Observations of Large-Scale Structures Contradict the Predictions of the Big Bang Hypothesis But Confirm Plasma Theory

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Abstract:

The Big Bang hypothesis (BBH) predicts that all structures in the universe must have formed in the time since the Big Bang currently calculated to be a maximum of 13.8 Gy ago. During that time, large-scale structures can only grow to a predicted maximum extent of no more than 250 Mpc. However, in the past decade increasing numbers of independent observations have demonstrated the existence of much larger structures up to 1.5 Gpc in radius, which must have taken at least 100 Gy to form. In contrast, if the BBH is discarded, these ultra-large structures have time to form and the evolution of the large-scale structures of the universe is correctly predicted in some detail, involving only well-studied processes of plasma filamentation and gravitation. Recent observations have confirmed the role of magnetized plasma filaments in this process, first predicted by Alfven and others over 40 years ago.

1. The age problem of the Big Bang Hypothesis

In the Big Bang hypothesis (BBH), all structures in the universe must have formed in the time since the Big Bang. However, over the past several years, there has been a growing "age problem" for the BBH—objects are older, and in many cases, far older than the age limits derived from the BBH. We will first examine these conflicts with BBH predictions, and then look at alternative theories of structure formation that abandon the BBH.

We begin by noting the age limits of BBH, derived from the "concordance" LCMD theory and observations of SNIa supernovae. These observations, plus the BBH theory, yield a measurement of H_0 of 73.5+-1.4 km/sMpc , [1] Ω_m =0.31 Λ=0.73 [2]. These figures in turn allow the calculation of the BBH prediction of the "age of the universe" [3] of 12.8+-0.2 Gy. We here use only the SN1a data, because they do *measure* H_0, while the CMB data *predict* H_0, assuming ΛCDM theory. However, as we will show, the conflicts with data are so large, that the differences between CMB predictions and supernovae measurements don't make a significant difference.

To compare the age of objects with this BBH limit, we can begin with dynamical age, which is conceptually simplest. An estimate of the time an object minimally took to form, and thus a lower limit on its age can be derived by dividing the object's radius by the observed velocity of matter within it. In an expanding BBH universe, this relationship is somewhat more complex. For a spherical void, the age would be about

1) $A = (\Omega_m^{0.6}/3)(C/(1+C)^{0.25})\,(r/V)$

where C is the density contrast, r the void radius and V the outflow velocity [4]. To make the most conservative (smallest) estimate of age, (most generous to BBH) we can use the largest bulk flow velocities observed. The largest V reported are 1,000 km/s [5] while most are of the order of 250 km/s.

If we set A=13.8 Gy, v=1,000 km/s and $\Omega_m = 0.3$, eq. (1) gives a maximum size for voids depending on the density contrast alone, varying from 113 Mpc for a density contrast of 1 to 260 Mpc for a density contrast of 0.4.

This analytical result is confirmed by simulations. While earlier simulations showed voids only up to 15 Mpc in radius [6] later ones with even multi-Gpc simulation volumes show *no* voids with radii> 200 Mpc [7-10]. These results are independent of the shape of the voids, which do not have to be spherical. This is unsurprising, as there is simply not enough time with BBH to form larger voids.

To see why future simulations, even with larger volumes, can't show larger voids, we look at the BBH predictions for bulk flow velocities [11] which can be approximated as

2) $V_{rms} = 2.8 \times 10^{23}\, \Omega_m^{\ 0.6}\, r^{\ -0.6}$ cm/s

, where V_{rms} is the root mean square velocity for a volume of radius r. The dependence in eq.(2) on Ω_Λ is negligible so is omitted. Substituting (2) for V in eq (1) we get an expression for the typical expected radius of voids with BBH:

3) $r = 9 \times 10^{25}\, (1+c)^{\ 0.16}/C^{\ 0.62}$ cm

This predicted radius ranges from 33 Mpc of C= 1 to 56 Mpc for C =0.4. Note that this result is independent of the specific BBH parameters as the Ω_m factors cancel. Since r depends linearly on V, maximum r in the simulations represent about 5σ results, reasonable for a rare object within a multi-Gpc simulated volume. From this calculation, it is clear that voids with r> 250 Mpc or so are precluded by BBH.

Observations of large-scale structures have over the past decades found structures with larger and larger radii as data has pushed further outwards in space. As early as 1991 Saunders et al [12] observed voids as large as 360 Mpc in diameter, far larger than predicted by early BBH simulations. However, in the past decade, simulations with larger scales have been able to predict, as rare occurrences, voids this large.

Simultaneously, observations have pushed the size of the largest voids and the largest over - densities to still larger radii that are *far beyond those compatible with BBH predictions, including the later simulations*. Clowes *et al* observed quasar concentrations with C=0.4 and r =500-600 Mpc [13]. Much larger concentrations of gamma-ray bursters [14], were observed with C= 0.8 and radius ~1-1.5 Gpc (Fig. 1). Shirokov, et al [15] report voids (or under-dense regions) in the galaxy distribution that are 50% the density of the peaks (C=0.4) with radii of 1.5Gpc (Fig.2). The authors point out that these Gpc concentrations and voids are not rare objects, being visible in deep surveys probing in a variety of directions in the sky. Subsequent analyses have confirmed the existence of such large concentrations [16]. In the past year, yet another report by Lopez, Clowes and Williger [17] shows a 1 Gpc long arc of galaxies detected with Mg absorption lines. Numerous other ultra-large-scale observations are cited in the same paper. Another large-scale alignment of quasar groups has been reported by Friday, Clowes and Williger [18].

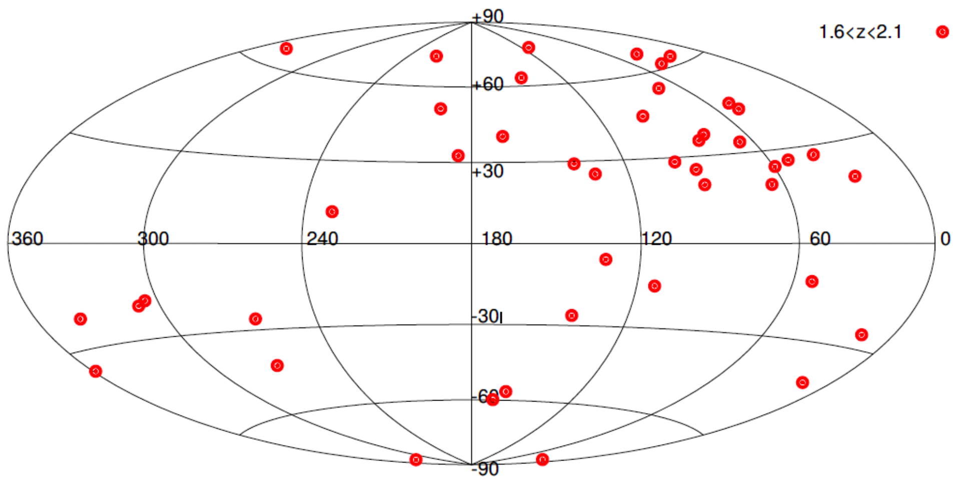

Figure 1. The distribution of GRBs in the redshift range 1.6 < z ≤ 2.1 at Galactical coordinates. Note the large concentration in the upper right. From Mészáros [19], based on data from Horváth, Hakkila, and Bagoly, [14].

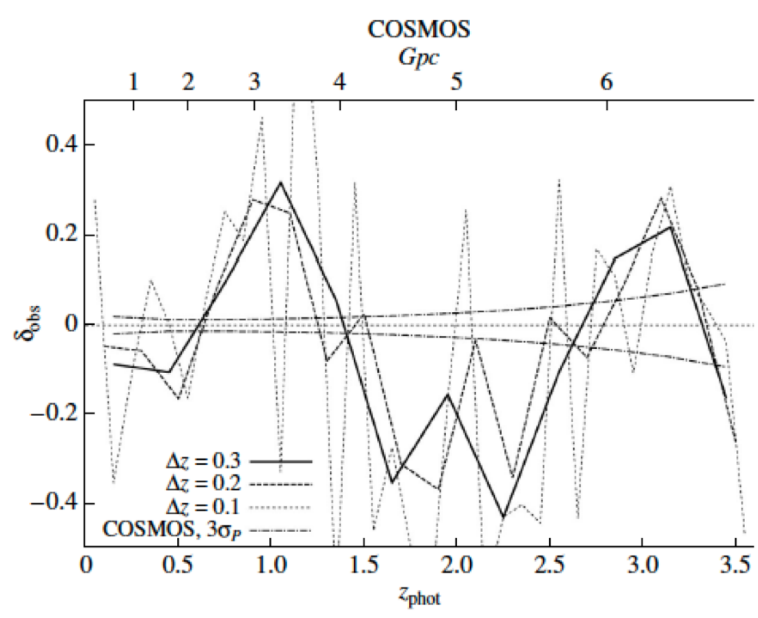

Figure 2. Deviation of the density of observed galaxies as a fraction of mean density is plotted here vs z(bottom) and distance(top) with ΛCMD distances. The data from the Cosmos survey shows large scale fluctuations of 0.3 on scales of at least 1.5 Gpc (solid black line).This is far beyond the 3 σ limits of random fluctuations (curved dot dash lines). From Shirokov [15].

Using (1) we can calculate minimum ages for these objects assuming an expanding universe and our conservative estimate of V=1,000km/s. These *minimum* ages are 27 Gy for the quasars, 80 Gy for the galaxy distributions, and 100-150 Gy for the GRBs. These ages are respectively 2, 6, and 8-12 times the age of the universe in BBH. *Simply put, the observation of objects of this size completely excludes an age of the universe anywhere near the BBH prediction.*

It is not possible to account for these structures by uncertainties in the values of V or Ω_m in eq (1). For the structures to be less than the Hubble age, they require V of the order of 2,000 km/s, 6,000 km/s and 12,000 km/s for the quasar, galaxy and GRB structures respectively. From eq (2), these velocities are 7σ , 25σ and 40σ, respectively, in excess of the V_{rms} predicted by BBH, so are in complete contradiction with the BBH predictions. As emphasized above, the choice of V=1,000 km/s is very conservative, (favorable to BBH), being already far above BBH predictions for V_{rms}. In addition, for the galaxy and GRB structures, the bulk flow velocities required to form these structures within a Hubble time would generate 200 keV and 800 keV peaks in the x-ray background radiation which have not been observed.

Nor can the results be altered by changing Ω_m. First, the dependency on Ω_m drops out of eq (3) and thus the limit on the size of predicted structures is not affected by Ω_m. Second, a significantly smaller value of Ω_m necessitates a much larger level of fluctuations in the CMB, which is also precluded by observations from the WMAP and Planck instruments.

The observation of such large-scale structure requires an age of the universe of *at least* 100Gy. Their existence makes clear that the "precision cosmology" prediction of the age, based on the CMB observations, of 13.78+-0.02 Gy is precisely wrong. As Silk [20] noted as long ago as 1988, "If one measured a gradient or large void that extended over a thousand megaparsecs, then I think he or she would have to seriously question the big bang theory." It is exactly such structure that has now been observed.

Since galaxies, which are much smaller than these LSS, can be formed in much shorter times, the age problem for the BBH is not as severe. However, an age problem still exists and has been widely noted. For example, Steinhardt et al [21] noted that the abundance of massive galaxies at high z exceeded predictions by up to a factor of 10^5, a problem they labeled as "impossibly early galaxies". Many local objects exceed the age limits set by the 12.7+-0.2Gy BBH prediction. To take just one example, the newly discovered Delve 2 globular cluster near the SMC has an age >13.3 Gy. Its age may be considerably larger, as the analysis set an upper limit on the age of 13.5 Gy because the authors assume accordance with CMB predictions [22].

In addition, with the BBH, structure formation can only take place if non-baryonic dark matter is also hypothesized. This is because formation of any high-contrast structures would take too long with only the amount of baryonic matter hypothesized by BBN, given the observed level of anisotropies in the CMB, which, it is hypothesized, reflects initial fluctuations in density. But the dark matter (DM) hypothesis makes a large number of predictions that are contradicted by observation.

First, DM particles are hypothesized to be attracted gravitationally both to each other and to baryonic matter and so should be observable on earth through their weak interactions with ordinary matter. Yet 40 years of increasingly sensitive measurements with larger and larger equipment have observed no such particles, [23-24]. Nor have they been observed in accelerator experiments [25].

Second, DM particles will create an apparent viscosity effect on moving galaxies as the particle orbits will cause them to converge behind a galaxy, slowing it down by gravitational attraction. Such a viscosity effect will inevitably cause groups of galaxies to merge into each other, making such groups short-lived and rare [26]. But observations show that such small groups are far more abundant than predicted, ruling out such a viscosity effect and thus the existence of the DM clouds that must cause it.

Third, since DM particles are hypothesized to have small interaction cross-sections with both each other and baryons, DM galactic haloes are predicted to be spherical, and galactic satellites formed from these haloes are predicted to have randomly-oriented orbits. Yet observations of the two closest massive galaxies, the Milky Way and M31[27], as well as in nearby Centaurus A [28] show that, in all three cases, satellite galaxies are orbiting in disks. This is what would be expected if the satellites' dynamics were only influenced by collisional clouds of baryonic plasma.

Fourth, because DM particles must be present wherever baryonic matter exists, there should be no galaxies which possess no DM. However, if a galaxy's rotation velocity implies a mass no greater than the mass in visible stars and gas, DM is excluded. Several such galaxies have now been observed [29].

These severe contradictions are by no means the only ones and many other important contradictions with observation have been pointed out in the literature [30]. The predictions of the DM hypothesis have thus been abundantly contradicted by observation. Yet without DM, the structure formation predictions of BBH diverge even further from observation.

2. Structure formation without BBH through plasma filamentation is confirmed by observation

By simply discarding the BBH, and thus the concept that the universe went through a dense, hot epoch around 14 Gy ago, the age problem disappears and ultra-large objects have unlimited time to form. *Without the time limitation imposed by the BBH*, it is possible to predict the evolution of the observed hierarchy of structure in the universe *without any additional hypotheses*. Indeed, this has been done, starting over 50 years ago. Alfvén, and his collaborators showed, beginning in 1963, [31-33] that such structures, given adequate time, were the inevitable result of the interactions of a small number of processes, all well-observed in laboratory experiments and explained by widely-verified theory. The main processes involved are the pinch effect, leading to the plasma filamentation instability; gravitational attraction; the homopolar generator process; and, in the acceleration of particles to high energy, the production of plasma double layers. These processes, Alfven showed, link into a cycle that generates structure on smaller and smaller scales from galaxies to planets and their satellites.

The process begins with the pinch effect—the attraction of currents moving in the same direction—generating large diffuse current through a plasma. Alfven emphasized that only by understanding currents, which are inevitably part of complete circuits, could plasma processes be understood.

Sufficiently large currents self-organize into nearly force-free filaments, with currents moving along field lines. Alfven emphasized that astrophysical plasmas outside of stars are magnetized—that is, their gyrofrequencies greatly exceed their collision frequencies. Therefore, currents can only move along field lines. In force-free filaments, this is possible, as current and fields are helical around the outside of the filament and axial along the axis.

Through the pinch effect, magnetic fields concentrate plasma along the axes of these filaments. On a large scale, gravitational attraction forms concentrations of plasma along the axis. As the rotation of these plasma blobs increases, motion of plasma across fields lines generates electric potentials between the axis and circumference of the blobs creating a homopolar generator. This leads to a new, smaller set of currents that flow towards the center of the blobs and out along their axes.

These radial currents are also necessarily filamentary, with local currents and field aligned, even though they move across the direction of the larger-scale fields. The filamentary currents transfer large amounts of angular momentum out of the blobs to surrounding plasma, allowing further contraction. In addition, the convergence of current at the center of the blobs set up double layers that accelerate beams of particles out along the axes, removing additional angular momentum. The smaller filaments in their turn begin to contract gravitationally along their axes, setting up the next cycle at a smaller scale.

The present author [34] added to the quantitative predictions of this structure-formation model by showing that the filaments had a characteristic velocity $v_c = (m/M)^{3/4}c$, which for hydrogen is 1,070 km/s. The concentration of plasma in the filaments can produce masses that can contract further gravitationally, but only if the plasmas are collisional—that is, if the mean free path is less than the radius of the filaments. Otherwise, ions in the plasma simply orbit each other without exchanging energy as is needed for condensation. Since the mean free path is simply a function of density and ion velocity a constant v_c of 1,070 km/s sets a relationship $nr > 1x\ 10^{19}/cm^2$ between plasma density n and vortex radius r before gravitational contraction.

Since the filaments that allow the transfer of angular momentum during compression are disrupted at plasma velocities $> v_c$, this velocity sets an upper limit as well for the orbital velocities of compressed objects. In the same work, I showed that the formation process of filaments sets a lower limit on the orbital velocity of compressed objects of (m/M)c, which is 163 km/s. This leads directly to quantitative predictions of the size and mass of cosmic structures (see figure 3). The hierarchy of clusters, galaxies and stars, already well-known, was quantitatively accounted for, using only principles based in plasma physics and gravitation. No dark matter was hypothesized or required.

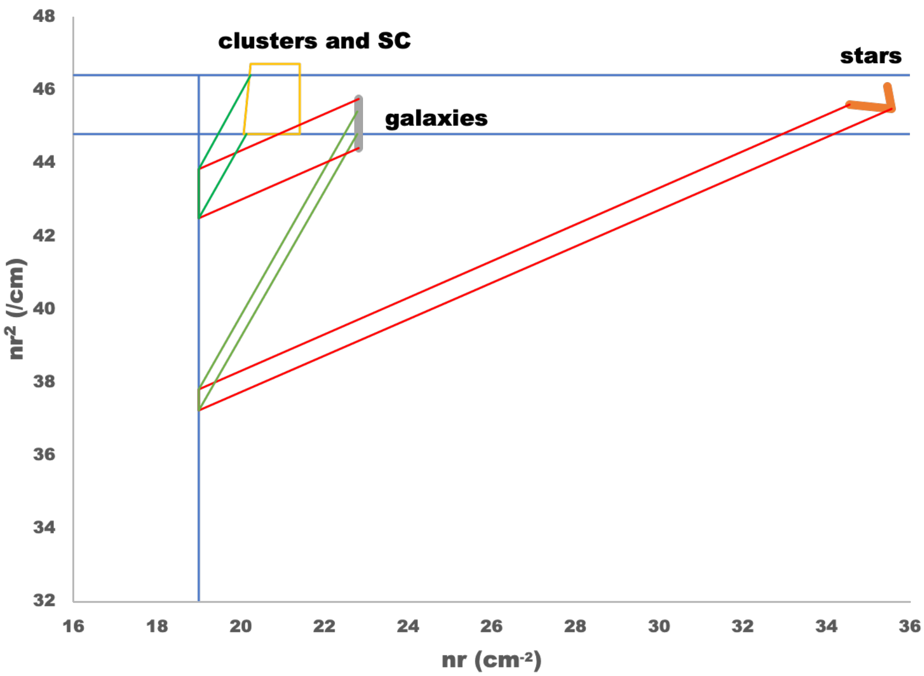

Figure 3. (modified slightly from Fig.1, [34]) Schematic of gravitational-magnetic structure formation process. Observed regions of superclusters (SC), clusters, galaxies and stars are plotted as log nr^2, (proportional to v^2), vs log nr. Horizontal(blue) lines show the predicted limits on v, while the vertical (blue) line shows the predicted nr for filaments that begin to self-compress. The slope =2 (green) lines are lines of constant density showing the density at which filaments start to form, while the slope=0.5 lines(red) are lines of constant mass, showing approximate path of objects compressing out of filament sections of length ~2r. The predicted largest structures with r ~ 1 Gpc are located at the upper-left intersection of the blue lines.

The same analysis predicted that the maximum size of structures would be considerably larger than any that had then been observed—around 375 Mpc for condensed objects, condensing out of filaments spaced about 3 Gpc apart. During the editing of this paper in 1986, preliminary confirmation of the first part of this prediction came in the observations by Tully [35] of massive conglomeration of galaxies 200 Mpc in radius and with streaming velocities of close to 1000 km/s [36].

The constancy of nr for the filaments prior to compression naturally leads to a fractal structure with D=2. A fractal organization of structure from the scale of molecular clouds to at least 100 Mpc was subsequently observed by many researchers [37-38] with 2<D<2.3, completely consistent with the dimension expected from nr =c.

The much deeper survey made more recently [15], cited in section 1, more fully confirms the prediction made 30 years earlier by showing the existence of concentrations 500-1,500 Mpc in radius, with spacing of approximately the 3 Gpc predicted. The exact same very largescale structures that contradict the BBH were actually predicted by a theory of structure formation that did not BBH.

If BBH is discarded, calculation of the age of these huge structures leads to still larger numbers. In a space without universal expansion, the minimum time for object formation, as noted above, is simply L/v, where L is the initial radius of the object and v the characteristic velocity of the matter within it. For the largest structures observed this is about *1 trillion years*. But without a BBH and its assumption of a finite age of the universe, these large ages don't create a contradiction. To be clear, the large ages for the LSS do not imply similarly large ages for the galaxies and stars within them, which clearly formed at much later times as the process of magnetic pinching and gravitational compression generated structure at smaller and smaller scales.

The absence of observed large-scale streaming velocities >1,000 km/s set upper limits on the particle density, n_m, of these LSS that can be compared with the 1986 predictions. This yields:

4) $n_m = (3/4\pi m_p G)\,(v/r)^2 = 2.4 \times 10^{-9}/cm^3$

for a radius of 1 Gpc. This is entirely compatible with the 1986 non-BBH prediction of $1\times10^{-9}/cm^3$ but is a factor of 100 below the BBH predicted baryonic matter density of $2.5\times10^{-7}/cm^3$, let alone the BBH predicted total matter density of $1.7 \times 10^{-6}/cm^3$.

3. Observed magnetic fields are strong enough to drive filamentary structure formation

The hypothesis that structure formation involves large-scale filamentary currents successfully predicted the existence of magnetic fields large enough to pinch together the largest-scale plasma concentrations. The author [34] predicted the field strength at the largest scales to be around 20 nG. While there still exist no actual measurements of magnetic field at scales of a Gpc, recent studies, [39] of the deflection of EeV cosmic rays show evidence for the existence of fields in excess of 10 nG on scales of at least 50 Mpc. The Faraday rotation produced by the predicted fields on Gpc scales with the predicted densities are only on the order of 10^{-14} nBL, or 0.1 rad/m^2. The observations of Faraday rotation [40-41] put upper limits on Faraday rotation at more than 1 rad/m ^{2}, so are consistent with the predictions.

There is now abundant observational evidence that the process of magnetic filamentation and gravitational compression operates at all astrophysical scales in the production of a fractal hierarchy of structure (Fig. 4). Magnetized filaments have been observed at the scale of supercluster-scales connecting cluster of galaxies [42-43] , within clusters [44], aligned along disk galaxies spiral arms [45] and at many scales within star forming molecular clouds [46-49].

The persistence of strings of stars over Gy time scales [50], impossible with purely gravitational dynamics, is expected as a consequence of magnetically-confined filamentary molecular clouds. Stars are carried with the gravitational fields of the far more massive clouds.

We can test if the magnetic field observed at various scales are strong enough to drive the filamentation process described by Alfven, Lerner and others. For this to be the case, three conditions must hold. First the plasmas must be *magnetized*, that is the gyroradii of both ions and electrons must be significantly smaller than the collision distances or mean free path. In such conditions, the electrical conductivity—that is, the ratio of current density to electric field—is far less for currents perpendicular to the magnetic field than for those parallel to the field. This is not due to large differences in the rate of energy loss in the different directions. It is instead due to the fact that in the field-parallel direction the electrons or ions travel between collisions a distance equal to the mean free path, L, while in the field-perpendicular direction they can only travel between collisions a distance equal to the gyroradius, r_g. Since $L/r_g = \Omega_e\tau_e$, where Ω_e is the gyrofrequency and τ_e is the time between collisions, for $\Omega_e\tau_e >>1$, there is a large difference in conductivity between the parallel and perpendicular directions. As derived in detail in Balescu, [51] (and others, for example, Kotelnikov, [52]) the conductivity for $\Omega_e\tau_e >>1$ is a tensor, not a scalar, and the ratio of conductivities $\sigma_{perp}/\sigma_{parr} \sim (\Omega_e\tau_e)^{-2}$.

If this condition is fulfilled, currents must be parallel (or anti-parallel) to the magnetic field direction and the magnetic field therefore must assume quasi-force free configurations that allow this collinearity of currents and fields to exist. The force-free filaments, with a magnetic field axial near the axis and increasingly azimuthal toward the outside of the filament, are the simplest examples of such force-free structures. In these plasmas, all properties are highly anisotropic, in sharp contrast to the isotropic plasma assumed in most astrophysical models. In particular isotropic MHD approximations do not give even roughly accurate predictions for such anisotropic plasma.

Putting this condition in terms of observable quantities, we get for fully ionized hydrogen plasmas,

5) $\Omega_i\tau_i = 2x10^{11}\ BT_i^{3/2}/n \ln \Lambda >>1$

, where B is in gauss, T in K, n in ions/cm^3 and ln is the Coulomb logarithm, of the order of 12. We here use the values for the ions, because even if the electrons are magnetized, cross-field currents can still be carried by ions. But when the ions are magnetized, the electrons are as well and cross-field currents are suppressed.

For partially ionized plasmas both of the following conditions must be fulfilled for magnetization, taking into account collisions of ions with neutrals:

6) $\Omega_i\tau_i = 2x10^{11}\ BT_i^{3/2}/n_0 f \ln \Lambda >>1$ and
7) $\Omega_i\tau_n = 2x10^{14}\ BT_i^{-1/2}/n_0 >>1$

, where f is the ionization fraction and the density of neutral atoms. In all real plasmas, if condition (7) is met, so will condition (6).

The second condition for filamentary compression is that the magnetic field energy exceed the thermal energy of the plasma. If this condition is not met, the thermal pressure will dominate over magnetic pinch forces. This condition can be expressed as
8) $2.75 \text{ x } 10^{14} B^2/nT > 1$

Finally, the magnetic fields must be strong enough to transfer sufficient angular momentum out of a contracting disk to allow gravitational compression. Physically, this is equivalent to the condition that the power carried by the currents that generate the field is large enough to transfer sufficient rotational energy out of the disk for compression to occur. For a disk generator the potential generated is

9) $E = 10^{-8}\, BvR$ V

Where E is potential in volts, B is axial field in gauss, v is rotational velocity at the circumference in cm/s and R is radius in cm. The current generated by the rotating plasma disk must be at least that needed to create the axial field, or 5BR A, so total power carried by the current must exceed

10) $P = \frac{1}{2} B^2vR^2$ erg/s

The rotational energy of the disk (assuming a flat rotational curve) is

11) $\varepsilon = (\pi/2)\, nMv^2R^2H$ erg

where H is the height of the disk and M the mass of the proton. The ratio of the spin-down rate to the rotation frequency is

12) $(2B^2/nMv^2)(R/H) = 8\pi(v_A/v)^2\, (R/H)$

,where v_A is the Alfven velocity. So, the third condition for magnetic filament structure formation is

13) $v_A/v > (H/8\pi R)^{1/2}$

Equivalently, for a magnetized body, there is a maximum ratio of H/R that allows the magnetic filaments to spin the object down in one revolution.

14) $H/R < 8\pi\, (v_A/v)^2$

Do observed fields actually fulfill these conditions? Table 1 shows observed typical magnetic fields, particle density, temperature, radius and velocity within classes of objects ranging in scale from the IGM down to stars. We have also calculated the Alfven velocity v_A from B and n. Table 2 shows the calculated ratios: magnetization, magnetic/thermal energy, v_A/v and $(H/R)c$ as defined by eq. (14), as well as the calculated current required to generate the B fields over the object's extent.

For each class of object, there is of course a large range of values for individual objects. But the range for the ratios relevant to our three conditions vary far less. In the case of molecular clouds, for example, densities range from 10^3 to $10^7/\text{cm}^3$ and B fields from 10 microgauss to 1 milligauss, but since $B \sim n^{1/2}$, V_A is almost a constant and V varies little as well. Even across classes, V varies over less than 3 orders of magnitude, compared with a range of 17 orders of magnitude in r and 32 orders of magnitude in n.

Table 1

object	B(G)	n(cm^{-3})	T(K)	r(cm)	V_A(km/s)	V(km/s)	refs
IGM	2 x10^{-8}	2x10^{-9}	6 x10^{7}	3 x 10^{27}	900	1000	39-42
Clusters of Galaxies	5 x10^{-6}	1 x10^{-3}	6 x10^{7}	3 x10^{24}	300	1000	53
Galaxies	5 x10^{-6}	0.1	1 x10^{4}	6 x10^{22}	30	200	54
Mol. Clouds	1x10^{-3}	1x10^{7}	1x10^{1}	1 x10^{17}	9	60	55
Protostellar disk	1.5x10^{3}	1x10^{17}	7x10^{3}	8 x10^{11}	10	30	56
TTauri stars	1x10^{3}	2x10^{22}	4 x10^{3}	2 x10^{11}	0.012	40	57
Main seq.	1	8 x10^{23}	1x10^{4}	6 x10^{10}	2 x10^{-6}	200	

Table 2

object	current(A)	Sp. ang mom(cm^2/s)	magnetization	Mag/thermal	V_A/V	$(H/R)_c$
IGM	3x10^{20}	3x10^{35}	8x10^{23}	0.9	0.9	13
Clusters of Galaxies	7x10^{19}	3x10^{32}	5x10^{21}	0.1	0.3	1.6
Galaxies	1.5x10^{18}	1x10^{30}	1x10^{13}	7	0.16	0.4
Mol. Clouds	5x10^{14}	6x10^{22}	6x10^{8}	2.8	0.15	0.2
protostellar disk	6x10^{15}	2.4x10^{18}	9x10^{4}	0.9	0.3	1.6
TTauri stars	1x10^{15}	8x10^{17}	0.01	3x10^{-6}	3x10^{-4}	2x10^{-6}
Main seq.	3x10^{11}	1.2x10^{18}	2x10^{-7}	3x10^{-14}	1x10^{-8}	2x10^{-15}

As noted above, for the largest scales of the IGM, only estimates of the B fields are available at present. But for the other classes of object, extensive observations have been made, as shown in the cited references. Conclusions can thus be drawn concerning the three conditions set out.

The first condition, that plasma must be magnetized, is clearly fulfilled by orders of magnitude for all objects except condensed stars as shown in Table 2. This is an extremely important generalization, since it means that in all these objects, currents must flow entirely along local magnetic field directions. For proto-stellar disks, the ratio of parallel to perpendicular conductivity is around 8x10^{9}, and for larger scales the ratio is even larger.

So all currents must flow in quasi force-free configurations, such as current filaments, that allow current and magnetic field to be everywhere parallel. This also means that all analyses of these objects that assumes an isotropic plasma conductivity are incorrect, (as Alfven pointed out long ago.) In highly anisotropic and inhomogenous filamentary currents, currents at small scale can move across mean magnetic fields at large scale, as for example inflowing currents in a protostellar disk flow perpendicular to the ambient field in the molecular cloud. But this is possible only because of the filamentary organization of the currents and fields on the small scales, where field and currents must be parallel. The filamentary form of currents also implies necessarily that the magnetic forces are compressional in general, rather than outwards, as is hypothesized in most of the literature.

The second condition, that magnetic energy exceed thermal energy is also broadly fulfilled, again excepting condensed stars. For galaxies and molecular clouds, magnetic field energy clearly exceeds thermal energy, while for the other classes, magnetic and thermal energy are approximately equal. This means that magnetic fields have adequate strength to confine the observed thermal pressure in these classes of objects. As a corollary, it means as well that any analysis that assumes the confining force is exclusively gravitational leads to incorrect conclusions.

At the scale of clusters, the observational situation is more complex, as the magnetic field configuration in nearly spherical clusters is much more difficult to determine than in thin disk galaxies. However, when the filamentary structure of magnetic fields is taken into account, there is observational evidence of magnetic fields a factor of ten larger than in Table 1, sufficient to confine the hot gas of cluster [58], a confinement that has been attributed to dark matter.

The third condition, fields strong enough for spindown during contraction, is clearly fulfilled for all classes of objects, excluding stars, since the critical ratio of $(H/R) > 0.1$, and actual galaxies and protostellar disks have H/R around this value, while for clusters the critical $(H/R) > 1$. In the case of molecular clouds, magnetic breaking becomes significant when gravitational contraction along the axis produces disks with $(H/R)<\sim 0.2$.

Thus, magnetic fields are sufficiently strong to remove all or nearly all of the angular momentum from all these objects as they contract. In the case of stars and protostellar disks, all angular momentum decrease has already occurred by the time the protostellar disks are formed. Typical specific angular momentum for protostellar disks are $\sim 2.4 \times 10^{18}$ cm^2/s, comparable to typical specific momentum for main sequence stars like the sun $\sim 1.2 \times 10^{18}$ cm^2/s, but a small fraction of the 6×10^{22} cm^2/s that is typical of molecular clouds. In other words, stars contract from protostellar disks about 10 times larger in radius without significant further loss of angular momentum.

The key conclusion here is that magnetic fields are in all cases strong enough to remove the angular momentum from contracting objects, to magnetize the plasma clouds, creating anisotropic, filamentary currents, and to compress clouds against their thermal pressure.

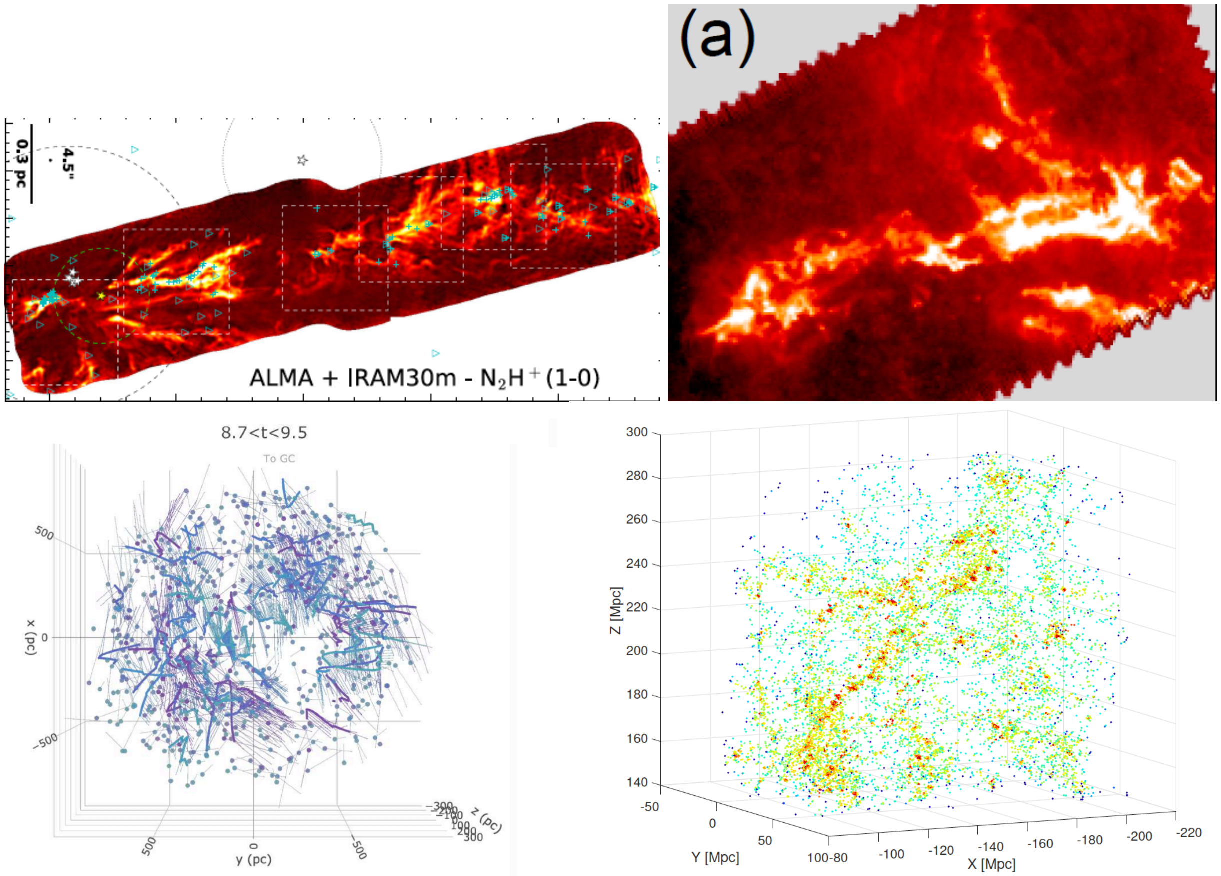

Fig. 4. Magnetized filaments have now been observed with radii from 0.05 pc (upper left,[46]) to 5pc (upper right, [47]) with embedded strings of stars with ages from 0.3-3 Gy(lower left. [50]) and with galaxies (lower right, [43]), with filament radii of 5 Mpc and length >100Mpc. The fractal nature of the filamentation is evident in these images.

The combined process of magnetic-gravitational structure formation not only needs no dark matter, but it also explains other phenomena, such as flat galactic rotation curves, that have been cited as support for the DM hypothesis, as researchers have pointed out for almost 40 years. Peratt and Green [59] showed that simulation of magnetically confined galaxies, even without gravitation, naturally produced flat rotation curves. Nelson [60] demonstrated analytically that in the outer regions of a galaxy, where the matter is mostly diffuse plasma, not stars, the observed magnetic field could easily account for elevated orbital velocities of plasma, which is the velocity generally measured at large radii. Battaner [54] showed that, for M31, a field of only 6μ G was needed to explain the velocity curve without DM. A more detailed model of the MW galaxy[61] confirmed that the outer regions of the velocity curve needed no DM and could be well fitted with a magnetic field confinement.

An observational consequence of this explanation is that the velocities of stars should be slower than that of plasma in the outer regions of a galaxy. This was indeed observed by Pont et al [62] and Jalocha et al [63], who demonstrated that magnetic fields could indeed explain the difference (Fig. 5) . Of course, if the rotation curve were due to DM, there would be no difference.

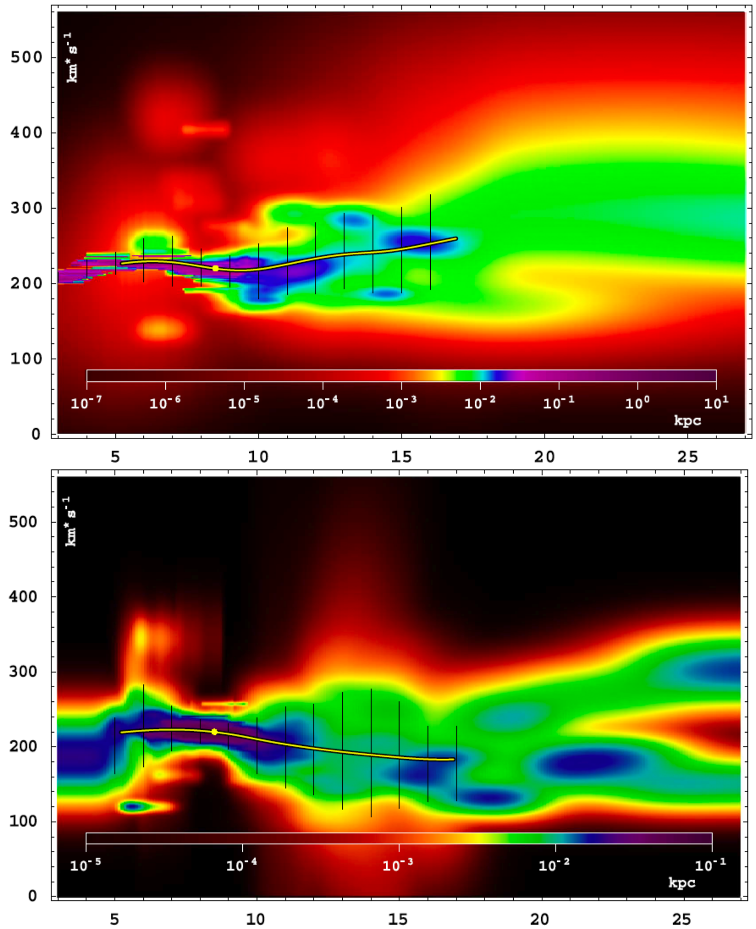

Fig. 5. Measurements of gas velocities in the Milky Way (top) show an increase to 300 km/s out to 25 kpc, while stellar velocities (bottom) show a decrease to <200km/sec [63]. This is only possible if the gas—in reality, plasma—is magnetically as well as gravitationally confined.

It is important to note that the magneto-gravitational structure formation process first proposed by Alfven shows that the laws of thermodynamics in no way require a Big Bang in the evolution of the universe towards greater structure. During the pre-galactic phases of this process, energy is supplied by gravitational contraction itself. Once stars form in galaxies, a portion of the thermonuclear energy released is converted to plasma kinetic energy through stellar winds and supernovae. A part of this kinetic energy then generates new currents and magnetic fields that powers continued structure formation. This entire structure-formation process produces greatly increased energy fluxes, albeit at smaller and smaller physical scales, thus driving the universe farther and farther from equilibrium.

4. Non-magnetic processes can't produce observed filamentary structures

We have shown that, with observed plasma parameters, magnetized filamentary currents must act to remove angular momentum from gravitationally contracting objects, thus forming the hierarchy of astrophysical structure actually observed. However, many astrophysical simulations form structures, including filamentary structures, without any magnetic field being included in the simulations [*e.g.* 64]. It is important to explain here that these simulated structures are *purely artifactual*, and do not correspond to any real physical processes being simulated.

We first consider why gravitation, in the absence of magnetic fields and electric currents, can't by itself produce the structures that we observe. For any rotating, gravitating object to contract in a direction perpendicular to the axis of rotation, angular momentum must be transferred away from the object. Since gravitational fields can't transfer angular momentum, angular momentum can only be transferred by the viscosity of the plasma or neutral gases. But on astrophysical scales, other than for condensed starts, viscosity is negligible.

Consider first neutral gas, which in the astrophysical case is mainly hydrogen.

The time for viscous damping is of the order of

$$t_v = r^2\rho/ \eta \text{ sec}$$

where r is the radius of the object, ρ the density and η the dynamic viscosity. Gravitational contraction occurs on time scales defined by

$$t_g = (3\pi/G)^{1/2} \rho^{-1/2} \text{ sec}$$

Viscous damping is important if the ratio t_v/t_g is comparable with unity or less.

$$t_v/t_g = (G/3\pi)^{1/2} r^2\rho^{3/2}/ \eta$$

Viscosity of H depends weakly on temperature, but is of the order of 10^{-4} poise, so,

$$t_v/t_g \sim 0.8\, r^2\rho^{3/2} = 1.7 \times 10^{-36}\, r^2n^{3/2}$$

This ratio is in fact on the order of 10^8 on scales from clusters of galaxies down to molecular clouds, so neutral viscosity is entirely negligible.

If we ignore magnetic fields, ion viscosity in a hydrogen plasma is

$$\eta_i = 2.4 \times 10^{-16}\, T^{5/2}$$

This exceeds neutral viscosity for $T > 1.8 \times 10^6$ K. But even for the hot plasma in clusters of galaxies, plasma viscous damping times are 70,000 times longer than gravitational contraction times. Put another way, only for plasma velocities >7,000 km/s can plasma viscosity, in the absence of magnetic fields, transfer angular momentum on time scales of gravitational collapse.

(Of course, in real plasmas, magnetic fields and currents are always important with the high ionization levels and energies that must occur with such high velocities.)

It is thus clear that if magnetic fields are ignored, there are no physical processes that can transfer angular momentum on times scales that enable gravitational collapse. How then does collapse occur in astrophysical simulations that do ignore magnetic fields? The answer is that such smoothed particle hydrodynamic (SPH) simulations always include “artificial viscosity”, which is an algorithm that introduces an unphysical viscosity effect that is many orders of magnitudes larger than actual physical viscosity.

As explained by Huang[65], for example, among many others, artificial viscosity is required in astrophysical SPH simulations because actual viscosity is far too small to produce realistic-looking simulations. Instead of solving this problem by including the real physical phenomena, namely magnetic fields and electric currents, that actually transfer angular momentum and dissipate energy, artificial viscosity introduces a purely numerical process without physical basis. Generally, this is justified by saying that such artificial viscosity imitates the (unmodeled) effects of turbulence, shock waves, or even the magneto-rotational instability (which of course does involve the magnetic fields ignored in the simulations). However, the formula for the artificial viscosity and its magnitude are not set on the basis of any comparisons with actual observations of shock waves in the laboratory or in astrophysical conditions, but are considered freely-adjustable variables.

As Imaeda& Inutsuka [66] demonstrated 20 years ago, artificial viscosity leads directly to the formation of wholly artifactual filamentation. “The results show that the introduction of this type of artificial viscosity causes the unphysical filamentary structures”, they demonstrated. Even in steady sheared flows, where no shock waves would be physically possible, artificial viscosity produces filamentation and transfers angular momentum. The elimination of artificial viscosity in turn eliminates both filamentation and the transfer of angular momentum needed for any gravitational contraction.

5. Conclusions

The basic prediction of the BBH that no objects in the universe should be older than the Big Bang has been repeatedly and decisively contradicted by observation, a contradiction that has grown significantly in the past several years. BBH structure formation also required the existence of non-baryonic dark matter, whose existence is contradicted by multiple data sets. On the other hand, observational evidence abundantly confirms the quantitative predictions of the plasma structure formation model first proposed by Alfven, if the BBH is abandoned and no origin in time is assumed for the universe. Observed magnetic fields at all scales larger than those of condensed stars are sufficient to magnetize plasma, so currents must flow along local magnetic field lines in force-free filaments. The observed fields are also sufficient to transfer angular momentum out of contracting objects during the contraction time The main features of the formation of cosmic structure have been accurately predicted by including the well-known effects of magnetic fields and electric currents, and by discarding the BBH. Simulations that neglect magnetic fields can only form structure by including unphysical artificial viscosity and therefore do not lead to valid conclusions.

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References

1) Riess, A., “The expansion of the Universe is faster than expected” Nature Reviews Physics 2, 10 Jan. 2020
2) Scolnic, D. M. *et al*, “The Complete Light-curve Sample of Spectroscopically Confirmed SNe Ia from Pan-STARRS1 and Cosmological Constraints from the Combined Pantheon Sample” ApJ, 859,101 June 2018
3) Wright, N., 2006. Pub.Ast. Soc. Pac., 118, 1711
4) Ceccarelli, L., Padilla, N. D., Valotto, C. and Lambas D. G., “Voids in the 2dFGRS and ΛCDM simulations: spatial and dynamical properties” MNRAS, 373, 1440 Nov. 2006
5) Salehi, A., Yarahmadi, M. and Fathi, S., “The cosmological bulk flow in QCDM model: (In)consistency with ΛCDM” arXiv:2001.01743v1 Jan. 2020
6) Betancort-Rijo,J., Patiri,S.G. Prada,F. & Romano, A.E., “The statistics of voids as a tool to constrain cosmological parameters” MNRAS, 400, 1835 Aug. 2009
7) Lambas, et al, “The sparkling Universe: the coherent motions of cosmic voids” MNRAS, 455, L99 Jan. 2016
8) Watson, W. A. et al, “Statistics of extreme objects in the Juropa Hubble Volume simulation” MNRAS, 437, 3776 Feb. 2014
9) Einasto, J., Hütsi, G., Suhhonenko, I., Liivamägi, L. J., & Einasto, M., “Evolution of superclusters and supercluster cocoons in various cosmologies” arXiv:2005.03480 May 2020
10) Lee, J. et al, “Discovery of Interstellar trans-cyanovinylacetylene (HC ≡ CCH = CHC ≡ N) and vinylcyanoacetylene (H2C = CHC3N) in GOTHAM Observations of TMC-1” ApJ, 908 11 Feb. 2021
11) Ma, Y-Z., & Pan, J., “An estimation of local bulk flow with the maximum-likelihood method MNRAS, 437, 1996 Nov. 2014
12) Saunders, W., Frenk, C., Rowan-Robinson, M., Efstathiou, G., Lawrence, A., Kaiser, N., Ellis, R., Crawford, J., Xiao-Yang Xia , X-Y., & Parry,I.” The density field of the local Universe”, Nature, 349, 32–38 , Jan. 1991
13) Clowes, R., et al, “A structure in the early Universe at z ∼ 1.3 that exceeds the homogeneity scale of the R-W concordance cosmology” MNRAS, 429, 2910 Jan. 2013
14) Horváth, I., Hakkila, J. & Bagoly, Z., “Possible structure in the GRB sky distribution at redshift two” A&A 561, L12 Jan. 2014
15) Shirokov, S. I., Lovyagin, N. Yu., Baryshev, Yu. V., Gorokhov V. L, “Large-scale fluctuations in the number density of galaxies in independent surveys of deep fields” Astronomy Reports, 60, 563 June 2016
16) Nikonov, M., Chekal, M., Shirokov, S., Baryshev, A. & Gorokhov,V., “The Line-of-Sight Analysis of Spatial Distribution of Galaxies in the COSMOS2015 Catalogue” Universe, 6, 215 Sept. 2020
17) Lopez, A., Clowes, R.G. and Williger, G.M., “A Giant Arc on the Sky” ArXiv:2201.06875v1, Jan.2022

18) Friday,T., Clowes, R.G. and Williger, G.M., “Correlated orientations of the axes of large quasar groups on Gpc scales” arXiv:2201.11474v1, Jan. 2022
19) Mészáros, A., “An oppositeness in the cosmology: Distribution of the gamma ray bursts and the cosmological principle” Astron. Nachr., 340, 564 Oct. 2019
20) J. Silk, “Oral history interview with Joseph Silk”,https://www.aip.org/history-programs/niels-bohr-library/oral-histories/38283 Oct. 1988
21) Steinhardt, C. L., Capak, P., Masters, D., Speagle. J. S., “The Impossibly Early Galaxy Problem”, Ap J, 824, 21 June 2016
22) Cerny, W. et al, 2020, arXiv:2009.08550, Sept., 2020
23) Adhikari, G., et al., “An experiment to search for dark-matter interactions using sodium iodide detectors” Nature 564, 83 Dec. 2018
24) Aprile, E. et al. (XENON Collaboration), “Dark Matter Search Results from a One Ton-Year Exposure of XENON1T” Phys. Rev. Lett. 121, 111302 Sept. 2018
25) Liu, J., Chen, X. & Ji, X., “Current status of direct dark matter detection experiments” Nature Phys 13, 212 Mar. 2017
26) Oehm, W and Kroupa, P. “Constraints on the existence of dark matter haloes by the M81 group and the Hickson Compact Groups of Galaxies” In *Conference Cosmology on Small Scales 2018 p.30,* Institute of Mathematics CAS, Prague Sept. 2018
27) Santos-Santos, I.M., Domínguez-Tenreiro, R., Pawlowski, M.S., “An analysis of satellite planar configurations around the MW and M31: singling out new high quality planes” arXiv:1908.02298v1 Aug. 2019
28) Müller *et al*., “A whirling plane of satellite galaxies around Centaurus A challenges cold dark matter cosmology” Science 359, 534 Feb. 2018
29) Mancera Pina, P.E., *et al,* “Off the Baryonic Tully–Fisher Relation: A Population of Baryon-dominated Ultra-diffuse Galaxies” ApJL 883**,** L33 Sept. 2019
30) Kroupa, P. Pawlowski, & M. Milgrom, M., “The failures of the standard model of cosmology require a new paradigm” Int. J. Mod. Phys. D 21,1230003 Dec. 2012
31) Alfvén, H., “Double radio sources and the new approach to cosmical plasma physics” Astrophys Space Sci 54, 279 Apr. 1978
32) Alfvén, H., “Cosmic Plasma”, Holland, Reidel 1981
33) Alfvén, H., and Falthammar, C-G., “Cosmical Electrodynamics, Fundamental Principles, UK, Oxford, 1963
34) Lerner, E. J., “Magnetic Vortex Filaments, Universal Scale Invariants and the Fundamental Constants”, IEEE Tran Plasma Sci, 14, 690-702, Dec., 1986
35) Tully, R.B., “Alignment of Clusters and Galaxies on Scales up to 0.1 C” ApJ, 303, 25 April 1986
36) Collins, C.A., et al, “Large-scale anisotropy in the Hubble flow” Nature, 320, 506 Apr. 1986
37) Sylos Labini, F, Vasilyev,N., Baryshev, Y. V. “Power law correlations in galaxy distribution and finite volume effects from the Sloan Digital Sky Survey Data Release Four”, A&A, 465, 23 April, 2007
38) Elmegreen, B.,& Falgarone, E., ApJ, 471,816, 2009
39) Abbasi, R.U.,et al, “Evidence for a Supergalactic Structure of Magnetic Deflection Multiplets of Ultra-High Energy Cosmic Rays” arXiv:2005.07312v1 May 2020

40) Vernstrom,T., Gaensler,B. M., Rudnick, L. Andernach H., “Differences in Faraday Rotation between Adjacent Extragalactic Radio Sources as a Probe of Cosmic Magnetic Fields” ApJ, 878, 2, [92] June 2019
41) O’Sullivan, S. P.,et al, “New constraints on the magnetization of the cosmic web using LOFAR Faraday rotation observations” arXiv:2002.06924v2, May 2020
42) Govoni, F. et al, “A radio ridge connecting two galaxy clusters in a filament of the cosmic web” Science 364, 981 Jun. 2019
43) Santiago-Bautista,I., *et al*, “Identification of filamentary structures in the environment of superclusters of galaxies in the Local Universe” arXiv:2002.03446v1 Feb. 2020
44) Kim, J. et al, “Filaments of galaxies as a clue to the origin of ultrahigh-energy cosmic rays” Science Advances, 5, eaau8227 Jan. 2019
45) Li, G-X, *et al*, “ATLASGAL: A Galaxy-wide sample of dense filamentary structures” A&A 591, A5 June 2016
46) Hacar, A. et al, “An ALMA study of the Orion Integral Filament - I. Evidence for narrow fibers in a massive cloud” A&A 610, A77 Mar. 2018
47) Wang, J-W. *et al*, “Multiwavelength Polarimetry of the Filamentary Cloud IC 5146. II. Magnetic Field Structures” ApJ 888, 13 Dec. 2019
48) Dall’Olio, D. “ALMA reveals the magnetic field evolution in the high-mass star forming complex G9.62+0.19 A&A 626, A36 June 2019
49) Doi, Y., et al, “The JCMT BISTRO Survey: Magnetic Fields Associated with a Network of Filaments in NGC 1333” arXiv:2007.00176v1 Jul. 2020
50) Kounkel M.& Covey K., “Untangling the Galaxy. I. Local Structure and Star Formation History of the Milky Way” AJ 158, 122 Aug. 2019
51) Balescu, R., Transport Processes in Plasmas, (North Holland Publishing) p.211, 1988
52) Kotelnikov, I.A., “Braginskii and Balescu kinetic coefficients for electrons in Lorentzian plasma”, Plasma Physics Reports, 38, 608, Aug. 2012
53) Clarke,, T.E., Kronberg, P.P., Bohringer , H. “A new radio-x-ray probe of galaxy cluster magnetic fields” ApJ, 547:L111–L114, Feb., 2001
54) Battaner, E., Garrido, J., Membrado, M. et al., “Magnetic fields as an alternative explanation for the rotation curves of spiral galaxies” Nature 360, 652 Dec. 1992
55) Li, H-B., “Magnetic Fields in Molecular Clouds—Observation and Interpretation” Galaxies 9, 41, 2021
56) Donati, J-F., Paletou,F., Bouvier,J. & Ferreira, J. “Direct detection of a magnetic field in the innermost regions of an accretion disk”,Nature, 438, 466, Nov, 2005
57) Feeney-Johansson, A.; Purser, S. J. D., Ray, T. P., Vidotto, A. A., Eislel, J., Callingham, J. R.; Shimwell, T. W.; Vedantham H. K., Hallinan G., and Tasse C. “Detection of coherent low-frequency radio bursts from weak-line T Tauri stars” arXiv:2106.15445v1, June, 2021
58) Eilek, J.A. & Owen, F.N, “Magnetic Fields in Cluster Cores: Faraday Rotation in A400 and A2634” ApJ 567:202 Mar. 2002
59) Peratt, A.L., & Green, J.C., “On the evolution of interacting, magnetized, galactic plasmas”, Astrphys.&SpaceSci, 91, 19, Mar., 1983
60) Nelson, A. H., “On the Influence of Galaxy Magnetic Fields on the Rotation Curves in the Outer Discs of Galaxies” MNRAS, 233,115 July 1988
61) Tsiklauri, D., “Galaxy rotation curves: the effect of $\vec{j} \times \vec{B}$ force, Astrophys Space Sci 334, 165 July 2011

62) Pont, F., Queloz, D., Bratschi, P.& Mayor, M. “Rotation of the outer disc from classical cepheids” Astron. Astrophys. 318, 416 Feb. 1997
63) Jałocha, J., Bratek, Ł., Pękala, J. Sikora, S.& Kutschera, M., “Magnetic flux density form the relative circular motion of stars and partially ionized gas in the galaxy mid-plane vicinity” Ap J, 833,174 Dec. 2016
64) Kuznetsova, A., Hartmann, L., and Ballesteros-Paredes, J. “Signatures of star cluster formation by cold collapse”, ApJ 815, 27 Dec. 2015
65) Huang ,S., Katz,N., Dav,R., Fardal, M., Kollmeier J., Oppenheimer,B.D. Peeples ,M.S. Roberts,S. Weinberg,D.H. Hopkins P.F. & Thompson,R. “The robustness of cosmological hydrodynamic simulation predictions to changes in numerics and cooling physics” MNRAS 484, 2021, Jan., 2019
66) Imaeda, S. & Inutsuka, S-I., Shear flows in smoothed particle hydrodynamics”, ApJ 569, 501–518, April, 2002