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ergs. The total energy radiated is $18x10^{66}$ ergs. If all the radiation is absorbed, the total momentum absorbed is $6x10^{56}$ g cm/s or 10^{51} g cm/s per spiral galaxy. The velocity of a 10^{12} solar mass spiral is then $5x10^{6}$ cm/s or 50 km/s.

9. CONCLUSIONS

In summary, the universe has evolved as follows since recombination:
1) small perturbations formed superluminous Pop III stars whose radiation caused
2) large perturbations to form globular clusters that
3) condensed into elliptical galaxies, some of which
4) evolved to form quasars and spirals that
5) gave off so much radiation that,
6) in some places, statistically, voids were formed, and then
7) void collisions and void walls produced clusters of galaxies and the large scale flows and structure that we see now.

The number of Population III stars was very small and they all exploded so that only remnants are left. Essentially all matter has been processed in stars so that there are no primordial samples of lithium or deuterium. Observed deuterium abundances are not a cosmological constraint on the baryon density. All galaxies that have not been damaged by collisions or interactions have large massive elliptical halos. Any dark matter is baryonic. The interstellar medium was produced by stars. The intergalactic medium was produced by galaxies. There has been no exotic physics since well before recombination.

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8. VOIDS AND LARGE-SCALE STRUCTURE

There are only a few hundred million years between the formation of Pop III stars and the formation of quasars. That is not enough time to form a cluster of galaxies. Bound clusters of galaxies may not exist even now. What if there were no primordial clusters of galaxies? What if they are found only in textbooks? Then primordial galaxies are uniformly randomly distributed. If there are no clusters there is no binding energy for the voids to overcome. The voids are the first large scale structure in the universe.

Quasar formation and void formation presumably occur sometime between $z = 10$ and $z = 5$ when galaxies were much closer together than now. For $z > 5$ a big collection of galaxies can have a filling factor larger than one, where the filling factor is defined to be the average number of galaxies intercepted by a radius vector. Between 1/4 and 1/2 of the galaxies are opaque quasars or spirals. Let us, or random statistics, choose the parameters so that the collection of galaxies is just optically thick. The filling factor is probably greater than 4. Radiation cannot escape from the interior. All of the momentum of the radiation is deposited in the opaque galaxies and the radiative acceleration pushes them outward. If a considerable fraction of the galaxies is accelerated to, say, 100 km/s outward, the seed of a bubble had been formed which continues to expand on its own and also with the universe. Galaxies absorb momentum in proportion to their projected area but they accelerate in inverse proportion to their mass. Small spirals will be the leading edge of the void wall. All radiation (except radio) from all the galaxies contributes to the acceleration, not just the quasars. In reality the filling factors may not be high enough for complete absorption so that the energy requirement for a viable bubble might be doubled. Or the filling factors might be more than adequate so that all the radiation would continue to be absorbed even as the void expanded. As the void expands the filling factor would go down but stellar evolution would also be producing more absorbing gas and dust and also more supernovas and quasars so there might be some sort of equilibrium that would last between a few hundred million and a billion years.

I guess that the ratio of voids to galaxies (within our horizon) is on the order of 100,000 voids to 1000 billion galaxies. There are 10 million galaxies for every void. Since the voids are formed statistically there would have been many small abortive voids that disappeared as the universe expanded. The large scale structure of the universe is a product of radiation, not gravity.

We can make a qualitative numerical estimate of the energy available for making a void. Consider an optically thick collection of 100000 10^{12} solar mass galaxies, half quasar-spirals. These galaxies are larger and brighter than average, but they are also harder to accelerate. The remainder of the galaxies are transparent ellipticals. Some of the larger ellipticals are quasars as well. A high quasar luminosity is 10^{47} ergs/s so a conservative guess would be 10^{46} ergs/s for 300 million years for a 10^{12} solar mass quasar (example 6 in Section 2), a total of 10^{62} ergs. For 50000 galaxies the total is 5×10^{66} ergs. In addition 10 billion 10-solar-mass or so B stars times 50000 galaxies produce 5×10^{66} ergs while on the main sequence and 5×10^{65} ergs as supernovas. Another 50 billion or so times 50000 lower mass B and A stars are less luminous but live longer and produce 7.5×10^{66}

Essentially all matter has been in stars. Stars burn deuterium and lithium. Deuterium and lithium that we see now is not primordial so observed deuterium abundances are not a cosmological constraint on the baryon density. Most likely, the primordial deuterium abundance is low, the primordial lithium abundance is high, and any dark matter is baryonic.

7. GALAXY FORMATION

In general the Pop III stars positioned around a large perturbation are not symmetrically balanced so they produce a globular cluster with a net velocity. All that is required to segregate the globular clusters into galaxies is excess Pop III stars spaced at galaxy scales. Radiation from excess Pop III stars pushes away the nearby proto-globular clusters to form empty lanes that grow as the universe expands. Galaxies are simply the space that is not empty. The still optically thick proto-globular clusters near these lanes are accelerated inward thereby triggering subsequent gravitational collapse of the whole system of globular clusters. The center and the angular momentum axis are not determined until the whole galaxy collapses. The globular clusters condense into elliptical galaxies, which is where we began in Section 2.

Why would there be an excess of Pop-III-star-producing small perturbations at galaxy scales? I tried to find an everyday analogy for this situation where there are large regions bounded by small structures. Grain boundaries and dislocations in solids immediately came to mind. And that made me think about crystallization and supercooling. If you take a pure liquid in a clean container and put it in a freezer that does not vibrate, it will cool below the freezing point while remaining a liquid because there are no perturbations large enough to initiate crystallization. If you drop any sort of seed particle into the liquid, the liquid will immediately crystallize spreading out from the seed. If you drop two seed particles, there will be two centers of growth and a boundary of smaller imperfect crystals between them.

Let us examine the idea of supercooling the universe. The universe operates statistically. Statistics are historical. The universe does not know about the future. It knows that today it is cooler and less dense than yesterday but it does not know that tomorrow it will be cooler and less dense than today. It cannot determine the present conditions by interpolating between the past and the future. A spectrum of perturbations must always reflect conditions at an earlier z. If the universe is uniform at early times it will be supercooled as it expands uniformly. At some point an extreme, say 20 sigma, perturbation will trigger the transformation of the perturbation spectrum closer to the current conditions with the new perturbation spectrum propagating radially outward from the triggering perturbation. What if such extreme perturbations occur at galaxy-scale spacing? Then each spatial region would have boundaries where the propagation of its perturbation spectrum is blocked by neighboring regions. These boundaries would be dominated by small perturbations that evolve into Pop III stars which produce enough radiation to accelerate the globular clusters away from the boundaries, and to trigger the gravitational collapse of the globular clusters into galaxies.

Part of the reason for the infrared filter photometer is to determine individual sources. Its resolution is 10 times higher than the other two instruments. It sees only 10 million square arcseconds. That is still room for quite a few small sources.

Unless one has a priori information about all the individual foreground and background sources, I do not understand how one can determine that there is a cosmic background. Because there is a dipole doppler shift to the radiation caused by our local motion, there is no question that there is microwave radiation coming from far away. It is premature to assume that the measured radiation is pure redshifted recombination radiation from the Big Bang or that the properties of the Big Bang can be fixed by blueshifting 2.735 K blackbody radiation. My intuition is that, when high resolution observations become possible, the observed radiation will show spatial and frequency structure from emission and absorption of the recombination radiation at early times, and that the recombination radiation itself is now redshifted to between 2.5 K and 3.0 K.

6. POPULATION III

Let us next think about using radiation to construct globular clusters. Imagine matter after recombination. There is a spectrum of density perturbations. A spectrum of perturbations is not a one dimensional line in a plot. It is a way of filling space in three dimensions. No matter what the spectrum, big perturbations are surrounded by little perturbations. The ratio of surface to volume is larger the smaller the perturbation. The universe cools slowly. At some point Li I and H_2, HD, and LiH molecules form. The small perturbations "instantly" gravitationally collapse because Li and the molecules radiate in the visible and infrared where the thermal flux is.

Set the smallest perturbations at, say, 100 solar masses, and the biggest perturbations, say, 10 million solar masses. We end up with massive Population III stars that burn very brightly for a million years, create metals, and explode. Any more massive perturbations that have collapsed in that million years also become Pop III stars and supernovas. Any perturbations that have not collapsed by one million years become contaminated with the supernova debris and must eventually form Population II stars. The large perturbations are surrounded by superluminous stars and supernovas. Debris contaminates the surface and radiation sculpts the surface to a depth where the surface becomes optically thick. These are small perturbations containing metals that can cool easily and form small stars. By small I mean small relative to the Pop III stars, not necessarily relative to a solar mass. This is the primordial mass distribution function. As a layer of stars forms the surface of the large perturbation is driven inward by starlight, by the supernova radiation, by the supernova debris, and by the blowoff from the new stars. The layer of stars is optically thin. A new optically thick surface forms a new batch of small stars. This process continues inward until essentially all the matter of the original large perturbation is formed into stars. All the Pop III stars are collapsed and dead. The fraction of mass in Pop III stars is small. The large perturbation has become a globular cluster of Pop II stars. Little perturbations make big stars. Big perturbations make little stars.

Now we mention the hardware problems. It turns out that FT spectrographs cannot do high precision absolute photometry. There are always non-linearities in the detectors and electronics at some level. The spectrograph measures Fourier components. The weakest components are linear while the strongest components can be non-linear. When the non-linear components are transformed to the spectrum they introduce low frequency sinusoidal variations. Some of my old solar spectra in the visible[6] are reliable only to 0.75% because of this effect. There are two ways to limit this effect. First reduce the signal with bandpass-limiting filters so that it is more nearly linear. Unfortunately, filters themselves introduce low resolution structure into the spectrum. The second method is to ratio to a standard lamp or blackbody that has the same spectrum as the spectrum you are measuring so that the same Fourier components are excited. The two spectra must have the same brightness and signal-to-noise. That is hard to do. There are more errors. If we compare spectra from the two beams of the ATMOS FTS, there are artifacts in the spectrum introduced by the spectrograph itself. The size of these artifacts cannot be determined, only their difference. Also there is a small frequency shift any time the illumination of the optics changes.

Now we turn to measuring the microwave background and consider the COBE experiment[7]. There is a differential radiometer, a Fourier Transform spectrophotometer, and a infrared filter photometer. The errors we have discussed apply to the FTS. COBE minimizes the errors by comparing the sky to a blackbody observed through a different optical path, and by observing a second blackbody physically inserted into the antenna horn so that it illuminates the same optical path as the sky. If the spectrum of the sky everywhere is the same as the spectrum of the blackbody this probably works. It is not very likely that the spectra of all the foreground objects are the same as the blackbody spectrum. It is not very likely that the spectra of all the background sources are the same as the blackbody spectrum. Also, if the illumination of the optics by the blackbody is not exactly the same as that of the sky, there will be a small frequency shift. The field of view is 7 degrees. That is one half billion square arcseconds. That is room for quite a few small sources both in the foreground and in the background. The instrument drift scans for one to two seconds which decreases the resolution by another 1/15 degree or so and introduces incomplete fourier components for sources at the edge of the field. This does not matter if the sky is completely uniform. The spectral resolution is 1 cm^{-1} so the resolving power is 10. The signal changes by 10% in one instrumental width if the signal is a 2.7 K blackbody.

The spectrum actually published[8], which looks like a perfect blackbody, is a 9 minute coaddition made by drift scanning approximately 35 degrees. It is the average of about 5 billion square arcseconds. I would guess that there are numerous foreground and background sources in 5 billion square arcseconds. I would guess that there are at least one billion galaxies. These galaxies not only act as sources but they absorb radiation coming from earlier times. They produce the multiple absorption line spectra seen in quasars. Every heteronuclear molecule in those galaxies has rotation lines of every vibration level of every electronic level that interact with or produce such microwave radiation at some redshift.

The differential radiometer measures the difference between two 7 degree fields separated by 60 degrees. That is one billion square arcseconds.

sky spectrophotometry in the microwave. At 6 cm photometry shows structure and point sources[2,3]. The structure must be removed to determine a smooth background. These point sources are not visible to the COBE satellite at shorter wavelengths, either because they are too weak, or because the COBE resolution is too low[4]. It is premature to interpret the observed "blackbody" radiation as pure recombination radiation from the Big Bang.

I try to make analogies to my own experience. Even if the analogy turns out to be wrong, it can give fresh insights. Errors and problems that come to light give some guidance in searching for errors and problems in the new case. As an analogy to measuring microwave background let us think about determining the continuum level of the solar spectrum. Actually, I do not care about the continuum level. I am interested in the lines, but the continuum is a by-product.

I have high signal-to-noise, high resolution FTS spectra of the sun in the visible and infrared. The visible and near infrared spectra were taken by James Brault at Kitt Peak. The signal-to-noise is as high as 10000 but typically 3000. The resolving power is as high as 522000. This resolution is high enough to resolve the solar spectrum but not high enough to resolve the foreground contamination produced by 300K lines in the earth's atmosphere. The resolution really should be 1000000. The far infrared spectra still show contamination lines even though they were taken above the atmosphere by the JPL ATMOS experiment flown on the shuttle[5]. There was shuttle contamination and residual gas in the spectrograph. In the Kitt Peak spectra there is also low resolution contamination by Rayleigh scattering, aerosols, ozone, O_2 "dimer", etc. For example, in the visible there is 5% absorption by ozone at 600 nm that appears as a 1% modulation of the background because of substructure in the Chappuis bands. O_2 "dimer" produces a number of 1% dips. To remove the contamination we have to model the foreground components as a function of altitude in the earth's atmosphere. Doppler shifts both degrade the resolution and help to identify foreground features. Even though the instruments are guided on the sun, changes in doppler shift during the integration time reduce the resolution. In the ATMOS spectra there are three different doppler shifts, that of the sun, the terrestrial atmosphere, and the space shuttle.

If you can remove the foreground contamination, then you can try to work with the solar spectrum itself. To find the continuum you can look for high points that look empty and fit curves between them and try to get a smooth background. However, a smooth background does not imply that the continuum has been found. There must also be a priori evidence that the millions of weak lines in the spectrum are below the signal-to-noise threshold at the high points. If you spend twenty-five years computing the strengths of those weak lines you will find out that they are not below that threshold. Another approach is to do Fourier analysis and to assign the lowest frequency components to the continuum. That approach has the same defect; it cannot distinguish a weak line haze. The third approach is to try to fit the line spectrum and to remove it leaving behind the background continuum. The spectrum features consist of many blended lines. One cannot deconvolve it without a priori knowledge of the wavelengths and characteristics of each blending line. Even if the solar spectrum is completely resolved and the signal-to-noise is greater than 10000 it is beyond the state of the art to determine the continuum level to 0.1%.

Population III, Population II, and Population I. When we look at a globular cluster we see stars in the background, stars in the foreground, and stars within the cluster itself that are not members of the cluster. And there are many more stars that are too faint to observe. In each orbit a cluster sweeps through a tremendous volume of the halo, equal to its cross-sectional area times the circumference of its orbit. There must be some interaction with those stars and there is a chance of losing or gaining stars in the interactions. Twice in each orbit globular clusters pass through the disk or the bulge. They have passed through the disk over a hundred times! The chance of interaction with stars and clouds is much higher than in the halo. And in the disk three out of every two stars are binaries, quoting Cecilia Gaposchkin, so that a three-body interaction is more probable than a two-body interaction. Further the external gravitational potential changes considerably during an orbit and is not uniform across the volume of the cluster. And one final point, during the early orbits the galaxy was filled with globular clusters so that there were frequent two-, and even three-, cluster interactions.

As an aside here, let me point out that the stars in a globular cluster, even if they are demonstrated to be dynamical members, do not have to be siblings or coeval or even Pop II. It is highly unsafe to draw conclusions about late stellar evolution from a few points in the color-magnitude diagram of a globular cluster.

It turns out that because of the voids, galaxy clusters are not leading mundane, quiet lives either. (As this development is too recent to be in elementary textbooks, cf Regős and Geller[1]). It is not obvious to me that clusters of galaxies are physically bound, let alone virialized. A cluster may just be a fugitive concentration of galaxies as the universe is churned by large scale motions. The clusters we see locally are always in a state of flux and interaction; they have peculiar velocities and their cores have peculiar velocity distributions. When clusters form at the interstices of voids, matter is continually streaming toward them at high velocity. It is even streaming into or through cluster cores. There are a few isolated, non-interacting clusters off in voids, but, of necessity, void walls must have passed through them in the past, or they are the remnants of void walls. It is unlikely that they have had enough time to virialize since they became isolated. There may be undiscovered regions of the universe that have not yet been disturbed by voids, where gravitational instabilities might have formed isolated, virialized clusters.

There is no reason to believe the virial masses derived for the clusters that have been measured thus far, or to believe the conclusions about the universe derived from virial masses.

5. PLANCKIAN DISTRIBUTIONS AND THE MICROWAVE BACKGROUND

Another abstraction we find in textbooks is Planckian, blackbody distributions. I have never seen any Planckian radiation. I have never computed any Planckian radiation. I do not think it exists. There are always interactions with matter that provide some character and color to all those photons.

If I do not believe in blackbody radiation, then I must wonder about the cosmic microwave background measurements. Actually there have not been any cosmic microwave background measurements. There has been low resolution

a spiral or remains elliptical. One test of this hypothesis is that the number density of quasars integrated over time is equal to the number density of spirals plus giant ellipticals now.

The models we just looked at are very simple. Anyone can understand them or work them out herself or himself for a whole zoo of distribution functions.

3. VOIDS AND THE MICROWAVE BACKGROUND

People do not realize how much their thinking is constrained by their education. Radiative transfer is not part of the physics curriculum so consequently not many people have a "feel" for radiation except, perhaps, for stellar atmospheres, supernova, and weapons laboratory researchers. Most people do not think of radiation as a construction tool. The universe, however, as we show below, manufactures a great deal of radiation and uses it to blow very large bubbles. Until the recent discoveries of voids this was completely beyond our experience, so I would like to present an analogy with which everyone is familiar.

Let us think of the universe as a loaf of bread. The best type for this sort of research is Italian scali. The ratio of walls to voids looks right and if you take small crouton-size pieces you can find one that looks like the local neighborhood. What made the voids? Carbon dioxide given off by yeast in the dough. There has been a phase change. The original universe of flour and water and yeast did not have carbon dioxide. Where are the bubbles located? I would guess that they correspond to primordial density peaks, either of flour or yeast or both, where the product of food times food-eaters was maximum, so that carbon dioxide was quickly produced and formed an early bubble that subsequently grew and accreted other bubbles. What is the density contrast in the current bread universe? Very high. The voids are really empty. What was the density contrast in the primordial dough universe? It might be as low as one percent and have the opposite sign if the voids correspond to the maxima. We can mix the flour, and yeast, and water to make a dough that looks perfectly uniform to the eye, but that in a few hours will be much larger and seem completely different, and will taste much better.

There is no inconsistency between a smooth background and a highly structured foreground when there has been a phase change. Voids were made by the radiation given off by primordial galaxies and quasars. We discuss the mechanism in Section 8 after a discussion of clusters and cluster formation. The cosmic microwave background has nothing to do with the structure of the universe now.

4. THE VIRIAL THEOREM

Textbook statistical mechanics is a mathematical abstraction that does not necessarily apply to real-world physics. In particular, there are not many situations to which the virial theorem applies. Those situations are, ideally, a closed system, or, practically, a system that does not interact with its environment.

Let us first think about globular clusters and what they do. They do not sit up in the halo in Platonic splendor. They exist in the real galaxy in the detritus of

metal abundance material. Once any significant amount of matter has settled in the core and disk all the supernova remnants will be collected in less than half an orbital period because they will no longer be able to penetrate the disk. They are "sticky" because of magnetic fields and clumpiness. Their kinetic energy will further heat the gas. Because the collisions and collapse are concentrated toward the center, the disk and core spin up to conserve angular momentum. The center of this maelstrom becomes a superquasar that jets and radiates out the poles. The bulge would form metal- rich stars. When the galaxy reaches its first billionth birthday it is a dusty spiral galaxy with a worn out quasar at its center and 100 billion dead stars in its halo. For the rest of its life it just goes through generations of increasingly very-metal-rich, by now, "Pop 1/2" or "Pop 0" stars.

Now we turn to more realistic distribution functions that include stars of all masses. We start with one that has a large peak at 2/3 of a solar mass, a small tail toward high mass, and a long tail toward low mass. In the first billion years this might be visible from now. Say 1% of the stars would be bright and there would be some supernovas. Supernova remnants would tend to collect at the center. If there are enough of them, they might form some sort of active core. Fifteen billion years later this galaxy looks like a real elliptical galaxy. It is going to look like an elliptical galaxy for a long time into the future, with the number of dead stars slowly increasing. It will always be rather transparent.

Next we go to a mass peak at one solar mass with high mass and low mass tails. The galaxy will always have been bright. It has had supernovas all along. Five billion years ago there would have been many bright supergiants. There has been a great amount of star formation over the last five billion years from all the gas and dust that has evolved from the more massive stars. Now there is a massive halo of unevolved, K giant, and dead stars. The halo may not be obvious depending on whether the gas and dust have collapsed into a disk. This galaxy might look like a giant version of the Magellenic Clouds.

If we go to a 10 solar mass peak with a big lower mass tail, we reproduce the behavior of our earlier 10 solar mass model but with moderation. There would be only, say, 10 billion supernovas, a few per month. Only a fraction of the supernovas would be visible. The initial supernova remnant collapse would form a disk and bulge that would spin up. There would be considerable energy in heat and radiation and magnetic fields. At the center would be a normal quasar. The bulge would be made of high abundance material and would form metal-rich stars. The collapse would continue over billions of years as the smaller stars lost mass. This lost mass would be Pop II material that would dilute the supernova material to lower abundances. Successive generations of stars in the disk would gradually enrich this material to Pop I abundances. The result after a few billion years would be a spiral galaxy with a very strong Pop II halo. Now the halo would be much less bright and would have at least 100 billion low mass evolving stars, say 100 billion white dwarfs, and over 10 billion neutron stars. If the spiral galaxy interacts with another galaxy in such a way that mass is added to its core, the quasar re-ignites and produces an active galaxy.

I suggest that these last three scenarios are qualitatively realistic; that all primordial galaxies are ellipticals; that all (unadulterated) spiral galaxies were once quasars and before that ellipticals; that there is some mechanism that biases the initial mass distribution function and determines whether the galaxy becomes

I suggest that theoreticians should be producing grids of models. I predict that a model with a baryon density near the closure density that produces high lithium and low deuterium will evolve to account for all known properties of the universe. In this paper we find that the lithium would facilitate Population III star formation by cooling as Li I and LiH. Then we account for the formation of globular clusters, galaxies, quasars, voids, and large-scale structure. Much of the development is mediated by radiation.

The examples given in this paper are not predicated on high lithium. That idea is a serendipitous afterthought: what if the lithium abundance is the opposite of common wisdom.

2. GALACTIC EVOLUTION AND QUASARS

I start with an example I first gave many years ago. We are going to make elliptical galaxies and watch them evolve. We will specify a primordial mass distribution function and make an elliptical galaxy with, say, 1000 billion solar masses of Population II stars. Then we watch it for 15 billion years assuming the universe is 15 billion years old.

First, for simplicity, we start with a distribution function that is almost a delta function at 1/2 of a solar mass, say a spike one one-hundredth of a solar mass wide to avoid excessive synchroneity. The galaxy starts out rather faint and would not be visible from here and now. We watch the galaxy evolve for 15 billion years. It becomes slightly brighter, but still faint. We can see through it; not enough gas has been given off to make it opaque. However mass loss has produced enough Pop II gas to form absorption lines in quasars seen through the galaxy.

Next we take a distribution function that is a one solar mass spike. Not much happens for the first five billion years. Then we start getting a significant amount of light as the stars evolve up the giant branch. Five billion years ago the galaxy was superluminous for, say, a hundred million years as the stars passed through the supergiant tip. The stars lose one half their mass and end up as white dwarfs. The galaxy becomes too faint for us to see. It has become a halo of 1000 billion white dwarfs and 500 billion solar masses of Pop II gas. The gas clouds have the same random orbits as the stars but they have a large collision cross-section. They collapse into a disk over a billion years or they might remain in the halo. Five billion years ago the gas and dust formed new stars with abundances higher than the original Pop II abundances but still low and the galaxy has been very bright ever since. Now the galaxy is some sort of low abundance spiral or perhaps an irregular. No halo is visible although the mass in the halo is tremendous. If the galaxy is a spiral, the disk is opaque and the halo is transparent.

For our third elliptical set the mass spike at ten solar masses. The galaxy is very bright from the beginning with one hundred billion B stars. The stars keep getting brighter and after 100 million years they start exploding. This continues for a few million years, say a few supernovas a day, until all 100 billion stars are gone. At the beginning of this stage all the supernovas are visible but soon the remnants start to mask the new individual explosions. We now have a halo filled with 100 billion neutron stars and with the majority of the matter in 100 billion supernova remnants which then collapse into a disk and bulge. This matter is high

GEDANKEN ASTROPHYSICS: THE UNIVERSE SINCE RECOMBINATION

We show that simple experiments can lead us to straightforward physical explanations for seemingly complex problems of modern astrophysics. We give examples for 1) galactic evolution and quasars, 2) voids and the microwave background, 3) the virial theorem, 4) measurements of the microwave background, 5) Population III, 6) galaxy formation, and 7) voids and large scale structure.

Key Words: microwave background, Population III stars, globular clusters, galactic evolution, voids

1. SCIENTIFIC METHOD AND PRIMORDIAL ABUNDANCES

The purpose of this paper is partly to show that the mode of thinking about a scientific problem greatly influences the result. I hope to stimulate the reader to perform the detailed calculations suggested by these simplified discussions. The information used in the discussions can be found in any elementary astronomy text.

A big bang cosmology predicts the formation of deuterium, helium, and lithium as the universe cools. The final primordial abundances of those species depend on the density of baryons and the density of radiation at that time, which can be related to the density of baryons and the density of radiation now, if the expansion of the universe since then can be computed. The logical way to proceed would be to make a grid of model universes varying the baryon and radiation densities and then to evolve the models until they produce predictions that can be compared directly to observation. Then make the necessary observations and test the theories against those observations and eliminate models that do not match.

That is not the way many astrophysicists proceed, however. Instead of trying to make predictions that can be tested by observation, they take observations that can be made, such as measurements of the abundances in Population II material, and try to determine the primordial abundances, knowing a priori what answer is needed to fit some particular model. Then they take those derived abundances and adjust the model to match more closely so that circularity is completely guaranteed. Unfortunately the baryon density derived this way is too low to account for the subsequent large scale structure of the universe. An ad hoc addition of cold, dark non-baryonic matter must be introduced.

There is no necessary relation between Pop II lithium and deuterium abundances and primordial abundances. In this paper we find that essentially all primordial matter has been processed in stars. Most of the primordial lithium and deuterium has been destroyed. The lithium and deuterium we see now has been made by secondary methods. The comparison of theory and observation has not tested anything or told us anything about the baryonic density or the universe.

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THE PRIMORDIAL LITHIUM ABUNDANCE

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RADIATIVELY DRIVEN COSMOLOGY

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