter cannot produce any gravitationally bound structures, so the void bubbles must be truly dark everywhere within, and indeed void of any structure. Still, these bubbles are the most powerful and the most massive form of matter in the universe. Nevertheless, they are composed of an ordinary gas with the addition of the electrons.

23. Bubbles of superextremal void matter and the accelerated expansion

The existence of the cosmic foam in a supercritical form indicates that the condensed galactic-cluster matter - the ‘soap’ in the foam – is so much stretched out that it does not itself significantly accelerate or decelerate the expansion of the universe (see a more nuanced discussion below). With time, and thus with more surface stretch, the long-range magneto-gravitational cohesion – the surface tension in the galactic foam - weakens (unlike in a rubber balloon). With the void-matter bubbles being as large as they are at the present cosmological time, it seems that the restraint against the accelerated expansion by the ‘soap’ matter in the foam could be negligible.

In a more nuanced approach, one should recognize that a certain amount of charge remains within superextremal galactic haloes, and in black holes that still have not completely discharged. The same, but to a much lesser degree, holds for galaxies, with their outward-pushing, ‘excessively’ energetic constituents. We concluded earlier that the true size of each galaxy is not any smaller than the size of the entire causally connected universe. Vice versa, each galaxy must also contribute to the accelerated expansion of the entire causally connected universe.

24. Balance among the first three migrations of net charge

To reach the level of 1.6 times the extremal, the concentration of charge in void matter has grown through the three charge-migration phases discussed above.

The amount of charge that transited during the initial charge migration, i.e. during the Electro-Gravitational Sinkhole Prolapse, was significantly lower than during the following two migrations. This is because the initial concentration of charge was extremal, i.e. right on the threshold for black-hole formation. We estimate that a very low displacement of charge, on the order of $\lesssim 10\%$, could already have secured black-hole formation.

With the formation of charged black holes, the first migration of charge stops, but the third and the last migration of charge into void matter – directly from the black hole - starts even before the second migration had started.

In contrast, the second migration is very fast. It is triggered by the recombination process, and enforced by the concurrent galaxy formation. It is completed by the end of the recombination period. During each of the last two migrations, the amount of charge that transits into the void matter from a galaxy is nearly equal to the original charge of its black hole. Some of residual charge still remains trapped within almost exhausted black holes, charged galactic haloes, and the cohesive matter of galactic clusters.

In summary, a possible charge migration scenario can be described as follows: from the initially extremal level, to $\epsilon < 1.1$, then to $\epsilon \leq 1.35$, and to the final $\epsilon \approx 1.6$.

The pressure of the superextremal void matter, which accelerates the expansion of the universe, grows with each charge migration. The increase in the acceleration follows the increase in the pressure, but the effects are delayed. The Hubble constant - a measure of the rate of expansion - should increase with time. Recent measurements of the (normalized) Hubble constant have indeed revealed a ~10% increase between the early and the late universe. (This result is statistically significant, but systematic errors may still be dominant because different methods have been used to estimate the Hubble constant across the cosmological time).

25. The fourth migration of net charge – reversal, from the voids into galaxies

The superextremal matter gradually squeezes and penetrates the cores of old galaxies, because their discharged central black holes cannot keep the electrostatic balance. Can we see any consequences of this effect on the galactic morphology and dynamics?

While the complexity of galactic structures sometimes leads to ambiguous and inconclusive results, a large number of galactic phenomena completely evade adequate explanation. From galaxies that should not be able to exist, to fields of stars without star-formation activity, to huge bubbles above the galactic planes that should be empty but are not, to spiraling electrons where no magnetic fields are expected.

The idea of this section is to speculate, to provoke a discussion whether such 'borderline' and 'unexpected' phenomena can make more sense when viewed through the framework of our new cosmology.

As the superextremal matter encroaches the galactic center, it plows the luminous dust away, and engulfs the existing stars and other compact objects, such as black holes, binaries, neutron stars, and the central black hole. These objects should appear as if being suspended in empty space. The same area that once used to be the home to an active quasar and opaque star-forming matter now appears empty.

The central black hole could thus even be directly visible, like e.g. in the case of the central black hole in the M87 Galaxy. In addition, the James Webb Space Telescope (JWST), Fig. 7, can see a large number of unobscured groups of stars around the galactic center of the M74 Galaxy in the recently released infrared images. No dust and star-forming material is visible in a wider central area, although the stars are present.

Furthermore, the superextremal matter should interact with the engulfed compact objects, revealing thus its own presence, as well as the existence of its interacting partners. For instance, one should expect to detect synchrotron radiation from the electrons that can spiral relic magnetic fields. Naturally, free electrons are abundant within superextremal matter. A multitude of such spirals, called ‘snakes,’ has indeed been observed close to the center of our galaxy. This phenomenon has presented a puzzle both because it is not clear where the net electrons are coming from, and why strong magnetic fields are present in empty space. Likewise, gamma-ray surveys of the space above the galactic plane have revealed the presence of surprisingly high activity, from a volume previously deemed empty.

What form could the superextremal matter take on its suspected way into subextremal galactic cores? Given the inability of superextremal matter to form internal structure, its repulsive gravitational potential, and its inability to mix with subextremal matter, the most likely form is again that of a foam. If so, we should see bubbles of superextremal matter within the subextremal, luminous matter of old galaxies. The entry point of the superextremal matter into the galactic spirals could be the ‘eye’ around the galactic center, and the bubbles should propagate outward along the spiral arms. These bubbles should appear as dark cavities among luminous matter that should always caves in to the bubbles.

Numerous dark ‘cavities’ that can be seen in Fig. 7 are indeed void of internal structure. Moreover, the luminous matter consistently caves in to these bubbles, independently of their size and shape. Furthermore, there is no sign of mixing of the two phases. In addition, a magnified image from the Hubble Space Telescope (HST) in visible light, Fig. 8, shows a thin veil of dust in a spherical shape, as if inflated by the bubble underneath.

Close to the galactic center, the bubbles are elongated ellipsoids, and later they gradually grow and become spherical. These spherical bubbles occasionally share a flat interface, or coalesce into larger bubbles. Independently of the size, the bubbles within this foam compress luminous dust into dense, concave walls that display strong star formation activity. These bubbles thus seem to play an active role in the star formation process. This, along with everything said above, is consistent with the properties and the role that the superextremal matter in general plays in the formation of cosmic structures.

The smooth evolution of cavities from narrow ellipsoids to the largest spherical bubbles suggests that all of these forms could be manifestations of a single physical phenomenon. Besides, the most easily identifiable cavities in Fig. 7 seem to be too large, too empty, and too regular to be consistent with traditional interpretations as supernova remnants, stellar winds, radiation pressure, turbulent vortices, or a combination of the above. Moreover, the persistent concave surfaces of the luminous walls can hardly be consistent with a self-gravitating pull. These structures rather seem to be compressed.

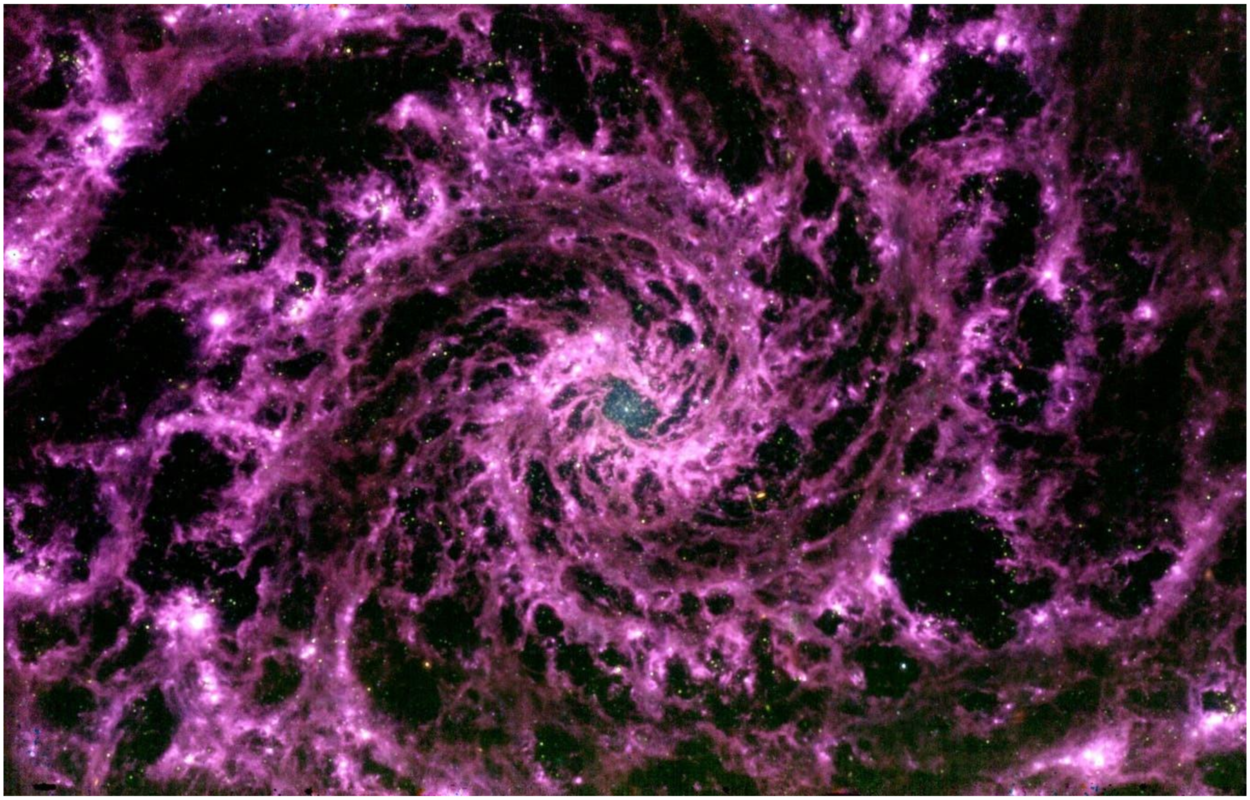

Fig. 7 An image of the M74 Galaxy (NGC 628) in the mid-infrared range, taken byJWST, shown without preprocessing. (Credit: Gabriel Brammer, Niels Bohr Institute, University of Copenhagen, Denmark, in collaboration with PHANGS-JWST).

Fig. 8 Magnified view of the large 'cavity' seen in Fig. 7, right and below the galactic center. Infrared light (left), and visible light (right).

As discussed above, the dynamics of galaxies is a very complex subject and the presented evidence for the foamy structure of the M74 Galaxy currently just provokes an exciting hypothesis. The unsolved problems in this area should be the focus of continued research. For instance, traditional models could not explain why some small galaxies still exist, let alone how could they pack enough compression for strong star formation. The nearby Small and Large Magellanic Clouds are a good example.

A possible answer to this problem can be that, just like all other galaxies, these small galaxies are compressed by the superextremal void matter into their Galactic Bags. They are thus safely 'encapsulated' and 'protected' from the outside. Likewise, the neutral cores of these old galaxies must feel a strong local pressure from the encroaching superextremal bubbles, which naturally leads to a buildup of high-density dust walls and star formation, as discussed above. The fabric of the Magellanic Clouds in the infrared [14] indeed looks like the outer parts of the spiral arms of the M74 Galaxy in Figs. 7 and 8. One can see large dark bubbles, and dense, concave walls of star-forming matter around and between them.

26. Discussion

This manuscript presents a brief introduction to our new cosmology, which we also call The New-Old Cosmology. The reason for the adjective "Old" is simple – our new cosmology is founded in Einstein's original General Relativity (GR) without the cosmological constant. The agent that, instead of dark energy, drives the accelerated expansion of the universe must be a component of the ordinary stress-energy tensor of the original GR, caused by an ordinary Standard-Model interaction. The electromagnetic interaction is the only possibility.

We show that with the proposition of an asymmetrically charged universe, Einstein's original GR provides a comprehensive and coherent explanation for the origin of cosmic structures. Our studies indicate that at the onset of the electromagnetic plasma phase, the universe must have been approximately, or perhaps even exactly extremally charged (2.9), i.e. suspended in a local equilibrium between gravitational attraction and electrostatic repulsion (2.10). Once in the electrically conducting plasma state, a fraction of the net charge migrated away from the initially overlapping charge- and mass-density peaks, making the mass-density peaks subextremal, and the surrounding shells superextremal. The repulsive electro-gravitational potential barriers formed by superextremal shells caused the prolapse of the surrounded highest-biased subextremal mass-density peaks into charged supermassive black holes, a process completed already during the first year. These black holes are the origin of all other structures, starting with galaxies, which formed around them by an equivalent electro-gravitational sinkhole collapse process already during the recombination period.

Crucially, while the subextremal matter is gravitationally attractive, the superextremal matter is gravitationally repulsive. The superextremal matter cannot form gravitationally bound structures within its own volume, but it can exert pressure on the subextremal matter. The interplay between these two forms of ordinary, Standard-Model matter is responsible for the formation of all major cosmic structures.

This universal push-pull structure formation mechanism is inherent in Einstein's original GR, as exemplified by its Reissner–Nordström solution (2.4). In contrast, the original GR of neutral matter, embraced by traditional cosmologies, provides only the pulling component of this mechanism (2.7), which has resulted in a need for an extraordinary pulling Deus ex machina on top of the known, luminous gravitating matter - dark matter. Einstein's original GR with net charge thus circumvents the primary problem of status-quo-ante cosmologies – the belief that cosmic structures must emerge exclusively as a result of the gravitational attraction of their constituents.

Since the latter is impossible, traditional cosmologies were forced to invoke a Deus ex machina - an additional attractive gravitating constituent in the form of dark matter. To be useful, this hypothetical constituent must even dominate the balance of masses. Furthermore, the hypothesized mix of gravitating matter (luminous and dark) must be able to create the large-scale structures (webs, strings, networks, superclusters), as well as the galaxies (cores, spinning haloes, central supermassive black holes) – all by itself, from within, and all of this exclusively by an attractive gravity. To fulfill this task, dark matter was granted some extraordinary properties, including even a separate history that must have been decoupled from the evolution of the 'ordinary' matter. The resulting worldview, which has evolved now for almost a century, got even more complicated with the two-decade old discovery of the accelerated expansion of the universe. Dark matter was joined by dark energy, but the formation of structures has remained the sole duty of dark matter.

In contrast, we argue that a rational design of the universe necessitates both attraction and repulsion. In our new cosmology, the gravitationally attractive subextremal matter and the gravitationally repulsive superextremal matter jointly participate in the formation and maintenance of cosmic structures.

The extra mass of cosmic structures, from galaxies to the whole universe, does not stem from hypothetical new forms of massive matter, but rather from the electro-kineto-gyro-magneto-gravitational energy provided by the dynamic interplay between the superextremal and the subextremal matter.

Our study was mainly carried out within the framework of analytic approaches, the Reissner–Nordström and Kerr-Newman solutions to the Einstein's General Theory of Relativity, and Maxwell's Theory of Electromagnetism. The theory of charged spinning black holes by Christodoulou and Ruffini played a key role.

We find it remarkable that even a rudimentary study such as ours can give a deep, coherent insight simultaneously into so many different phenomena. We believe that the transparency of this welcoming landscape indicates that the "vista point" provided by our New-Old Cosmology is indeed correct.

Edwin Hubble's discovery of the expansion of the universe was a turning point in our understanding of the universe, despite the fact that the expansion rate he presented as the experimental evidence for his revolutionary framework turned out to be incorrect by almost a factor of ten. Admittedly, our ambitions are similar, but we hope the evidence presented in this manuscript does not err as much as Hubble's.

27. Predictions and Experimental Verification

We already discussed numerous predictions of our new cosmology, mainly in passing, and in this brief introduction, even without references. Occasionally, we underlined the fact that some of the already observed effects that come as natural consequences of our cosmology present surprises and puzzles for status-quo-ante cosmologies. Early reports from the James Webb Space Telescope (JWST) support growing evidence that galaxies in the very early universe were 'surprisingly mature.' We predict that this trend will strongly intensify with the coming results of JWST.

An immediate set of tests of key predictions of our new cosmology is already in the making. We predict that JWST will soon report on the existence of fully formed, 'mature' galaxies, at the earliest times detectable. Moreover, the earliest observable galaxies will already be organized into 'mature' clusters, with massive galaxies closer to the cluster center, and frequently an ultramassive galaxy at the center. Some of these galaxies could already display their active quasars, since the black holes predated galaxies.

We also predict that the observation of the earliest galactic clusters will provide direct access to the universe's density landscape when it was only one year old. This is because the progenitor black holes were all formed during the first year, within the highest peaks in the biased density distribution, and we do not expect any major reconfiguration of the corresponding patterns before galaxy formation.

Lastly, we are confident that the searches for dark matter and dark energy will keep confirming the nonexistence of both phenomena. Unlike the potentially decisive results of JWST, these searches will remain open-ended and inconclusive for a long time.

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