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Survey of Evidence for Top-Down versus Bottom-Up Evolution of Structure on Various Scales

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Abstract. This overview paper describes how the discovery of superclusters dictated a bottom-up cosmic evolution in order to remain compatible with the big bang theory. Weaknesses of the concordance cosmology are pointed out and top-down cosmic evolution is explored as a plausible alternative. Top-down evolution requires an unconventional interpretation of red-shift phenomena and a greatly expanded cycle of creation on various scales. Top-down cosmologies may be too radical for conservative mainstream astrophysicists but their future prospects are brighter than the search for dark matter and dark energy.

1. Introduction

Structures can evolve from large-to-small (top down) or small-to-large (bottom up) with respect to cosmic, galactic, stellar and atomic scales. Galaxy surveys reveal astounding patterns known as supercluster-void networks. These remnants of the early universe reveal much about the evolution of the cosmos. Careful observations of large scale structures inform us about the origin of galaxies, stars and atoms and could finally determine whether the direction of cosmic evolution has been from the bottom upwards or the top downwards.

Some researchers claim to have detected a periodicity in the large scale structure similar to the periodicity of a crystal lattice. Other researchers are examining the fine structure of superclusters, searching for clues about the origin and evolution of galaxies based on their location and behavior within superclusters. Meanwhile, active galactic nuclei, quasars and supermassive black holes puzzle cosmologists, who seek to understand the creation and evolution of whole galaxies and stars within galaxies. The concepts of accretion and ejection are intimately connected to whether the evolution of galaxies occurs from the bottom-up or the top-down.

This overview paper describes how the discovery of superclusters dictated a bottom-up cosmic evolution in order to remain compatible with the big bang theory. Weaknesses of the concordance cosmology are pointed out and top-down cosmic evolution is explored as a plausible alternative. Top-down evolution requires an unconventional interpretation of red-shift phenomena and a greatly expanded cycle of creation on various scales. Top-down cosmologies may be too radical for conservative mainstream astrophysicists but their future prospects are brighter than the search for dark matter and dark energy.

2. Overview of Superclusters

2.1. Checking out the Neighborhood

The Milky Way Galaxy is part of a local cluster within a local supercluster known as the Virgo supercluster, which encompasses several large clusters and spans about 60 Mpc.

Superclusters are described as poor, rich or very rich, depending on the number of clusters that they encompass and the activity level of the galaxies within them. Many superclusters are considerably larger, denser and more active than the Virgo supercluster.

Harlow Shapley was perhaps the first to notice that clusters of galaxies tend to be found in larger-scale structures known as superclusters in 1930 when he casually noted the existence of what is now known as the Shapley Supercluster (SSC) (Shapley 1970).

Nearly three decades later in 1958, George Abell, an astronomer at UCLA, published the now well-known catalog of clusters in the northern sky (Abell 1958). Another three decades passes before a similar catalog of clusters in the southern sky was published in 1989 by Abell (1989). These two catalogs account for about 4000 clusters with more than 30 members. They are nearly complete up to $z \approx 0.2$.

Interest in superclusters intensified in the 1980s. As astronomers searched for the Great Attractor, they rediscovered the Shapley Supercluster. Nowadays, the SSC is one of the most studied objects in all of astrophysics. The SSC is an example of a very rich supercluster.

2.2. Very Rich Superclusters

In 1994, by carefully studying various catalogs of rich clusters and voids, Einasto et al. determined that about 25 percent of all the rich clusters in the volume of space up to $z \approx 0.1$ are contained in just eight very rich superclusters (Einasto et al. 1994). In that now classic paper, these authors observed an "islands in the ocean" distribution of superclusters surrounded by interconnected voids. Two of the largest very rich superclusters identified at that time were the Horologium Reticulum supercluster, which contains about 32 rich clusters; and the Shapley supercluster, which contains 25 rich clusters. The Sloan Great Wall and the Sculptor supercluster also belong to this category of very rich superclusters (Einasto et al. 2008). Many very rich superclusters are located in what has been called the Dominant Supercluster Plane (Einasto et al. 1997), which encompasses the Sloan Great Wall and rests perpendicular to the supergalactic plane (SGP) (Lahav 2000) of our own local supercluster.

2.3. Recent Catalogs and Research

In recent years, using data from detailed galaxy surveys such as the Sloan Digital Sky Survey (SDSS), many catalogs of galaxy groups, clusters and rich clusters have been compiled [e.g., SDSS (2007); Einasto et al. (2007); Tago et al. (2008); Aguerri et al. (2007); Popesso et al. (2007); Miller et al. (2005)] enabling the identification and characterization of superclusters to even greater distances.

Very rich superclusters have been studied by many groups in considerable detail (Einasto et al. 2007). For example, according to Bahcall (1993), quasars are more likely to appear in the core regions of these very rich superclusters. There is tendency for a preponderance of older redder galaxies in the core regions but this is not always the case [Einasto et al. (2007); Aragon-Calvo (2007)]. X-ray and radio astronomy have also been important in advancing our knowledge of the cores of very rich superclusters (Brandt & Hasinger 2005).

Other features that can studied are morphology, void and filament dimensions, densities of galaxies within core regions and between voids, galaxy type compared to location in the supercluster, presence or absence of quasars in superclusters, velocities of galaxies, orientations of galaxies relative to voids and the chirality of galaxies in clusters. Such studies and data are relevant to the comparison of top-down versus bottom-up theories of structural evolution.

3. Quasi-Cubic Periodicity

Several independent methods suggest that superclusters and their subclusters exhibit the periodicity of a cubic lattice with a lattice parameter of 120 to 150 h^{-1} Mpc (Einasto et al. 1997). Galaxy densities show periodicity in some directions but not in others as would be expected in an anisotropic crystal lattice. Crystal anisotropy is well known and understood in materials science. It is used to advantage, for example, in x-ray diffraction analysis and ion implantation. Similar periodicity could also result from multi-scale wavelet structures (Martinez et al. 2005). Pencil beam surveys corroborate this quasi-crystal structure of the cosmic web (Guzzo et al. 2008).

It is possible that, in an earlier epoch, the supercluster-void network or cosmic lattice had sharply defined features, which gradually disintegrated and homogenized so that today we see only the remnants of an earlier periodic lattice. This regular structure could be hypothesized to have occurred in the inflation era of the concordance cosmology or, more credibly, in the early universe of an alternative cosmology.

The proponents of the concordance cosmology follow recessional velocities backward to the creation of matter in a big bang. A much more complicated problem in inverse physics is to reconstruct the structure of the early universe from the peculiar velocities of galaxies and large scale structures. Solutions already have been proposed for nearby galaxies for which data on peculiar velocities are available (Mohayaee et al. 2006).

4. Bottom-Up Evolution in the Big Bang

Top-down evolution was the preferred paradigm among mainstream cosmologists prior to the 1980s. A well-known textbook published in 1980, for example, describes a top-down evolution (Peebles 1980). These now obsolete models did not describe strictly top-down evolution at each scale because they assumed atoms were created in the early instants of the big bang. The sequence of structure development in these older models was as follows:

1. Atoms are created in the big bang

2. Cluster-sized nebulae take shape

3. Galactic nebulae form within cluster nebulae
4. Stellar nebulae form within the galactic nebulae

The rediscovery of superclusters in the 1980s doomed the traditional top down scenario because the big bang theory is explicit about the age of the Universe. Yet the universe contains very old stars and very old galaxies, which would not have had sufficient time to form subsequent to the formation of superclusters in a top-down evolutionary scenario in a big bang universe.

The time required to travel 100 Mpc (326 Mly) at the speed of light is about 326 million years. Non-recessional galaxy velocities are typically only 1/1000 the speed of light, so 326 billion years would be required for a galaxy traveling at 300 $km\ s^{-1}$ to cross this vast expanse of space. Even accounting for the expansion of space, top-down evolution does model well in a universe that is only 13.7 billion years old.

Big bangers therefore went back to the drawing boards and developed a bottom-up evolutionary scenario:

1. Atoms are created in the big bang
2. Stellar nebulae form and in some cases stars form from atoms
3. Stars and stellar nebulae aggregate into galaxies
4. Galaxies aggregate into clusters

This bottom-up approach allows more time for superclusters to form, particularly if this scenario is playing out in an expanding universe with galaxies closer together in the early universe. Unfortunately for the big bangers, bottom-up evolution still poses severe embarrassments, not the least of which is the need to introduce cold dark matter (CDM) into the gravitational equations to achieve the desired evolution.

A centerpiece of the concordance cosmology is the Millennium simulation, which succeeds in recreating the cosmic web only when cold dark matter in the form of galactic haloes is introduced into the simulation (Springel et al. 2005). In this model, it is imagined that a bottom-up evolution of structure occurs in the primordial plasma and continues into present time.

1. Atoms and CDM are created in the big bang
2. Stellar haloes form from the CDM distributions in the primordial plasma
3. Galactic haloes coalesce from stellar haloes in the primordial plasma
4. Cluster haloes form from galactic haloes
5. Supercluster haloes result from cluster haloes combining in the primordial plasma

It is imagined that cosmic microwave background radiation (CMB) is a snapshot of this supercluster-halo structure taken at the instant when radiation separated from mass. Stars and galaxies soon afterwards coalesce from the baryonic matter within the supercluster haloes. It is conceded in this model that there may be some bias for galactic nebulae to form before stellar nebulae.

These simulations are flawed in many respects. For example, they do not produce very rich superclusters in the quantities that are observed in recent detailed surveys and analysis (Einasto et al. 2006). The main idea is that superclusters are generated by large-scale density perturbations that evolve very slowly. In these simulations, in truth, a top-down structure is imposed on the CDM in the early universe, so these simulations are really top-down evolutionary scenarios in disguise.

The idea of CDM in a hot primordial-plasma arranging itself in a periodic lattice stretches the imagination. Nonetheless, in this manner, the concordance cosmology allows for the invocation of scores of top-down cosmologies, e.g., plasma physics, baryon acoustic oscillations, magnetohydrodynamics, fluid mechanics or you-name-it in a last ditch effort to salvage the big bang theory.

In summary, the big bang theory first invoked a top-down evolution of structure until the discovery of superclusters forced the development of a bottom-up evolution of large scale structure. The so-called concordance cosmology mandates that supercluster structure appear in the primordial plasma through some unknown top-down process. Stellar and galactic structures are accommodated by top-down or bottom-up evolution as suits the observations.

5. Alternative Top-Down Scenarios

The concordance big-bang cosmology has many shortcomings, including missing matter, so it is worthwhile to examine the merits of alternatives. A strict top-down evolution of structure on four scales would proceed as follows.

1. The total mass of universe is divided among primordial supercluster precursors
2. Supercluster precursors eject galaxy precursors
3. Galaxy precursors eject stellar precursors
4. Stellar precursors form atoms within, in some cases exploding into supernovae

As an example, in one such scenario, the initial mass of the universe can be considered to be distributed among an estimated 600,000 sites on a hypothetical body-centered cubic lattice (assuming a cosmic radius of 4200 Mpc, a lattice cell parameter of 100 Mpc and two supercluster masses per unit cell). These supercluster masses split into galactic masses that are ejected in the directions of neighboring lattice sites and they remain in the regions between voids. Primordial galactic masses subsequently eject stellar masses, which in turn produce atoms.

Such alternative top-down cosmologies require adjustments to the concordance cosmology:

- Transformation of energy into mass by some other mechanism than a big bang singularity
- Variation of fundamental constants such as the fine-structure constant and gravitational constant over long periods of time
- Reinterpretation of redshift-distance relationships to allow a universe that is much older than 13.7 billion years

These adjustments are far-reaching but not as radical as the introduction of inflation, cold dark matter and dark energy into the big bang theory. The main falsehood of the big bang theory is the demand for a relatively young universe imposed by running the clock backwards with respect to the expansion of space. Cosmic evolution is arbitrarily constrained to 13.7 billion years, which greatly confuses our understanding of large scale structure evolution.

A strict top-down scenario is not very radical and allows for much more flexibility in the evolution of the universe. Greater "concordance" would be reached if adherents of the concordance cosmology would realize that the concepts of a "primordial plasma" and "early universe" are equivalent and both are shrouded in mysteries: In the former case, the primordial plasma is obscured by the mysteries of cold dark matter and inflation; in the later case, the early universe is veiled by time scales of hundreds of billions of years.

6. Matter Creation

True concordance will not be realized until a superior theory emerges for the creation of mass in the early universe. A major difference between the big bang theory and alternative theories is that, in the former, baryons and leptons are created in the first instant of the universe, during a brief period of big-bang baryogenesis (BBB).

Hoyle, Burbridge and Narlikar developed a theory of matter creation that supports the idea of matter creation by mechanisms different than BBB [Hoyle, Burbidge & Narlikar (1995); Narlikar, Burbidge, & Vishwakarma (2007)]. The growing number of papers on baryonogenesis and leptogenesis suggest that Grand Unified Theories (GUTs) and quantum cosmology are still active fields of research. A better understanding of the structure of baryons and leptons is required to fully develop this theory.

The production of baryons late in the lifetime of the universe is supported by observations of the ejection of matter from active galactic nuclei as well as the work on quasars by Arp (1998). The ejection of matter from the cores of superclusters and galaxies and the production of baryons in stars may not be so far fetched if fundamental constants varied over long time scales. Possibly electrodynamics was dominant in past epochs. Evidence for a changing fine structure constant is pertinent in this context (Tzanavaris et al. 2007).

7. Age of the Cosmos

Our universe could be much older than the big bang theory allows. In the bottom-up big bang cosmology, most of the creation of superclusters, galaxies, stars and atoms was complete earlier than the past 13 billion years. Interestingly, the same holds true for a top-down cosmology. Hence, alternative cosmologies viewed from the present look much the same as the concordance cosmology, even though the universe may be much older in the alternative cosmology compared to the concordance cosmology.

There is much contention about the real meaning of the redshift versus distance relationship. In the usual "expansion of space" theory, atoms and galaxies and stars remain the same size while the space around them increases. The mathematical idea of the expansion of space has no meaning without physical rulers to measure the dimensions of space. In the concordance theory, matter remains the same size but the expansion of space results in a stretching out of photons.

A more intuitively satisfying interpretation of the same phenomena is that the rulers are shrinking with time, meaning that the atomic dimensions are decreasing. Smaller rulers then measure existing light to be longer in wavelength. In this theory, the energy of the universe is conserved but it is continually reapportioned among a larger number of smaller particles (Schmitz 2005). The relevant equation leads to a satisfactory redshift relation for lower redshifts, i.e., $z{\sim}1.5$. Details of this derivation are given in the appendix below.

In the strict top-down evolution, atoms form after stars, which form after galaxies, which form after clusters. The remnants of this creation process are visible; however, the time scales are so vast that it is easy to falsely attribute these remnants to a primordial plasma, which is supposed to have existed a mere 13 billion years ago.

8. Oldershaw's Universe

The work of Robert Oldershaw takes on new meaning in the context of top-down evolution. Oldershaw denies any evolutionary process between his self-similar cosmological scales (SSCS's, including atomic, stellar and galactic) but he has accumulated evidence for similarities between these scales (Oldershaw 2007).

Oldershaw's ideas seem naïve on first encounter but are epiphanic in the context of the top-down evolution of structure. Oldershaw has made more than 60 predictions (and retrodictions) based on his theory. Top-down evolution could underlie the observed self-similarity on galactic, stellar and atomic scales. Primordial superclusters could well have behaved like giant atoms with diameters measured in megaparsecs with today's rulers. Various astronomical objects such as stars and galaxies may indeed turn out to be remnants of gargantuan atomic-like processes.

In an evolutionary interpretation of Oldershaw's universe, atoms are produced last. Primordial objects on the scale of galaxies are the first to form. These split into stellar scaled objects. Finally, the latter disintegrate into atoms and ignite as stars.

9. Topics for Further Research

Observations about large scale structure should be kept in a pure form without biasing toward the concordance model or any other model. It is difficult enough to determine cause and effect in a universe where no significant changes have occurred in the past 13 billion years. Force fitting observations into the epicycles of the big bang theory only serves to confuse an already complicated subject. The fact is that the top-down evolution looks much the same as bottom-up evolution from our present-time vantage point.

Evidence for a top-down evolution of structure requires a close examination of supercluster cells within the cosmic web. Some areas of interest are the chirality of galaxies with respect to filaments; the distribution of old and new galaxies in filaments; supermassive black holes in the centers of galaxies; the size and shape of super-voids; and much more.

Ongoing investigation of large-scale cosmic structures promises to reveal detailed answers to questions about the fine structure of very rich superclusters, the periodicity of the supercuster-void network and the evolution of superclusters from past to present.

The universe has distinctly recognizable structures on at least four scales: atoms, stars, galaxies and superclusters. Why these scales? What is so special about these scales? A most spectacular discovery would occur if the large scale structure of the universe were found to resemble some type of condensed matter in its fine details.

There is much that we can learn from the large scale structure of the universe. Fortunately, the data being collected in support of the concordance cosmology also provides clues to alternative cosmologies. To the extent that ongoing research focuses on top-down evolution in the primordial plasma, it will be useful in the development of alternative cosmologies. Unfortunately, the existing paradigm is a bottom-up paradigm, so evidence for top-down evolution is unlikely to be examined with the same openness and enthusiasm as evidence for the bottom-up evolution of structure.

It is the author's intention that this overview will change that bias to some degree.

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Appendix A: Redshift Derivation for an Alternative Cosmology

In a previous paper (Schmitz 2005) describing an alternative cosmology, particle size r_0 as a function of time is given by an exponential relationship:

$$r_0 = R_0 \exp(-t/T_0) \tag{1}$$

where T_0 equals the radius of the universe divided by the speed of light.

$$T_0 = R_0/c. \tag{2}$$

This exponential relation can be used to compute redshifts at various distances. The redshifts are due to the decreasing wavelength of elementary particles rather than a velocity relationship. Present time will be designated T_A with a particle size r_A and the time when light was emitted from the galaxy will be designated T_G with a particle size r_G.

$$\begin{aligned} r_A &= R_0\ \exp(-T_A/T_0) \\ r_G &= R_0\ \exp(-T_G/T_0) \\ r_G/r_A &= R_0\ \exp[(T_A - T_G)/T_0] \end{aligned} \tag{3}$$

But the time difference is just equal to the distance to the galaxy divided by the speed of light.

$$\begin{aligned} T_A - T_G &= D/c \\ r_G/r_A &= \exp(D/cT_0) = \exp(D/R_0) \\ r_G/r_A &= 1 + D/R_0 + (D/R_0)^2\,(1/2!) + (D/R_0)^3\,(1/3!) + ... \end{aligned} \tag{4}$$

The light observed appears to have a longer wavelength than expected because the ruler used to observe the light is shorter compared to when the light was emitted. Actually the wavelength does not change relative to the radius of the universe; only the ruler changes.

A redshift is observed on Earth because the ruler used to observe the wavelength is smaller. The wavelength is measured on Earth at time T_A with a smaller ruler that is smaller than it was when light was emitted from the galaxy at time T_G. Redshift z is defined as follows.

$$\begin{aligned} z &= \Delta\lambda/\lambda = \frac{\textit{wavelength observed} - \textit{wavelength emitted}}{\textit{wavelength emitted}} \\ z &= \frac{(r_G/r_A)\,\lambda - (r_G/r_G)\,\lambda}{\lambda} = r_G/r_A - 1 \\ z &= D/R_0 + (D/R_0)^2\,(1/2) + (D/R_0)^3\,(1/6) + ... \end{aligned} \tag{5}$$

Hubble's Law is given as a linear expression.

$$cz = H_0\ D. \tag{6}$$

Therefore, to a first approximation, the Hubble constant can be simply calculated as follows.

$$H_0 \approx c/R_0 = \frac{3.00 \times 10^5 \ km \ s^{-1}}{4228 \ Mpc} = 70.96 \ km \ sec^{-1} \ Mpc^{-1} \tag{7}$$

For distances significantly less than the radius of the universe, the fractal cosmos theory predicts the same value for the Hubble constant as the general theory or relativity, which predicts that the Hubble constant = 1/Hubble time, where Hubble time = R_0/c.

At first glance, this interpretation of redshift is no better — but no worse — than the big bang theory in predicting redshifts. However, it is a much simpler theory and so Occam's razor applies and would seem to favor this alternative interpretation. Furthermore, the age of the universe is given by

$$\begin{aligned} R_0/r &= \exp(t/T_0) \\ t &= T_0 \ \ln(R_0/r) \\ T_A &= T_0 \ \ln(\frac{1.3 \times 10^{25}}{1.6 \times 10^{-16}}) \approx 93 \ T_0 \end{aligned} \tag{8}$$

This means that light has had a chance to cross the entire expanse of the universe more than 46 times since the substrate of the visible universe was first formed as described in earlier papers (Schmitz 2008). Of course, this effectively eliminates the so-called "horizon problem" that has been so troublesome to the big bang theory and has been the main motivation for the development of theories of cosmic inflation.

There are two basic equations of interest in speculations about possible mechanisms for the evolution of the large scale structure in the visible universe.

$$\begin{aligned} R_0/r_0 &= \exp(t/T_0) \\ N_b &= (R_0/r_0)^2 \end{aligned} \tag{9}$$

where N_b is the number of baryons in the universe. For more information about this alternative cosmology, see various papers online (Schmitz 2008).