Primordial Comets: Big Bang Nucleosynthesis, Dark Matter & Life

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ABSTRACT

Primordial comets are comets made of Big Bang synthesized materials—water, ammonium, and carbon ices. These are the basic elements for life, so that these comets can be colonized by cyanobacteria that grow and bioengineer it for life dispersal. In addition, should they exist in large enough quantities, they would easily satisfy the qualifications for dark matter: low albedo with low visibility, gravitationally femtolensing, galactic negative viscosity, early galaxy formation seeds, and a self-interaction providing cosmic structure. The major arguments against their existence are the absence of metals (elements heavier than He) in ancient Population III stars, and the stringent requirements put on the Big Bang (BB) baryonic density by the BB nucleosynthesis (BBN) models. We argue that CI chondrites, hyperbolic comets, and carbon-enriched Pop III stars are all evidence for primordial comets. The BBN models provide the greater obstacle, but we argue that they crucially omit the magnetic field in their homogeneous, isotropic, "ideal baryon gas" model. Should large magnetic fields exist, not only would they undermine the 1-D models, but if their magnitude exceeds some critical field/density ratio, then the neutrino interacts with the fields, changing the equilibrium ratio of protons to neutrons. Since BBN models are strongly dependent on this ratio, magnetic fields have the potential to radically change the production of C, N, and O (CNO) to produce primordial comets. Then the universe from the earliest moments is not only seeded for galaxy formation, but it is seeded with the ingredients for life.

1. INTRODUCTION

The study of comets has been a journey that brought most surprising results. We began in 2004 with a physics problem—can comets possess liquid water in the vacuum of space? The solution became clear once the question was asked as we wrote in 2004[1] and 2005[2] discovering how water explains all the peculiar properties of comets as they travel in from Jupiter's orbit. In 2006 we published predictions for NASA's Deep Impact mission[3] predicting the "punching through" of the copper bolide to produce an anomalously small crater with a water geyser but were disappointed—the spacecraft team targeted the hot, dry subsolar region. JASA's Hyabusa mission was supposed to visit an asteroid, but Itikawa revealed itself as something other, an uninfected dehydrated comet—the exception that proves the rule. Finally NASA's Stardust returned material from a comet: clays, amino acids, cubanite, and something we did not expect—a forsterite sand grain—which proved that comets do vacuum up detritus and thus can be infected the same way. In 2007, while waiting for the Rosetta comet encounter we looked at where comets go, and how they prepare for the journey.[4] In 2008 we argued that infected comets are more ancient than the Earth, filling the galaxy with information that bootstrapped life on Earth some 3.8 billion years ago.[5] In 2011 we addressed the Origin-of-life (OOL) that filled the galaxy with infected comets, arguing that the inter-connected network of comets holds more information than the mere multiplicity of comets, i.e., permutations rather than combinations can explain the information of OOL.[6–8] In 2012 we looked inward, examining the nanometer-scale magnetites that fill infected comets, arguing that they are biological machines for harvesting energy and magnetic field.[9] In 2013 we brought the large and small together, showing how magnetic fields permit information addition, how biology "violates" the 2nd law of thermodynamics.[10] Now in 2015 we look at another attribute of magnetic fields, how in breaking the homogeneous, isotropic symmetry of the Big Bang they solve the flatness problem, the horizon problem, possibly the dark matter problem by producing abundant carbon, nitroge, oxygen (CNO) for primordial comets, and set up a universe designed for life—the Origin of Life problem.

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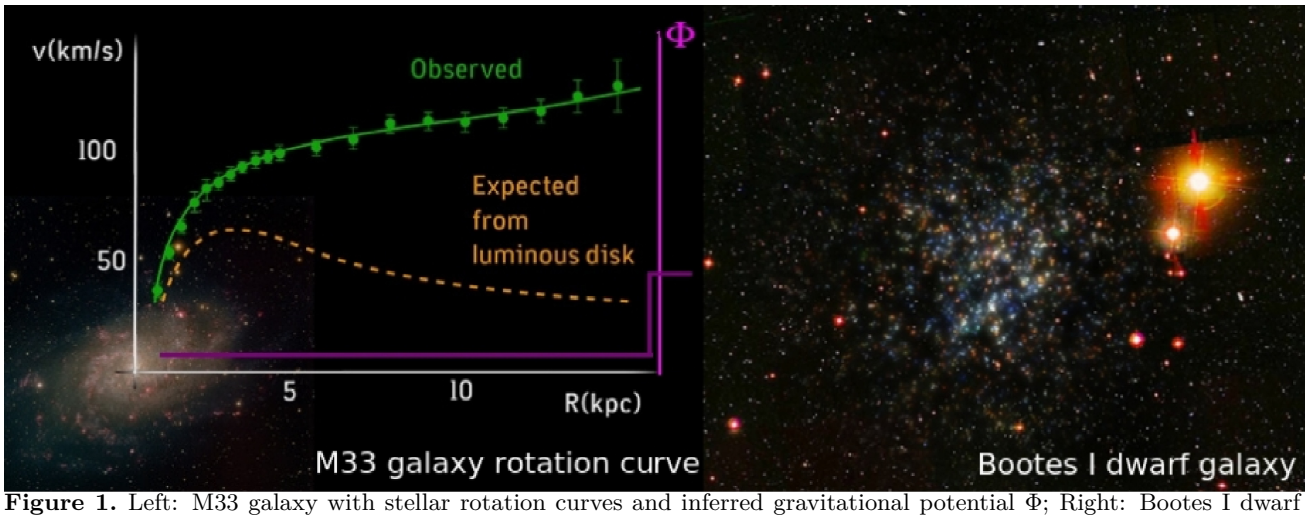

Figure 1. Left: M33 galaxy with stellar rotation curves and inferred gravitational potential Φ; Right: Bootes I dwarf galaxy.

In section 2, we describe how primordial comets can solve the dark matter problem. In section 3 we adress the minor objection that Population III stars do not show metals, with a discussion of carbon-enhanced metal-poor (CEMP) stars. In section 4 we address the major objection that Big Bang Nucleosynthesis (BBN) models do not produce enough carbon, nitrogen and oxygen (CNO) by reviewing the assumptions in the models. In section 5 we review some of the relevant literature on neutrinos, and justify the introduction of coherent magnetic fields and the neutrino-inflation event. In section 6 we speculate on a timeline that begins with a neutrino plasma and ends with life-bearing comets, and draw conclusions in the final section 7.

2. WHAT IS DARK MATTER?

Franz Zwicky[11] first noted that there appeared to be more gravitationally attracting matter in galaxies than just the stars, but it was Vera Rubin[12–14] who carefully mapped out the rotation speed of stars in several galaxies, showing that they rotated more as a plate rather than a Keplerian solar system. This motion required that the gravitational potential of the galaxy have a "boxcar" or "boater" shape, with a constant density of matter throughout the disk and no "bulge" in the center (see Fig. 1 left panel). Excluding any potential black hole in the center of the galaxy, the responsible matter did not match the way the stars were distributed, but had to outweigh the stars some 7:1. Despite this huge amount of matter, it was not seen either in emission or in absorption; it neither glowed nor obscured the light from stars. Likewise dwarf galaxies like those that orbit our Milky Way galaxy have far too few stars to have held together for their estimated ∼12 Gy lifetime, suggesting 90-99% of their matter is dark (Fig. 1 right panel).

The search for the source of this anomalous gravitational potential has continued for 50 years. We are now in a position to list many things that it is not, and a few attributes that we know it must exhibit. It is not due to a Modified Newtonian gravity (MOND),[15,16] but obeys standard gravity. It is not due to dust, gas, or black holes (of stellar size or greater), though we cannot exclude clumps of matter with size ranges between peas and asteroids. It is not a neutrino-like "weakly interacting particle" (WIMP), either of the normal particle physics model, nor of the more exotic SUSY or axion speculative models. In fact, recent WIMP theories have taken to postulating both a "dark" particle and a "dark" force to account for the failure to find the invisible source. I think it is safe to say that WIMPs are excluded by present experiment.

However, we do know quite a few facts about this material. Its even distribution means that it has either no viscosity or negative viscosity which would otherwise clump the material in the center of the galaxy. It extends out of the galaxy only a bit further than the stellar disk, so its kinetic temperature is only very slightly greater than that of the stars. For example, it cannot be primordial neutrinos because this "hot dark matter" will not stay in a single galaxy, but collect in superclusters forcing the distribution of galaxies in the cosmos to be one big blob. Hence the standard model is named "cold dark matter" (CDM). It is a higher percentage of the matter

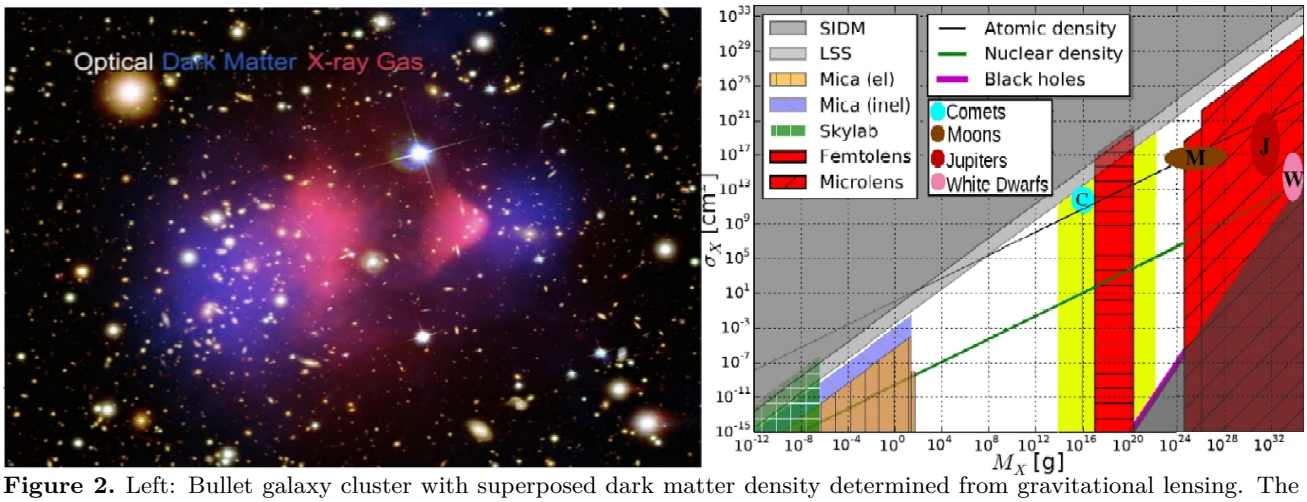

Figure 2. Left: Bullet galaxy cluster with superposed dark matter density determined from gravitational lensing. The two clusters have just passed through each other, heated gas showing more friction than dark matter. Right: Excluded regions of the dark-matter particle mass versus cross-section parameter space. Yellow bands are regions proposed for a Fermi-GBM femto-lensing search.

of big galaxies than small galaxies, which suggests that it is primordial, causing rather than a result of galactic formation. And finally, it has a low geometric cross section for collision either with stars or with itself as seen in Fig. 2, which if not due to a particle-physics WIMP, must be due to low surface area to mass, $\sigma < 0.47 cm^2/g$, spherical clumps.[17]

Looking over the previous two paragraphs, we can begin to construct a model of what dark matter looks like. (a) It is likely baryonic; (b) It is in clumps, which, interpolating between 10^6m (asteroids) and 10^{-2}m (peas), are ∼100m in size; (c) It emits no photons, so it must both be very cold and be very dark to prevent scattered light; (d) It must not self-interact, say, by colliding with itself or emitting Alfvén waves, so it cannot have a large geometric, magnetic, gravitational, or electric cross-section; (e) It must interact with stars gravitationally, yet maintaining a slightly hotter kinetic temperature (negative viscosity); and finally, (f) it must predate the stars in order to explain how galaxies are distributed.

Primordial, often interstellar, comets satisfy every one of these constraints.

(a) They exist, for despite stale claims that no interstellar comets have ever been observed, review of long-period comets from 1901-1950 with modern orbit tools found at least three[18,19] and at least one in the first decade of the 21st century.[20] A rate of one per decade is consistent with estimates of the density of interstellar comets necessary to account for dark matter.

(b) They are clumpy, with expected diameters similar to observed comets: 3-30km. This is slightly larger than our interpolated guess, but comets are also less dense than stars and asteroids, which biasses the distribution toward larger diameters.

(c) If they are similar to observed comets, then they have albedos < 0.05, which make them excellent black bodies, and regulates their surface temperatures in deep space to $\sim$ 4K. Since this precisely matches the background CMBR temperature, it makes them invisible to telescopes.

(d) Primordial comets have geometric cross-sections commensurate with their size (a few square kilometers), and due to their low density, a gravitational cross-section nearly the same size. That is to say, their gravitational lens is nearly obscured with matter (though still potentially visible to extremely bright background point light sources.[21–25]). Because comets outgas, they are not expected to charge up and have a Coulomb cross section. Nor are they expected to conduct electricity, as say, an iron meteorite, nor possess a magnetic cross-section, though bioengineered comets will have larger than normal magnetic effects.[9]

(e) They respond to stellar gravity fields, but also to stellar heating, especially at periastron where they outgas and jet, which lifts their apastron and gives them a slightly hotter kinetic temperature than the stars

themselves (as well as a non-NFW profile.[26]) If our Sun is orbiting the Milky Way at 230km/s, then compared to the galactic comet velocity, the geyser outflows of ∼2 km/s on the comet, may make a 1% difference, which also behaves as an "anti-gravity" when the comet approaches stars, or equivalently, a negative viscosity against the stellar background.[27] Because of jetting, the density of comets will be lower in high density star fields, exactly as needed (7km/s according to deBlok[28]) to even out the gravitional potential around the galactic bulge, which may solve the "core-cusp" problem plaguing cold dark matter models as well as the "too-big-to-fail" problem of dwarf galaxy dark matter.[29]

(f) Since dark matter not only holds galaxies together, but also condenses the galaxies from the big bang expanding gas, then primordial comets must also predate the formation of stars and galaxies. This is a problem for our model, since the CNO of comets is thought to be produced in stars, so they cannot predate them. We argue that CNO can be made in the Big Bang and in sufficient quantities also provides the raw elements of primordial comets. This then produces a minor and a major objection to primordial comets. The minor objection is that the most ancient stars within galaxies, the Population III stars, are deficient in CNO, which would seem to contradict the theory that primordial comets are responsible for seeding galactic formation. The major objection is that BBN models do not produce enough CNO by five or six orders of magnitude to account for dark matter. Nor are there any "easy" fixes to the BBN models since they are nearly "parameter free" models, without adjustable dials.

We address these two objections in the next two sections.

3. WHAT ARE PRIMORDIAL STARS?

Since the metallicity of stars (elements heavier than helium) is thought to be generated after the BBN, stars such as the Population III stars in our galaxy, have been classified as "ancient" if they have low metallicity spectra. However some of the most ancient stars, stars with the very lowest ratios of Fe/H in their spectra, also have anomalous increases in carbon, and are called "carbon-enhanced-metal-poor" (CEMP) stars.[30–32] And among the CEMP stars, the very lowest Fe/H also exhibit little trans-Fe elements, the *s*- and *r*- neutron capture isotopes, but do exhibit high and constant CNO abundances, which we take as evidence of a carbon-cycle uncoupled from an Fe core.[33]

In the standard model, carbon is made through the triple-alpha process in massive stellar furnaces, so that these CEMP stars must have gained their carbon either from supernovae that coincidentally did not transfer any iron,[34] or binary star systems that fractionate their winds,[35] and all this dynamics had to happen early in galactic evolution. Furthermore, this miracle of dynamic mass fractionation must occur frequently to account for the multiplicity of CEMP stars, but nowhere does the proposed dynamics explain why it is only the lowest metallicity stars in the early universe that must suffer these coincidences. Conversely the proposed models have many inputs, variable mixing ratios and adjustable parameters which we suspect can achieve any desired result, and therefore only weakly explain the phenomenon.

Could these CEMP stars be exhibiting primordial composition instead of unique dynamics? The constant CNO/H ratio for the oldest (lowest metallicity) stars is intriguing. The depletion of Li in the oldest stars is a weak indicator, since Li is usually destroyed in stars, though being below the "Spite plateau",[36,37] suggests that current BBN model prediction of Li abundance may be even worse than a factor of three. An even better indicator of primordial composition is a high D/H ratio since D is only consumed in stars and supernovae, it is never created. But since stellar furnaces are hostile to D, it is unlikely that stellar spectroscopy can give us a reliable number for D/H ratio—if the star is hot enough to burn H, it has already burnt its D. But the accretion disks around young stars are most often taken to be the parent material, the proto-stellar dust from which the star is born. If this material has a high D/H ratio, then it is a fair bet that the star itself primordial, however CEMP stars are very ancient, and it is not expected that their accretion disks have survived a few billion years of stellar winds and supernovae. If current stellar nurseries (planetary nebulae) have high D/H ratios, however, then it is argued, so would ancient stellar nurseries.

This is precisely what was observed by infrared telescopes, the highest D/H ratios are in icy, extrasolar accretion disks around young stars, and furthermore, these high ratios cannot be the result of stellar disk fractionation, but are primordial.[38] Additionally, the Herschel telescope found extrasolar accretion disks where

water ice is a major component corresponding to several thousand Earth oceans, which intriguingly, appears to never have been warmed above 17K since its formation.[39] Recently, they also report ammonia ice in these same clouds.[40] Combining these observations, it would seem that the primordial ice component of proto-stellar disks has never been processed through a star, or even through the chemical fractionation of a stellar disk, which makes the nitrogen and oxygen component of the deuterated ice something of a mystery.

We argue that both mysteries can be solved if these icy protostellar disks are composed of primordial comets. This might also account for the metallicity of the intergalactic gas seen in a halo around galaxies.[41] Likewise CEMP stars are not freak accidents of the 2nd generation of Pop III stars, but the 1st generation of galactic stars seeded by primordial comets, which accounts for both their low metallicity and their abundant carbon. These stars, however, would heat the primordial comets, causing them to outgas and give them the high kinetic temperatures that prevent them from clumping, discouraging further CEMP star formation. Therefore only the 1st generation of stars formed when the galaxy was dark will readily acquire primordial comets and demonstrate CEMP composition.

But how could the BBN produce the CNO necessary for primordial ices? That is the major objection discussed in the next section.

4. IS BIG BANG NUCLEOSYNTHESIS A PARAMETER FREE MODEL?

The BBN model, as coded by Wagoner, Fowler and Hoyle in 1967, has been more successful that seemed possible, with every modification and addition hardly changing the original calculation by more than a few percent.[42,43] Current estimates on the errors in the model put it as $\sim 0.1\%$, or three decimal places precision. The model has been used to put cosmological constraints on many unknown physical parameters, from fifth forces to new families of leptons.

This admirable precision, however, is also its undoing, because the Li/H ratio predicted by the model is 3X higher than observed, which is some 3-5 sigma discrepancy from the most recent measurements.[44] With shrinking error barrs, even the He/H ratio is now a few sigma away from the measurements. Despite many suggested changes—mystery particles, transient radioactive elements, extra neutrinos, primordial magnetic fields—the solutions remains stubbornly resistant to change. This has caused many people to refer to BBN as a "parameter-free" model, since it appears immune from the theorist's addiction to dial-twiddling.

However there are two inputs that BBN models remain highly sensitive to: the ratio of photons to baryons in the keV-temperature nucleosynthesis era, and the ratio of protons to neutrons at the time of neutrino decoupling at $\sim$1 MeV-temperature. The photons destroy nascent deuterium and inhibit nucleosynthesis, while the coupled neutrinos convert neutrons into protons. Both higher photon density and higher neutrino cross-sections drive the output of BBN toward more H and less He/metals. If we need to produce more CNO, we need to find ways to suppress their effects. Unfortunately, the photon to baryon ratio has been measured to higher and higher accuracy by the COBE, WMAP, and Planck satellites, so it is difficult to vary this process. On the other hand, the neutrino cross-section is only indirectly measured, with fundamental theoretical uncertainties such as whether neutrinos are Dirac or Majorana particles unresolved. This is not simply a slight correction, but as Wagoner et al point out,[42] Dirac anti-neutrino degeneracy—perhaps caused by the observed asymmetry of electrons over positrons—would lead to an very enhanced neutron and CNO production. Needless to say, neutrino and $0\nu2\beta$ experiments to distinguish Dirac from Majorana neutrinos are proliferating as these theoretical issues become more important in the dark matter mystery.

If this cross-section can be scaled to the conditions of the BB near the time of neutrino decoupling, will it change the BBN model output? Listing some of the more important cross-sections: $\nu\gamma \rightarrow \nu\gamma\gamma$ is e+/e- emission; $\nu + n \rightarrow p + e$ is reverse-beta decay; $\nu \rightarrow e^+ + W^- \rightarrow e^+ + e^- + \nu$ is the pair-production or 1-loop interaction (combining $e^- + e^+$) resulting in a magnetic moment; and $\bar{\nu} + p \rightarrow n + e^+$ is beta-decay. All of these cross-sections reduce the energy of the neutrino, and therefore act as neutrino opacity. Normally the opacity is thought of as solely dependent on the density, but because of the magnetic moment of the neutrino, all of these interactions depend on the magnetic field as well. Current theories put the magnetic moment of the neutrino at $\sim 10^{-19}\mu_B$ though experimentally the cross-section has only been measured $\mu < 2.9 \times 10^{-11}\mu_B$,[45] or atrophysically $\mu < 10^{-12}\mu_B$,[46,47] where μ_B is the Bohr magneton. But since the magnetic field and the density

appear in the reaction rates above as a ratio, (B/density)^2, the effect near threshold is non-linear—it is either on or off.[48] So even a $B < B_c$ will have an effect on shifting and sharpening the decoupling time of the neutrinos toward later, less dense, times.

To first order, enhanced reverse-beta decay should increase the hydrogen density at the expense of He/metals, but the large magnetic field also influences the electron/K-capture reaction: $p+e \rightarrow n+\nu$ because the proton and electron current of the LHS contributes to magnetic field. Therefore the equilibrium between reverse-beta-decay and e/K-capture is moved toward e/K-capture by increased magnetic field, which is expected to create a higher n/p ratio in the early BB.

There is also an anisotropy introduced by the magnetic field which changes the 3-D expansion of the BB into a quasi 1-D expansion along the B-field. In more detail, the magnetic field forms chaotic, "force-free knots" that expand at a much slower rate than the universe itself. This keeps the density high in these primordial tokomaks, which increases the likelihood of 3-body reactions, such as triple-alpha. We propose that a magnetized BBN (MBBN), is responsible for creating abundant helium without the corresponding need to enhance deuterium. It may open up a "neutron-drip" channel for the creation of helium.

If a large magnetic field is so critical for neutrinos, why would the neutrino so critical for a large magnetic field? That is the subject of the next section.

5. CAN NEUTRINOS FORM A PLASMA?

As described above, the neutrino interacts with matter via the weak interaction to become a lepton and a W-gauge boson, say an e+ and W- boson. In turn, the W- boson decays in 10^{25}s to become an electron and a neutrino. Since the W-boson is 160,000 times heavier than the lepton, the leptons travel faster and carry most of the current. To conserve momentum, the lepton and anti-lepton travel in opposite directions, but because they are oppositely charged, they still carry a net current. That is to say, we have "opened up" the 1-loop interaction when the energy of the neutrino is greater than 1MeV so as to create a pair-produced current, which then induces a magnetic field which then acts to limit the current and recombine the leptons.

It would seem that 1MeV thermal energies needed to make the e+/e- pair would also destroy the coherence of the current, erasing the magnetic field, but although thermal fluctuations may sramble the field, chaotic fields still possess magnetic energy. Additionally, Dvornikov argues that a possible asymmetry between neutrinos and antineutrinos (due to a non-zero Chern-Simons term) leads to an instability and an exponential growth of a seed B-field, which cannot happen in an e+/e- plasma without neutrinos.[49] Most importantly, the neutrino induced exponential growth terms change the dynamics.

That is, because the neutrino interaction rate depends on the ratio of magnetic field strength to mass density,[48] then up until some threshold field, the neutrinos are decoupled from the field, but above that field, they couple strongly, generating more leptons and more magnetic field. The critical B, B_C, calculated semiclassically gives $B_C = 4 \times 10^{13}$ Gauss, above which the reaction rate goes as exp(-$\frac{8m_e^3}{3\omega eB}$) producing an effective threshold affect.[50]

Because this magnetic field enhances e+/e- emission, this drag cools the neutrino flux until the neutrino flux is in thermal equilibrium with the background particles. In the usual BBN model, when the temperature drops below 1MeV, or the matter density diminishes, the pair-production channel closes, the drag diminishes and neutrino decouples from the matter. However, in the presence of magnetic fields, the zero-point energy is increased effectively lowering the energy barrier of the interaction channel. With two factors, density and magnetic field, now controlling the reaction rate, we can begin to produce negative feedback.

If we imagine a small perturbation of B-field near the critical strength, a lower field will increase the neutrino mobility and flux which will then strengthen the field, while a higher field will decrease the neutrino flux and hence weaken the field. Likewise, a perturbation of the matter density upward will increase the drag on the neutrino flux, deposit more heat and raise the temperature which acts to lower the density. Conversely, a density perturbation downward will increase the neutrino mobility, lower the heating rate and pressure, which enables surrounding magnetic fields to compress the matter.

This negative feedback means that the system maintains the critical ratio even as the temperature and density are slowly (adiabatically) changing, which means that the magnetic field must be increasing even as the BB is

cooling and expanding. Eventually, some other effect causes the magnetic field to saturate, and it can no longer maintain negative feedback.[51] At this point, several things happen very rapidly: the neutrino flux decouples from matter and electron/positron production ceases; the plasma cools and contracts, causing nearby plasma to expand and likewise drop below threshold; the BB goes through a phase transition which quickly quenches the magnetic field; the resulting dB/dt accelerates charged particles; since electrons are near threshold 1 MeV, they pair-produce avalanche, dumping the entire B^2 magnetic field energy into material heating, which preferentially heats higher density plasma, smoothing density inhomogeneities; the photon/baryon ratio nearly doubles; and a second round of "inflation" smooths out inhomogeneities left over from the previous negative feedback magnetic era.

Note that this MBBN model has several features that are desirable: (a) It answers the horizon problem by providing a ready explanation for why density perturbations are so smoothed out in the CMBR. (b) It provides a mechanism for resolving the matter/anti-matter asymmetry problem via the helicity of the primordial B-field. (c) It couples the thermal expansion energy to the particle plasma density (twice!) so that the flatness problem is naturally explained. (d) By moving the neutrino decoupling time toward cooler, less dense, later times, but at such high magnetic field strengths, it likely stabilizes the neutron against reverse-beta decay. It is this stabilization that we postulate converts nearly all the matter to helium, and sets up the conditions for triple-alpha carbon formation in the first three minutes, thereby solving the CEMP-no star riddle while not overproducing Lithium—clearly a programme for further study.

But does this really solve the dark matter problem? The next section addresses this topic.

6. CAN A MAGNETIC BIG BANG PRODUCE DARK MATTER?

In order to explain how 80% of the baryonic matter ends up in comets, we need a typical primordial comet composition. We have several proxies: spectroscopic analysis of comets, spectroscopic analysis of CEMP-no stars, and mass analysis of carbonaceous chondrites. In Table 1 we get a rough idea of the distribution of primordial elements looking at the solar photosphere and carbonaceous type-I (CI) chondrites—meteorites thought to be extinct comets—where we plot the logarithm of the atomic abundance in "dex", which is normalized to 12.0 for Hydrogen. The difference (or ratio) is tabulated in column 3. Columns 4-6 show mass ratios used by astronomers: X=mass percent of hydrogen, Y=mass percent of helium, Z=mass percent of the remainder (metals) Lithium to Uranium, and Z/X gives the metal/hydrogen mass ratio. For our purposes, only the top three or four elements contribute substantially to the total mass. We bolded the CI-solar differences that were more than one sigma away from zero.

The first impression is that hydrogen and helium make up most of the solar photosphere and CI chondrites. The second impression is that CI chondrites do not retain noble gasses very well, nor can they be measured easily in the Sun. Asplund et al. used satellite recovery of noble gasses to determine the contribution to the solar photosphere because the photosphere was too cool to ionize them, and therefore no spectral lines can be used.[52] The third impression is that most of the remaining Solar-CI differences involve "volatiles", such as H, C, N, O. And that leaves the odd-ball, the Lithium deficit in the solar photosphere which is often attributed to nuclear burning or depletion in the Sun that did not occur in the meteorites. Had Asplund et al. included deuterium, it would likewise show the same solar photosphere depletion. Gonzalez[53] attribute some the remaining differences to condensation temperatures, or fractionation that occurs as stars evaporate their photospheres to make the next generation of stars, but this would be an average effect below the threshold of individual error bars.

If carbonaceous chondrites truly are primordial, then it would appear that they are somehow processed to look more solar, especially for masses greater than neon. We take this to be evidence for accretion of interstellar dust (as evidenced by the sand grain returned in the Stardust aerogels),[54] but not evidence of primordial composition. That is, many of the elements above neon are made through neutron capture in supernovae, and would not have been made in any reasonable Big Bang scenario. Therefore we focus on the elements below neon that might have been made in the Big Bang. But these are the very same ones that fluctuate so much from volatility! How then can we get a handle on the primordial abundances? By examining the parent bodies of carbonaceous chondrites—comets and planetary nebulae around young stars.

Table 1. Primordial Elements in dex ($\log n_H$=12.0)

Elem.	**Solar***	**CI meteor.***	**Sol-CI**	**%Mass**	**Solar**	**proto-Solar**
D	7.5	5.0	**1.0**	←Encrenaz 2007		
H	12.00	8.25	**3.75**	X	0.738	0.715
He	10.93	1.29	**9.64**	Y	0.248	0.270
Li	1.05	3.25	**-2.2**	Z	0.0134	0.0142
Be	1.38	1.38	0	Z/X	0.0181	0.0199
B	2.70	2.75	-0.05			
C	8.39	7.40	**0.99**			
N	7.78	6.25	**1.53**			
O	8.66	8.39	**0.27**			
F	4.56	4.43	0.13			
Ne	7.84	-1.06	**8.9**			
Na	6.17	6.27	-0.1			
Mg	7.53	7.53	0			
Al	6.37	6.43	-0.06			
Si	7.51	7.51	0			
P	5.36	5.40	-0.04			
S	7.14	7.16	-0.02			
Cl	5.50	5.23	0.27			
Ar	6.18	-0.45	**6.63**			
K	5.08	5.06	0.02			
Ca	6.31	6.29	0.02			
Fe	7.45	7.45	0			
Solar & CI from Asplund et al.(2009)[52]						

If CI meteorites are comets that have lost most of their volatiles, then we can use the nitrogen depletion seen between the solar abundances and the CI meteorites to recalibrate. Nitrogen is a "true" volatile, because the high stability of the N_2 molecule means that on meteorites, most nitrogen bearing non-volatiles such as organics, will decay into N_2 in a few tens of million years..[55,56] If nitrogen ices are mixed with water and carbon ices in the primordial comets, then we can scale C and O up from CI meteorites by the same 1.5 dex to get the primordial comet CNO abundances: 8.9/7.8/9.9 dex. As a corroboration, the gas/dust mass ratio of planetary nebular disks is usually taken to be about 100, which if mostly water vapor, would suggest that primordial comets would have roughly 150 times as much oxygen in water as in the SiO2 dust fraction, very close to the 1.5 dex determined from nitrogen. In long-period comets, such as Hale-Bopp, water makes up 80% of the comet, and CO makes up about 2-20% of the ice, ammonia only 0.1-2%, roughly consistent with these numbers..[40,57] Comparing to the solar abundances then, the nitrogen remains about the same, carbon is slightly enhaced over solar, while oxygen is strongly enhanced.

Since each atom of oxygen needs two hydrogen, and each atom of nitrogen needs three hydrogens, the hydrogen locked up in the primordial comets is about 10% of the mass, where most of the remainder is in carbon and oxygen. Conversely, none of the Big Bang helium was captured by the primordial comets, so the dark matter has no helium. This changes all the usual abundance ratios in the MBBN, which we recaculate as follows. Since we know that approximately 85% of the matter in the universe is dark, and assuming that it has the above determined mass ratios, then the total mass percent of hydrogen in the MBBN = visible + dark matter = 0.15 * 0.75 + 0.85 * 0.1 = 0.2 or 20%. If IR telescopic observations of high D/H ratios in protostellar disks are correct, then some 0.85 * 0.1 * 0.002 = 0.00017 or 0.02% of the MBBN mass was deuterium. The mass percent of helium remains unchanged = 0.15 * 0.25 = 0.0375 or 3.75%. But the mass percent of oxygen is now enormous = 0.15 * 0.0004 + 0.85 * 0.88 = 0.75 or 75%. If Carbon was depleted as volatile CO like N2 (an upper limit) then we add 1.5 to the dex ratio for Carbon, we have 0.15* 0.75* (12/1) * 10(8.3-12) + 0.85 * 0.88 * (12/16) * 10(8.9-9.9) = 5.6% of the MBBN mass. This is also in agreement with CEMP-no star composition whose composition becomes similar to other main sequence stars (or solar abundance) for elements heavier than magnesium.[58,59]

Converting these to number densities with respect to hydrogen, we have for the MBBN, D/H = (0.017/20) * (1/2) = 0.00042, He/H = (3.75/20) * (1/4) = 0.047, C/H = (5.6/20) * (1/12) = 0.023, and O/H = (75/20) * (1/16) = 0.23, the major component of dark matter.

So it would appear that for every ten He atoms built, the MBBN made 50 oxygen, but only two carbon. Whatever the physics of the triple-alpha process that makes carbon, it must also efficiently burn those carbons into oxygen. What can we say about the physics of such a process?

The triple-alpha process takes a high density of helium at high temperature. So somehow, helium must form while bypassing the deuterium bottleneck. As discussed earlier by Wagoner,[42] this is a natural outcome of anti-neutrino degeneracy, and also, we hypothesize, of a strong magnetic field. Then early production of helium would then take advantage of the high density of the young BB to rapidly burn helium into carbon and oxygen, before the expanding and cooling BB shut down further burning of oxygen into neon and magnesium. This carbon and oxygen would readily combine with hydrogen to form ices: water, ammonia, carbon dioxide, methane. As the universe cooled, these ices would then condense within 15 Myr, forming the seeds for gravitational instabilities to form stars and galaxies. This may be why the earliest galaxies formed so quickly, and why they looked so "mature" at 600Myr after the BB.[60,61]

7. CONCLUSIONS

We have provided evidence that dark matter possesses all the properties of comets—low optical cross section, low gravitational cross-section, cold thermal temperature, hot kinetic temperature, negative viscosity, while roughly matching the density of hyperbolic comets observed entering our solar system. We address that the minor objection that spectroscopic study of stars does not see cometary composition by examining the oldest stars observed, the CEMP-no stars, finding them to be in remarkable agreement with comets. We then address the major objection that BBN models produce too little carbon and oxygen by several orders of magnitude, by developing the magnetic BBN model, whereby magnetic fields produce abundant helium early in the process. As a side benefit, the MBBN may also solve the horizon problem, the flatness problem, the antimatter asymmetry problem, the early galaxy problem, and the observed fractal galaxy distribution (currently explained by tweaking the dark energy dial). With so many physical benefits, the model deserves greater attention than our time or expertise allows.

We remind the skeptic that Copernicus' heliocentric model in 1543 did not return as accurate a result as Ptolemy's geocentric model until Kepler revised it in 1609 to include elliptic orbits. Nevertheless, it was wildly popular because it was far simpler to use than Ptolemy's model with its many tweaks and patches. We submit this model in the hope that it will be seen in a similar light—a simpler model that one day may even be more accurate than the current "precision" cosmology. But for all of its simplicity, one should not overlook that primordial comets provide the elements of life in greater abundance, in greater distribution, over larger expanses of time, and with far more water than any previous model. This model is not simply a universe constructed for a cosmologist, but a universe constructed for life. This may then be the meaning of Genesis 1:

בְּרֵאשִׁית בָּרָא אֱלֹהִים אֵת הַשָּׁמַיִם וְאֵת הָאָרֶץ׃ וְהָאָרֶץ הָיְתָה תֹהוּ וָבֹהוּ וְחֹשֶׁךְ עַל־פְּנֵי תְהוֹם וְרוּחַ אֱלֹהִים מְרַחֶפֶת עַל־פְּנֵי הַמָּיִם׃

"In the beginning God created the spacetime and the matter; And the matter was nebulous and dilute, but the Spirit of life brooded over the eggshell waters."

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REFERENCES

1. R. B. Hoover, E. V. Pikuta, N. C. Wickramasinghe, M. K. Wallis, and R. B. Sheldon, "Astrobiology of comets," in *Instruments,Methods,and Missions for Astrobiology VIII*, R. B. Hoover, G. V. Levin, and A. Y. Rozanov, eds., pp. 93–106, Proc. of SPIE Vol 5555, (Bellingham,WA), 2004.
2. R. B. Sheldon and R. B. Hoover, "Evidence for liquid water on comets," in *Instruments, Methods, and Missions for Astrobiology VII*, R. B. Hoover, G. V. Levin, A. Y. Rozanov, and G. R. Gladstone, eds., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **5906**, pp. 127–145, Sept. 2005.

3. R. B. Sheldon and R. B. Hoover, "Implications of cometary water: Deep impact, stardust and hayabusa," in *Instruments, Methods, and Missions for Astrobiology IX*, R. B. Hoover, G. V. Levin, and A. Y. Rozanov, eds., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **6309**, pp. 6309–0L, Proc. of SPIE, (Bellingham, WA), 2006.
4. R. B. Sheldon and R. B. Hoover, "The cometary biosphere," in *Instruments, Methods, and Missions for Astrobiology X*, R. B. Hoover, G. V. Levin, and A. Y. Rozanov, eds., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **6694**, pp. 6694–0H, Proc. of SPIE, (Bellingham, WA), 2007.
5. R. B. Sheldon and R. B. Hoover, "Cosmological evolution: Spatial relativity and the speed of life," in *Instruments, Methods, and Missions for Astrobiology XI*, R. B. Hoover, G. V. Levin, and A. Y. Rozanov, eds., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **7097**, pp. 7097–41, Proc. of SPIE, (Bellingham, WA), 2008.
6. R. B. Sheldon and R. B. Hoover, "More evidence for liquid water on comets," in *Instruments, Methods, and Missions for Astrobiology XIV*, *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **8152**, Sept. 2011.
7. R. B. Sheldon, "The cometary biosphere and the origin of life," in *Instruments, Methods, and Missions for Astrobiology XIV*, R. B. Hoover, G. V. Levin, and A. Y. Rozanov, eds., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **8152**, pp. 8152–42, Proc. of SPIE, (Bellingham, WA), 2011.
8. R. B. Sheldon, "Comets, information, and the origin of life," in *Genesis–In The Beginning: Precursors of Life, Chemical Models and Early Biological Evolution*, J. Seckbach, ed., *COLE* **22**, pp. 363–386, Springer, 2012.
9. R. B. Sheldon and R. Hoover, "Carbonaceous chondrites as bioengineered comets," in *Instruments, Methods, and Missions for Astrobiology XV*, *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **8521**, Oct. 2012.
10. R. B. Sheldon and G. Webb, "Comets and entropy hydrodynamics: Does origin-of-life violate the 2nd law?," in *Instruments, Methods, and Missions for Astrobiology XVI*, R. B. Hoover, G. V. Levin, A. Y. Rozanov, and C. Wickramasinghe, eds., *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **8865**, pp. 8865–09, Proc. of SPIE, (Bellingham, WA), 2013.
11. F. Zwicky, "Die Rotverschiebung von extragalaktischen Nebeln," *Helvetica Physica Acta* **6**, pp. 110–127, 1933.
12. V. C. Rubin, "Differential rotation of the inner metagalaxy.," *Astr. J.* **56**, p. 47, 1951.
13. V. C. Rubin, "The dynamics of the Andromeda nebula.," *Scientific American* **228**, pp. 30–36, 1973.
14. V. C. Rubin, "Extended optical-rotation curves of spiral galaxies," *Comments on Astrophysics* **8**, pp. 79–88, 1979.
15. S. McGaugh, "The Third Law of Galactic Rotation," *Galaxies* **2**, pp. 601–622, Dec. 2014.
16. S. S. McGaugh, "A tale of two paradigms: the mutual incommensurability of ΛCDM and MOND," *Can. J. Phys.* **93**, pp. 250–259, Feb. 2015.
17. D. Harvey, R. Massey, T. Kitching, A. Taylor, and E. Tittley, "The nongravitational interactions of dark matter in colliding galaxy clusters," *Science* **347**, pp. 1462–1465, Mar. 2015.
18. M. Królikowska, G. Sitarski, E. M. Pittich, S. Szutowicz, K. Ziołkowski, H. Rickman, R. Gabryszewski, and B. Rickman, "New catalogue of one-apparition comets discovered in the years 1901-1950. I. Comets from the Oort spike," *Astr. Astrophys.* **571**, p. A63, Nov. 2014.
19. M. Królikowska and P. A. Dybczyński, "Near-parabolic comets observed in 2006-2010. The individualized approach to 1/a-determination and the new distribution of original and future orbits," *Mon. Notices Royal Astr. Soc.* **435**, pp. 440–459, Oct. 2013.
20. P. A. Dybczyński and M. Królikowska, "Near-parabolic comets observed in 2006-2010 - II. Their past and future motion under the influence of the Galaxy field and known nearby stars," *Mon. Notices Royal Astr. Soc.* **448**, pp. 588–600, Mar. 2015.
21. G. F. Marani, R. J. Nemiroff, J. P. Norris, K. Hurley, and J. T. Bonnell, "Gravitationally Lensed Gamma-Ray Bursts as Probes of Dark Compact Objects," *Astrophys. J. Lett.* **512**, pp. L13–L16, Feb. 1999.
22. A. Barnacka, J.-F. Glicenstein, and R. Moderski, "New constraints on primordial black holes abundance from femtolensing of gamma-ray bursts," *Phys. Rev. D* **86**, p. 043001, Aug. 2012.
23. A. Barnacka, "Detection techniques for the H.E.S.S. II telescope, data modeling of gravitational lensing and emission of blazars in HE-VHE astronomy," *ArXiv e-prints* , July 2013.
24. D. M. Jacobs, G. D. Starkman, and B. W. Lynn, "Macro dark matter," *Mon. Notices Royal Astr. Soc.* **450**, pp. 3418–3430, July 2015.
25. S. Burdin, M. Fairbairn, P. Mermod, D. Milstead, J. Pinfold, T. Sloan, and W. Taylor, "Non-collider searches for stable massive particles," *Phys. Reports* **582**, pp. 1–52, June 2015.
26. J. F. Navarro, C. S. Frenk, and S. D. M. White, "A universal density profile from hierarchical clustering," *Astrophys. J.* **490**, pp. 493–508, 1997.
27. M. Królikowska, "Long-period comets with non-gravitational effects," *Astr. Astrophys.* **427**, pp. 1117–1126, Dec. 2004.
28. W. J. G. de Blok, "The Core-Cusp Problem," *Advances in Astronomy* **2010**, p. 5, 2010.
29. G. Ogiya and A. Burkert, "Re-examining the too-big-to-fail problem for dark matter haloes with central density cores," *Mon. Notices Royal Astr. Soc.* **446**, pp. 2363–2369, Jan. 2015.

30. M. Spite and F. Spite, "High resolution study of the abundance pattern of the heavy elements in very metal-poor field stars," *Astronomische Nachrichten* **335**, p. 65, Jan. 2014.
31. S. Keller, "First Stars: probes of the early universe." Keck Observatory Archive HIRES Z296Hb, Aug. 2013.
32. S. C. Keller, M. S. Bessell, A. Frebel, A. R. Casey, M. Asplund, H. R. Jacobson, K. Lind, J. E. Norris, D. Yong, A. Heger, Z. Magic, G. S. da Costa, B. P. Schmidt, and P. Tisserand, "A single low-energy, iron-poor supernova as the source of metals in the star SMSS J031300.36-670839.3," *Nature* **506**, pp. 463–466, Feb. 2014.
33. A. Maeder and G. Meynet, "The first stars: a classification of CEMP-no stars," *Astr. Astrophys.* **580**, p. A32, Aug. 2015.
34. S. Marassi, G. Chiaki, R. Schneider, M. Limongi, K. Omukai, T. Nozawa, A. Chieffi, and N. Yoshida, "The Origin of the Most Iron-poor Star," *Astrophys. J.* **794**, p. 100, Oct. 2014.
35. C. Abate, O. R. Pols, R. J. Stancliffe, R. G. Izzard, A. I. Karakas, T. C. Beers, and Y. S. Lee, "Modelling the observed properties of carbon-enhanced metal-poor stars using binary population synthesis," *ArXiv e-prints* , July 2015.
36. T. Hansen, C. J. Hansen, N. Christlieb, T. C. Beers, D. Yong, M. S. Bessell, A. Frebel, A. E. García Pérez, V. M. Placco, J. E. Norris, and M. Asplund, "An Elemental Assay of Very, Extremely, and Ultra-metal-poor Stars," *Astrophys. J.* **807**, p. 173, July 2015.
37. A. Maeder, G. Meynet, and C. Chiappini, "The first stars: CEMP-no stars and signatures of spinstars," *Astr. Astrophys.* **576**, p. A56, Apr. 2015.
38. L. I. Cleeves, E. A. Bergin, C. M. O. . Alexander, F. Du, D. Graninger, K. I. Öberg, and T. J. Harries, "The ancient heritage of water ice in the solar system," *Science* **345**, pp. 1590–1593, Sept. 2014.
39. M. R. Hogerheijde, E. A. Bergin, C. Brinch, L. I. Cleeves, J. K. J. Fogel, G. A. Blake, C. Dominik, D. C. Lis, G. Melnick, D. Neufeld, O. Panić, J. C. Pearson, L. Kristensen, U. A. Yıldız, and E. F. van Dishoeck, "Detection of the Water Reservoir in a Forming Planetary System," *Science* **334**, pp. 338–, Oct. 2011.
40. M. Hogerheijde, V. Salinas, E. Bergin, I. Cleeves, C. Brinch, C. Dominik, C. Dullemond, and E. van Dishoeck, "Cold water and ammonia vapor in the disks around TW Hya and HD100546," *IAU General Assembly* **22**, p. 56838, Aug. 2015.
41. J. M. Shull, C. W. Danforth, and E. M. Tilton, "Tracing the Cosmic Metal Evolution in the Low-redshift Intergalactic Medium," *Astrophys. J.* **796**, p. 49, Nov. 2014.
42. R. V. Wagoner, W. A. Fowler, and F. Hoyle, "On the Synthesis of Elements at Very High Temperatures," *Astrophys. J.* **148**, p. 3, Apr. 1967.
43. O. Pisanti, A. Cirillo, S. Esposito, F. Iocco, G. Mangano, G. Miele, and P. D. Serpico, "PArthENoPE: Public algorithm evaluating the nucleosynthesis of primordial elements," *Computer Physics Communications* **178**, pp. 956–971, June 2008.
44. Planck Collaboration, R. Adam, P. A. R. Ade, N. Aghanim, Y. Akrami, M. I. R. Alves, M. Arnaud, F. Arroja, J. Aumont, C. Baccigalupi, and et al., "Planck 2015 results. I. Overview of products and scientific results," *ArXiv e-prints* , Feb. 2015.
45. H. T. Wong, H. B. Li, S. T. Lin, F. S. Lee, V. Singh, S. C. Wu, C. Y. Chang, H. M. Chang, C. P. Chen, M. H. Chou, M. Deniz, J. M. Fang, C. H. Hu, H. X. Huang, G. C. Jon, W. S. Kuo, W. P. Lai, S. C. Lee, J. Li, H. Y. Liao, F. K. Lin, S. K. Lin, J. Q. Lu, H. Y. Sheng, R. F. Su, W. S. Tong, B. Xin, T. R. Yeh, Q. Yue, Z. Y. Zhou, and B. A. Zhuang, "Search of neutrino magnetic moments with a high-purity germanium detector at the Kuo-Sheng nuclear power station," *Phys. Rev. D* **75**, p. 012001, Jan. 2007.
46. G. G. Raffelt, *Stars as laboratories for fundamental physics: the astrophysics of neutrinos, axions, and other weakly interacting particles*, U. Chicago Press, 1996.
47. G. G. Raffelt, "Particle Physics From Stars," *Annual Review of Nuclear and Particle Science* **49**, pp. 163–216, 1999.
48. K. Bhattacharya and P. B. Pal, "Neutrinos and magnetic fields: a short review," *ArXiv High Energy Physics - Phenomenology e-prints* , Dec. 2002.
49. M. Dvornikov, "Generation of cosmic magnetic fields in electroweak plasma," *ArXiv e-prints* , Sept. 2014.
50. P. Satunin, "Study of neutrino decay in a magnetic field within the "worldline instanton" approach," *Soviet Journal of Experimental and Theoretical Physics Letters* **101**, pp. 657–663, May 2015.
51. S. P. Gavrilov and D. M. Gitman, "Creation of neutral fermions with anomalous magnetic moments from a vacuum by inhomogeneous magnetic fields," *Phys. Rev. D* **87**, p. 125025, June 2013.
52. M. Asplund, N. Grevesse, A. J. Sauval, and P. Scott, "The Chemical Composition of the Sun," **47**, pp. 481–522, Sept. 2009.
53. G. Gonzalez, "Solar system chemical abundances corrected for systematics," *Mon. Notices Royal Astr. Soc.* **443**, pp. L99–L103, Sept. 2014.
54. F. J. M. Rietmeijer, "Stardust glass: Indigenous and modified comet wild 2 particles," *Meteoritics and Planetary Science* **44**, pp. 1707–1715, Dec. 2009.
55. R. B. Hoover, "Microfossils, biomolecules and biominerals in carbonaceous meteorites: implications to the origin of life," in *Instruments,Methods,and Missions for Astrobiology XVI*, *Society of Photo-Optical Instrumentation Engineers (SPIE) Conference Series* **8521**, p. 6, Nov. 2012.

56. Private communication, 2015.
57. T. Encrenaz, *Searching for water in the Universe*, Springer-Praxis, 2007.
58. P. Bonifacio, E. Caffau, M. Spite, M. Limongi, A. Chieffi, R. S. Klessen, P. François, P. Molaro, H.-G. Ludwig, S. Zaggia, F. Spite, B. Plez, R. Cayrel, N. Christlieb, P. C. Clark, S. C. O. Glover, F. Hammer, A. Koch, L. Monaco, L. Sbordone, and M. Steffen, "TOPoS . II. On the bimodality of carbon abundance in CEMP stars Implications on the early chemical evolution of galaxies," *Astr. Astrophys.* **579**, p. A28, July 2015.
59. H.-N. Li, G. Zhao, N. Christlieb, L. Wang, W. Wang, Y. Zhang, Y. Hou, and H. Yuan, "Spectroscopic Analysis of Metal-poor Stars from LAMOST: Early Results," *Astrophys. J.* **798**, p. 110, Jan. 2015.
60. R. J. Bouwens, G. D. Illingworth, P. A. Oesch, M. Stiavelli, P. van Dokkum, M. Trenti, D. Magee, I. Labbé, M. Franx, C. M. Carollo, and V. Gonzalez, "Discovery of z ˜ 8 Galaxies in the Hubble Ultra Deep Field from Ultra-Deep WFC3/IR Observations," *Astrophys. J. Lett.* **709**, pp. L133–L137, Feb. 2010.
61. A. Zitrin, I. Labbe, S. Belli, R. Bouwens, R. S. Ellis, G. Roberts-Borsani, D. P. Stark, P. A. Oesch, and R. Smit, "Lyman-alpha Emission from a Luminous z=8.68 Galaxy: Implications for Galaxies as Tracers of Cosmic Reionization," *ArXiv e-prints* , July 2015.