# The Large-Scale Structure of the Physical Universe

## *Part I: The Cosmic Bubbles*

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Extensive astronomical observations carried out during the decade that passed have for the first time revealed a most unexpected picture of the universe on a cosmic scale. The picture that emerged is defying all the present cosmological theories. In the present paper, therefore, an attempt has been made to apply the principles developed in the *Reciprocal System* of theory with a view to show that the conclusions reached are in consonance with these recent observational findings. In order to demonstrate the power of the Reciprocal System as a truly general physical theory, in Part II: Mathematical Aspects of the Cosmic Bubbles, a mathematical treatment of the concepts developed herein will be undertaken and the results compared with facts.

## 1 The Bubbles in Space

In the 1980's, astronomers have surveyed billions of light years into space and millions of galaxies and analyzed their redshifts. These studies show that the galaxies are not distributed evenly in space but tend to occur in clusters and then these clusters themselves occur in large groups (the superclusters). The most *unexpected* discovery, however, is the occurrence of immense voids in space, empty of galaxies, between the superclusters.[1,2] Three-dimensional maps of the universe prepared from the redshift surveys indicate that "…the universe is made up of gigantic bubbles: spherical or slightly elliptical regions of space apparently void of matter, whose outer surfaces are defined by galaxies.… All the galaxies… lie on the surfaces of bubbles that measure from about 60 to 150 million light years across."[3]

The investigations of Geller and Huchra[4] have brought to light large-scale clustering of galaxies stretching in the form of "gigantic filaments and sheets" 170 Mpc (megaparsecs) by about 15 Mpc. The group led by Faber[5] finds the "Great Attractor," a stupendous concentration of galaxies with "…a diameter of about 80 Mpc and a mass of $3\times10^{16}$ suns. That would be the mass of tens of thousands of typical galaxies, including the dark matter one infers from the dynamics of galaxies."[6] Reference 2 gives a graphic description:

> Three-dimensional maps of the distribution of galaxies… show features quite unlike those of most other astronomical objects: the galaxies are concentrated in enormous sheets and filamentary structures whose greatest dimension, roughly 100 million light years, is an order of magnitude larger than its lesser dimensions.… Moreover, within each structure the

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1 Stephan A. Gregory and Laird A. Thompson, "Superclusters and Voids in the Distribution of Galaxies," *Scientific American*, 246 (3), March 1982, p. 88.
2 A. S. Szalay and Y. B. Zel'dovitch, "The Large-scale Structure of the Universe," *Scientific American*, 249 (4), October 1983, p. 56.
3 *Science and the Citizen,* "Cosmic Cartography," *Scientific American*, 254 (3), March 1986, p. 49.
4 Margaret J. Geller and John P. Huchra, *Science,* 246, 1989, p. 897.
5 A. Dressler and S. M. Faber, *Astrophysics J. Letters,* 354, 1990, L. 45.
6 Bertram Schwarzschild, "Gigantic Structures Challenge Standard View of Cosmic Evolution," *Physics Today,* 43 (6), June 1990, p. 20.

  

> galaxies are not evenly distributed: one can distinguish more densely populated clumps and strings… Finally, interspersed among the largest structures are huge voids, virtually free of galaxies, that are between 100 and 400 million light years across.

Broadhurst and his collaborators[7] have investigated the galaxy redshifts out to a distance of 2,000 Mpc in two narrow regions in the direction of the galactic north and south poles where the obscuration by dust is the least. Their measurements reveal periodic oscillation of the density of galaxies with distance, all the way out to 2,000 Mpc. The Fourier spectrum of these oscillations peaks sharply at a spacing of 128 Mpc (about 417 million lightyears), as though dense globs of galaxies are alternating with regularly spaced voids.

## 2 Trouble for the Conventional Theories

There are two diametrically opposite views of galaxy formation. Some astronomers hold that the galactic structures form as *ascending cascades.* According to their "bottom-up" theory galaxies form out of a soup of gas and dust and subsequently coalesce to form clusters and superclusters. Other theorists advocate the "top-down" theory which proposes that the matter in the universe first collapses into vast pancake-like sheets, which then fragment, giving rise to superclusters, clusters and galaxies (the *descending cascades*). But neither model predicts the formation of bubbles which have the sharply-defined surfaces of galaxies that are now observationally revealed.

John Horgan[8] commenting in ***Vigyan*** (**Scientific American**, Indian edition) states:

> The cold dark matter model predicts that most galaxies take at least several billion years to form, so few should be found at distances greater than 10 billion light-years. …
> Astronomers have now identified a score of galaxies more than 10 billion light-years away.

Since astronomers currently assume that the universe began in a big bang about 13 billion years ago, Horgan remarks that, "Theorists have a hard time explaining how galaxies formed so soon after the big bang." While models positing cold dark matter thus have difficulty producing such large structures as now discovered, Powell[9] remarks that: "…models that assume fast-moving dark particles—"hot dark matter"—do not accurately mimic the smaller-scale details seen in the universe… Cosmologists… agree, at the very least, that current theories are far from complete."

Among other things, the universality and the immensity of the spherical voids have caught the theorists utterly unawares. "Valérie de Lapparent and Margaret J. Geller note… that the immense size of the bubbles suggests that powerful stellar explosions—and not the force of gravity, as is widely thought—had the primary role in the formation of the universe."[3] Some astronomers suggest that supernova explosions drove matter into spherical shells, but the predicted shell sizes are orders of magnitude smaller than those of the observed bubbles.

Another severe problem that now plagues the astronomers is concerning the recent findings by the ***Cosmic Background Explorer*** (COBE) satellite which show the temperature of the microwave sky to be uniform to within one part in 10,000. At much finer angular resolution than that of COBE, recent measurements of selected patches of microwave background by Readhead[10] find no fluctuations down to two parts in 100,000. Since astronomers conventionally regard the microwave background radiation

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7 Thomas J. Broadhurst *et al., Nature,* 343, 1990, p. 726
8 John Horgan, "Universal Truths," *Vigyan,* October 1990, p. 88
9 Corey S. Powell, "Up Against the Wall," *Scientific American,* 262 (2), February 1990, p. 12
10 Anthony Readhead, *et al., Astrophysics J.,* 346, 1989, p. 566

as the relic from the primordial (hypothetical) big bang, its absolute isotropy implies that the early universe was extremely uniform. The current theories of cosmology—including the "inflationary theory"—are unable to account how the large-scale structure of the distribution of galaxies now evident emanates from the prevenient absolute uniformity.

# 3 The "Cycle" of the Universe

We will now try to examine what the Reciprocal System of theory has to offer in this regard. The most important factor that is relevant to our present discussion is the finding of the Reciprocal System that the vista of the physical universe is not limited to the familiar three-dimensional space of the conventional reference system but that, by virtue of the reciprocal relation between space and time, there exists another half, the ***cosmic sector***, the region of motion in three-dimensional time. For a complete description of the logical development of the Reciprocal System that leads to the discovery of the various "regions" of the universe Larson's original works[11,12,13] must be consulted. We will give here a brief outline of the evolutionary process of the dual sector universe to serve our present purposes.

Quoting from Larson:[14]

1. Because of the reciprocal relation between space and time in scalar motion, there is an inverse sector of the universe in which motion takes place in time rather than in space. All scalar motion phenomena in three-dimensional space are thus duplicated in the cosmic sector…
2. There is a limiting size for galaxies, and… some of those that reach this limit explode, ejecting fragments, known as quasars, at speeds in the ultra high range, between two and three times the speed of light.
3. When the retarding effect of gravitation is reduced enough by distance to bring the *net* speed of a quasar above two units (twice the speed of light) the gravitational effect inverts, and the constituents of the quasar are dispersed into three-dimensional time (the cosmic sector of the universe).
4. The effect of the explosion and its aftermath is to transform a quantity of matter from a state in which it is highly concentrated in space to a state in which it is widely dispersed in time.
5. By reason of the reciprocal relation between space and time in scalar phenomena, it follows that the inverse of the foregoing processes likewise take place, the net effect of which is to transform a quantity of matter from a state in which it is highly concentrated in time to a state in which it is widely dispersed in three-dimensional space.

We thus find that there is a constant inflow of widely dispersed matter into the material sector from the cosmic sector.

# 4 Origin of the Bubbles

The two principal forces deciding the course of events in the universe are gravitation and outward progression of space-time. The ultimate ejection of quasars into the cosmic sector takes place when the net speed reaches two units. Then gravitation ceases to operate in space. This leaves the outward

11 Dewey B. Larson, *Nothing but Motion*, North Pacific Pub., Portland, Oregon, U.S.A., 1979
12 Dewey B. Larson, *The Neglected Facts of Science*, North Pacific Pub., Portland, Oregon, U.S.A., 1982
13 Dewey B. Larson, *The Universe of Motion*, North Pacific Pub., Portland, Oregon, U.S.A., 1984
14 Dewey B. Larson, *The Neglected Facts of Science, op. cit.,* pp. 112-113

progression of the natural reference system unopposed, and that progression carries the constituent units of the spatial aggregates outward in all directions at unit speed (the speed of light). Thus, centered around the physical location of the erstwhile quasar, a spherical void starts growing. All the matter that constituted the quasar now gets either uniformly dispersed over the expanding spherical surface or ejected out of the material sector altogether. This leaves the inside of the void genuinely empty.

Meanwhile there is a continual inflow of matter, which has been similarly ejected from the cosmic sector. Since it comes from sources that are not localized in the three-dimensional space it emerges in the conventional reference frame spread absolutely uniformly throughout its extent. In addition, the rate of inflow of this matter is constant, since the Reciprocal System posits a steady state on the large scale. Therefore the density of matter in the expanding bubble rises steadily, starting from zero.

This diffuse matter in the bubble, however, is not observable until such time that it condenses into stars and becomes self-luminous. In the meantime the bubble appears as a void. (The reason why we prefer to call it bubble rather than void must now be apparent.) Since the phenomena that give rise to these bubbles, namely, the ejection of quasars and their ultimate exit into the cosmic sector of the universe, are the necessary end results of the evolutionary process in the material sector, one must see the whole of space strewn with these bubbles. Their diameters, of course, reflect their lifetimes. We will show in Part II that the sizes of these bubbles predicted from the Reciprocal System do indeed fall within the observed range.

## 5 Growth and Decline of the Bubbles

Consider a large sphere of diffuse (unconsolidated) matter of uniform density. We note that while the inward speed due to gravitation, being proportional to the total mass, increases with radius and density, the outward speed due to the progression of the natural reference system is constant. Therefore, at the center of the sphere there is a net outward speed, and as we move away from the center this net outward speed decreases and eventually reaches zero at some radius. Let us call this radius the "zero-point radius." Beyond this point gravitation predominates and the net speed becomes inward. The zero-point radius varies inversely as the density of matter in the sphere.

In the early stages of the bubble the density is extremely low and the zero-point radius far outspans the actual radius. Thus the net speed everywhere in the bubble is outward. Since the bubble is already expanding at unit speed, which is the maximum that is possible in the dimension of the conventional reference system, the net positive (outward) coordinate speed has no further effect on the rate of expansion.

It must be seen that the expansion of the bubble is a *scaling* expansion, that is, corresponding locations in the bubble at two different stages are related by the same geometrical relationship. The matter density in the bubble always remains uniform, although this uniform density steadily increases due to the ever-present inflow. As the density increases, the zero-point radius decreases. Meanwhile the actual radius is increasing. Therefore, at some point of time these two radii become equal. That is, the net scalar speed at the bubble periphery becomes zero. We will call this the "point of criticality," the corresponding radius the "critical radius" and the time when it happens (measured from the instant of creation of the bubble) the "critical time" of the bubble.

Beyond this point, with further accumulation of matter, the zero-point radius becomes smaller than the actual radius and the scalar direction of the net coordinate speed of the spherical shell of matter between these two radii becomes inward. This net *inward* speed can now act to oppose the outward progression and slow down the expansion of this portion of the bubble, while the portion inside of the zero-point radius continues expanding unabated at unit speed. The speed differential occurring across this shell at the bubble periphery raises the density there relatively rapidly. This rise in density acts as a positive feedback to augment the inward speed of gravitation in this shell further, and makes possible the collapsing and condensing of the matter in the peripheral regions of the bubble.

In due time, it can be shown, this collapsing matter forms into the globular star clusters and becomes observable. The ostensible effect is the seeming cessation of the expansion of the bubble or its retardation. As the density of matter in the bubble continues to rise, more globular clusters start precipitating, in successive spherical layers towards the bubble center, and we see that the *observable* radius of the "void" (zero-point radius) decreases.

If conditions are unaltered it takes infinite time for the matter at the center to reach the stage of star formation. But long before that, the concentration of the consolidated and aggregated matter, in the form of the globular clusters and groups of these clusters in the outer stretches of the bubble, rises high enough for the central mass to be brought into the ambit of their *gravitational limits*.[15] This finally terminates the existence of the bubble as its diffuse material is swallowed up by the surrounding stellar aggregates.

# 6 The Uniformity of the Microwave Background

The problem of reconciling the high degree of uniformity of the cosmic microwave background radiation with the observed large-scale non-uniformity of the galaxy distribution does not arise in the Reciprocal System for the simple reason that the source of the background radiation is not set in the conventional three-dimensional space at all. Both its absolute isotropy and lack of connection with the spatial distribution and evolution of the material aggregates result from the fact that the background radiation originates from "aggregates" in the three-dimensional temporal reference frame of the cosmic sector.

Larson explains: "…electromagnetic radiation is being emitted from an assortment of sources in the cosmic sector, just as it is here in the material sector. Radiation moves at unit speed relative to both types fixed reference systems, and can therefore be detected in both sectors regardless of where it originates. Thus we receive radiation from cosmic stars and other cosmic objects just as we do from the corresponding material aggregates. But these cosmic objects are not aggregates in space. They are randomly distributed in the spatial reference system. Their radiation is therefore received in space at a low intensity and in an isotropic distribution."[16] Of its low intensity we have had occasion to elaborate elsewhere.[17]

There is another point of significance that emerges from the nature of the origin of the background radiation and is noteworthy. It is not the case that this radiation starts its journey entirely at the edges of the universe and reaches us after traversing long stretches of space. Insofar as the locations in three-dimensional space through which the atoms of the cosmic aggregates happen to pass are randomly distributed, the background radiation originates ubiquitously. So long as large enough volumes of space are considered (in view of the low energy density of this radiation) the existence of absorbing media does not have any effects on its overall isotropy and uniformity. The possible attenuation by

15 K.V. K. Nehru, "The Gravitational Limit and the Hubble's Law," *Reciprocity*, XVI (2), Winter 1987-88, pp. 11-16
16 Dewey B. Larson, *The Neglected Facts of Science*, *op. cit.*, p.73
17 K. V. K. Nehru, "The Cosmic Background Radiation: Origin and Temperature," *Reciprocity*, XIX (4), Winter 1990-91, p. 20 and XX (1), Spring 1991, pp. 1-4

intervening dust and gas—whose occurrence is an almost certainty—is not alluded to in the astronomical literature for the simple reason that the large-scale anisotropy it introduces is patently contrary to the observed fact, and thus it poses an additional problem for the current theories.

## 7 Summary of Part I

Recent astronomical observations reveal the occurrence of large-scale voids/bubbles in space. Galaxies and their clusters appear distributed in sheet-like and stream-like structures at the peripheries of these cosmic bubbles. None of the current cosmological theories is able to accommodate these facts, leave alone predict them.

It is shown that, in contradistinction, the Reciprocal System of theory not only explains their occurrence but also predicts their existence.

Recent observations of the cosmic microwave background radiation reveal its absolute uniformity to an accuracy that leaves no room for the current theories to reconcile this uniformity with the observed large-scale non-uniformity of the distribution of galaxies.

In the case of the Reciprocal System, however, this difficulty does not arise since it shows that the cosmic background radiation originates not in the region of three-dimensional space but in the region of three-dimensional time.

### *Part II: Mathematical Aspects of the Cosmic Bubbles*

In Part I: The Cosmic Bubbles (*Reciprocity,* XX (2), Summer 1991, pp. 5-8), we have highlighted the recent observational findings in the field of astronomy leading to the discovery of large-scale voids in space coupled with the distribution of galaxies as clumps at the peripheries of these voids. We called these voids bubbles. We have demonstrated there how the new facts could be readily explained in a natural way by the Reciprocal System of theory. In the present Part we attempt to develop the mathematical consequences of those concepts delineated in Part ??.

## 8 Analysis of the Motion in the Bubble

With the knowledge of the origin and nature of the bubbles we can now attempt to evaluate some of their properties. Let:

| | | |
|---|---|---|
| $\mathbf{c}$ | Speed of Light | $2.99793\times10^{10}$ cm/s |
| $\mathbf{G}$ | Universal constant of gravitation | $6.673\times10^{-8}$ cm$^3$/g-s$^2$ |
| $\mathbf{r}$ | Radius of the bubble | cm |
| $\mathbf{t}$ | Time since creation of the bubble | s |
| $\boldsymbol{\sigma}$ | Rate of mass inflow into the material sector | g/cm$^3$ s |
| $\boldsymbol{\rho = \sigma.t}$ | Mass density in the bubble at time | t, g/cm$^3$ |
| $\mathbf{M}$ | Total mass of a material aggregate | g |
| $\mathbf{M_0}$ | Mass of the Sun | $1.99\times10^{33}$ g |
| $\mathbf{d_0}$ | Gravitational limit of a consolidated material aggregate | cm |
| $\mathbf{k_0}$ | A constant | $3.5664\times10^{18}$ cm |

| | | |
|---|---|---|
| **P** | The universal constant of progression | $1.044\times10^{-11}$ cm/s$^2$ |
| **v** | Speed | cm/s |
| **a** | Acceleration | = v dv/dr, cm/s$^2$ |

We note from Reference 15 the following:

$$d_0 = k_0 \left( \frac{M}{M_0} \right)^{1/2} \tag{1}$$

$$P = G \frac{M}{d_0^2} = G \frac{M_0}{k_0^2} \tag{2}$$

We will first evaluate the expressions for the speed due to progression and the speed due to gravitation in the bubble. In the beginning stages (Section 5), the net speed in the entire mass is outward and we have to consider the expressions relevant to motion in *equivalent space.* Only when gravitation balances (or predominates) progression does the motion come back into the space of the conventional three-dimensional reference frame.

## 8.1 Speed due to Progression

In the conventional reference system:

$$\begin{gathered} a_p = v_p \left( \frac{dv_p}{dr} \right) = P \\ v_p = (2Pr)^{1/2} \end{gathered} \tag{3}$$

On the basis of the explanation given in Reference 15 the corresponding speed in equivalent space is given by:

$$\frac{V_{P,E}}{V_0} = \frac{\left( \frac{V_p}{V_0} \right)^2}{2}$$

where $V_0$, the *zero-point speed,* is given by:

$$V_0 = \left( \frac{2GM}{d_0} \right)^{1/2} = (2Pd_0)^{1/2} \tag{4}$$

Therefore we get:

$$V_{P,E} = \alpha \left( \frac{r}{\rho} \right)^{1/4} \tag{5}$$

where:

$$\alpha = \left( \frac{P}{2k_0} \right)^{1/2} \left( 0.75 \frac{M_0}{\pi} \right)^{1/4} = 1.7861\times10^{-7} \mathit{cgs\ units} \tag{6}$$

### 8.2 Speed due to Gravitation

In the conventional reference system, considering a location at the periphery of the bubble:

$$a_G = v_G \left( \frac{dv_G}{dr} \right) = \frac{4}{3} \pi G \rho r$$
$$v_G = \left( 4 \pi G \frac{\rho}{3} \right)^{1/2} r \tag{7}$$

The corresponding speed in equivalent space is given by:

$$\frac{v_{G,E}}{v_0} = \frac{\left( \frac{V_G}{v_0} \right)^2}{2}$$

Adopting $V_0$ from Equation (4) we get:

$$v_{G,E} = \beta \rho^{3/4} r^{5/4} \tag{8}$$

where

$$\beta = \pi \left( \frac{2 G k_0}{9} \right)^{1/2} \left( \frac{0.75}{M_0} \pi \right)^{1/4} = 2.391 \times 10^{-3} \, cgs \, units \tag{9}$$

### 8.3 Net Speed

In the conventional reference system, the net speed is (using Equations (3) and (7))

$$v_N = v_P - v_G = (2 P r)^{1/2} - \left( 4 \pi G \frac{\rho}{3} \right)^{1/2} r \tag{10}$$

and in equivalent space (using Equations (5) and (8))

$$v_{N,E} = v_{P,E} - v_{G,E} = (\alpha - \beta \rho r) \left( \frac{r}{\rho} \right)^{1/4} \tag{11}$$

### 8.4 Zero-Point Radius

We have called the radius of a uniform spherical mass at whose periphery the net speed becomes zero the zero-point radius, $r_z$. Equating Equation (11) to zero and using Equations (6) and (9), we obtain

$$\rho r_Z = \frac{\alpha}{\beta} = \frac{(3 P)}{(2 \pi G)} = 7.47 \times 10^{-5} \frac{g}{cm^2} \tag{12}$$

This relationship gives, for any given value of mass density, the corresponding radius where the net speed becomes zero.

### 8.5 Advent of Criticality

In Section 5 we have set forth that the mass of the expanding bubble reaches a critical state when its actual radius equals the zero-point radius. We have called this radius the critical radius $r_{cr}$ and the corresponding age of the bubble the critical time $t_{cr}$. Substituting in Equation (12) r = σ.$t_{cr}$ and $r_z = r_{cr}$, and noting that:

$$r_{cr}=c\cdot t_{cr} \tag{13}$$

we get

$$t_{cr}=\left(\frac{\alpha}{\beta c\rho}\right)^{1/2} seconds \tag{14}$$

Now if the rate of mass inflow, σ, could be evaluated, one obtains the time it requires for the bubble to reach criticality and the corresponding size of the bubble. We, therefore, proceed as follows.

## 8.6 The Universal Constant of Materialization

We may call s the *universal constant of materialization,* like we call G and P respectively the corresponding universal constants. Noting that r = c.t and ρ = σ.t we rewrite Equation (11)

$$v_{N,E}=(\alpha-\beta\sigma c t^2)\left(\frac{c}{\sigma}\right)^{1/4} \tag{15}$$

At the moment of the quasar exit (that is, the start of the bubble expansion), we take t = 0. Therefore, at this moment, $v_{n,e}$ reduces to

$$v_{N,E,0}=\alpha\left(\frac{c}{\sigma}\right)^{1/4} \tag{16}$$

This is an outward speed and can be equated to the speed that is coming in, $V_I$, with the inflowing matter from the cosmic sector, wherein gravitation acts inward in time (equivalent to outward in space). It is not yet attenuated by gravitation in space (as could be seen from ß.σ.c.$t^2$ = 0). The inter-sector transition of matter takes place on individual mass unit basis. Normally, the speed effective on unit mass basis is the unit speed c. However, as elaborated in Reference 15, the scalar rotation of atoms that is the origin of gravitation is distributed over $156.44\bar{4}$ directions (degrees of freedom) in the *time region* (the region inside unit space) and 8 directions in the *time-space region* (the region of motion in three-dimensional space). In the corresponding situation of the cosmic atom, the cosmic gravitation gets distributed over $156.44\bar{4}$ directions in the *space region* (the region inside unit time) and 8 directions in the *space-time region* (the region of motion in three-dimensional time). Consequently, the incoming speed, $V_I$ , is given by

$$V_I=\frac{c}{(156.444\times 8)} \tag{17}$$

remembering that the contact between motion in space and motion in time is one-dimensional. Equating Equations (16) and (17) we arrive at the important value

$$\sigma=9.2679\times 10^{-47}\frac{g}{cm^3 s} \tag{18}$$

# 9 The Bubble Parameters

We can calculate the critical time by Equation (14), the corresponding critical density by $\rho_{cr} = \sigma.t_{cr}$ , and the total mass of the bubble at criticality:

| | |
|---|---|
| $t_{cr}$ | $1.643\times10^{8}$ years |
| $r_{cr}$ | $1.643\times10^{8}$ lightyears |
| $\rho_{cr}$ | $4.8055\times10^{-31}$ g/cm$^3$ |
| $M_{cr}$ | $3.7994\times10^{15}$ Solar masses |

We will examine these results one by one to see if they tally with the observations.

## 9.1 Matter Density

All the above values can be seen to be within the range of corresponding actual observed values. Current estimates of the density (in g/cm$^3$) of matter are as follows[18]:

| | |
|---|---|
| Interstellar space | $10^{-24}$ |
| Space near edge of galaxy | $10^{-28}$ |
| Intergalactic space | $10^{-31}$ |

The calculated critical density is slightly higher than the estimated density in intergalactic space but very near it.

## 9.2 Globular Clusters

As the net speed at the bubble periphery changes its scalar direction from outward to inward (on reaching criticality), it initiates the collapse of a large number of individual masses of diffuse matter all around the spherical boundary of the bubble. Each of these masses, as it collapses, further splits into a number of aggregates of stellar size, eventually resulting in a globular cluster. We will not here enter into detailed discussion of the mechanics of the formation of the globular clusters for want of space. The interested reader may refer to Larson.[13] At this juncture we would merely want to make an estimation of the collapse time of these globular clusters.

Let us consider the condition at the bubble periphery. There the net speed is given by Equation (10). Letting $\rho = \sigma.t$, $r = c.t$ (strictly $r < c.t$ since gravitation now predominates: but its effect is negligible in the initial stages of the post-critical phase), and x the radius of a proto-globular cluster of mass $M_G$, we have

$$\frac{dx}{dt} = V_N = (2Pct)^{1.2} - \left(4\pi G\sigma c^2 \frac{t^3}{3}\right)^{1/2} \tag{19}$$

The equation can now be integrated between the limits $x = x_G$ to 0 and $t = t_{cr}$ to $t_G$, where

$$x_G = \left[\frac{M_G}{\left(4\pi\frac{\rho_{cr}}{3}\right)}\right]^{1/3} \tag{20}$$

18 William K. Hartmann, “Astronomy: the Cosmic Journey,” Wadsworth Publishing Company, U.S.A., 1978, p. 309

The following table gives the calculated collapse time as a function of the proto-globular cluster mass.

| $M_g$ (Solar masses) | Collapse Time (years) |
|---|---|
| $10^3$ | $0.41\times10^8$ |
| $10^4$ | $0.59\times10^8$ |
| $10^5$ | $0.85\times10^8$ |
| $10^6$ | $1.22\times10^8$ |

The relationship between the collapse time and $M_g$ obtained by regression is

$$Collapse\,Time = 0.138\times10^8 (M_G)^{0.158} \quad (21)$$

and indicates that a star of, say, one solar mass would condense in $0.138\times10^8$ years. Thus the individual stars form well before the globular cluster as a whole arrives at its final stage of equilibrium.

In passing, we would like to remark that while it is possible for the globular cluster to form from a matter density of about $5\times10^{-31}$ g/cm$^3$ under the gravitational assistance of the bubble as a whole, simple calculation from Equation (12) shows that, left to itself, it requires a density of nearly $10^{-26}$ g/cm$^3$ to accomplish the same result.

## 9.3 The Bubble Size

The above calculations indicate that it takes nearly 0.4 to $0.6\times10^8$ years for the globular clusters to form and become observable after the bubble attains criticality. During this period the original bubble continues to expand, though not at the speed of light, at a slightly slower rate. Adding, therefore, a distance of $0.4\times10^8$ light-years to the radius at criticality we find that the bubble diameter at this juncture works out to be

$$2(1.643\times10^8 + 0.4\times10^8) = 4.1\times10^8\,lightyears$$

It must be noted that this result gives the maximum possible size. Beyond this stage the observed size actually decreases because (i) gravitation retards/nullifies the expansion and (ii) continued formation of globular clusters and dwarf galaxies shifts the spherical boundary between the visible and the dark matter ever inward, toward the bubble center. From Equation (12) we can see that the apparent void radius (equal to the zero-point radius) varies with time as

$$r = r_{cr}\frac{t_{cr}}{t} \quad (22)$$

Since the number of clusters grows as time passes, their combined gravitational effect draws up the matter at the bubble core and simultaneously they close in on it. A preliminary calculation on the basis of the gravitational limit of the surrounding group of clusters indicates that the last stage of the bubble, before it rapidly dissipates, will occur at a bubble diameter of about 84 million light-years.

The observed bubble sizes reported in the literature range from 60 to 400 million light-years. Broadhurst's survey,[7] though covering only two narrow regions but extending to depths of 2000 Mpc, puts it at 417 million light-years (see Section 1). Thus the results of calculations made on the basis of the Reciprocal System of theory are entirely in agreement with the facts.

### 9.4 Total Mass

The bubble mass at criticality has been calculated to be $3.8\times10^{15}$ solar masses. But as the formation of the globular clusters and other galaxies continues in the post-critical stage, the incessant inflow of matter from the cosmic sector adds to the total mass. When the bubble eventually reaches the supercluster stage its mass—that is, the mass of that portion of the original bubble that condenses into groups of clusters and clusters of stars—would be well within the $10^{16}$ solar mass range of the current estimates.

## 10 Computer Simulations

B. B. Mandelbrot,[19] investigating *fractal* shapes in nature, has studied the distribution of galaxies and clusters of galaxies in three-dimensional space. By postulating the existence of intergalactic voids he tried to evolve models of clustering. His findings are very interesting and pertinent.

He starts with a completely filled space and keeps on removing spherical volumes of matter. Both the size of the spherical hole and the location of its center are chosen randomly. The size of the hole is treated as a Poisson random variable with a distribution.

$$N(>v) \propto \frac{1}{v} \tag{23}$$

which reads as the number of holes with volume greater than v is inversely proportional to v.

The model is simulated on computer. His results—both the covariance between two points in space and the covariance between two directions in the sky—indicate a very good fit of data. The graphics output shows the views of the material remained after removing the spherical chunks and bear an amazing resemblance to the actual sky maps.

### 10.1 Unforced Clusters

A rather significant and *unforeseen* result of Mandelbrot's model above is that the distribution of the remaining points shows an apparent hierarchical structure. Mandelbrot exclaims: "Each point stands for a whole minicluster… In addition… the miniclusters are themselves clustered. They exhibit such clear-cut hierarchical levels that it is hard to believe that the model involves no explicit hierarchy, only a built-in *self-similarity*."[20] Or again, "Increasing clustering is not provoked by the concentration of all points around a few of them but by the disappearance of most points, leading to an increasing number of apparent hierarchical levels."[21] Hence he refers to them as "unforced clusters."

His finding is directly in line with the conclusions which Larson obtains from the Reciprocal System. "…the largest units in which gravitation is effective toward consolidation of its components are the groups of galaxies. These groups begin separating immediately, but until the outward movement produces a clear-cut separation, their identity as distinct individuals is not apparent to observation. Here, then, is the explanation of the large "clusters" and "superclusters" of galaxies. *These are not structural units in the same sense as stars or galaxies, or the groups of galaxies that we have been discussing."*[22] [italics mine] These are *default clusters* with apparent hierarchical structure brought into

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19 Benoit B. Mandlebrot, *The Fractal Geometry of Nature*, W. H. Freemand & Co., U.S.A., 1983
20 *Ibid.*, p. 294
21 *Ibid.*, p. 298
22 Dewey B. Larson, *The Universe of Motion*, *op. cit.*, p. 28[

relief by the randomly generated bubbles.

### 10.2 Difficulties with Mandelbrot's Model

The above model suffers from two shortcomings, and Mandelbrot has to introduce two *ad hoc* assumptions to make it successful. These concern the hole size distribution assumed by him (Equation (23)). Firstly, while the model shows reasonable verisimilitude when limited portions of sky are considered, the overall sky maps are completely wrong in that they include voids as immense as one-tenth of the sky or more. This defect could be traced to the unrealistically large hole sizes allowed by the hyperbolic distribution function N (>v) $\propto 1/v$ and could be eliminated by imposing an "upper cut-off," $v_{max}$, on the hole size.

Secondly, the unrealistically large number of small-sized holes allowed by this hyperbolic distribution leaves no portion of the sky not covered by the holes. In fact, Mandelbrot imposes the constraint that

$$P(>v)=1 \; for \; v<1 \tag{24}$$

(where P stands for probability) to save the model. It would, therefore, be interesting to see what the *Reciprocal System* has to offer in this context.

### 10.3 Distribution of the Hole Size According to the Reciprocal System

According to the Reciprocal System, the large-scale universe is in a steady state. That is, both the rate of inflow of matter from the cosmic sector and the rate of final quasar transitions to the cosmic sector are uniform in time (as well as in space) and equal each other. Therefore, for a given volume of space, the number of bubbles created per unit time, which is the number of quasars exiting per unit time, is given by

$$\frac{dN}{dt}=b \tag{25}$$

where b is a constant directly calculable from σ and the average mass of a quasar. Assuming an average quasar mass of $10^9$ solar masses, b works out to be $1.37\times10^{-15}$ per second per cubic megaparsec of space.

**For $0 \le t \le t_{cr}$**

We have seen that till criticality the radius is given by the relationship r = c.t. Differentiating this we get

$$\frac{dt}{dr}=\frac{1}{c}$$

and finally

$$\frac{dN}{dr}=\frac{dN}{dt}\frac{dt}{dr}=\frac{b}{c} \tag{26}$$

Integrating we have

$$N_1(>r)=\frac{b(r_{cr}-r)}{c} \tag{27}$$

where $N_1$ is the number of bubbles of radii larger than a specified radius r. It may be seen that $N_1$ is the contribution to the bubble population from the pre-critical phase of the bubble evolution.

**For t ≥ t$_{cr}$**

Beyond the critical point, we have seen that the bubble size decreases according to Equation (22). We obtain on differentiating it

$$\frac{dt}{dr}=\frac{-r_{cr}t_{cr}}{r^2}=\frac{-r_{cr}^2}{c r^2}$$

since $r_{cr} = c.t_{cr}$ by Equation (13). Finally

$$\frac{dN}{dr}=\frac{dN}{dt}\frac{dt}{dr}=\frac{-b\,r_{cr}^2}{c\,r^2} \tag{28}$$

On integrating

$$N_2(>r)=\frac{b}{c}\left(\left(\frac{r_{cr}^2}{r}\right)-r_{cr}\right) \tag{29}$$

where, again, $N_2$ is the number of bubbles of radii larger than r. $N_2$ is the contribution to the bubble population from the post-critical phase. We have shown in Section 9.3 that in the post-critical phase there is lower cut-off to the bubble size due to its quick dissipation. Let this lower cut-off radius be $r_0$. On adding $N_1$ and $N_2$ from Equations (27) and (29) respectively we get the following total distribution.

**For 0 ≤ r ≤ r$_0$**

$$N(>r)=\frac{b}{c}\left(\frac{r_{cr}^2}{r_0}-r\right) \tag{30}$$

**For r$_0$ ≤ r ≤ r$_{cr}$**

$$N(>r)=\frac{b}{c}\left(\frac{r_{cr}^2}{r}-r\right) \tag{31}$$

We take the one-dimensional analogue of Mandelbrot's Equation (23) for the sake of comparison

$$N(>r)=\frac{C'}{r} \tag{32}$$

where C' is a constant. It can readily be seen that the difficulty of unrealistically large number of small-sized holes that occurs in Mandelbrot does not arise here because N (>0) is not infinite but a finite constant (see Equation (30)). Similarly the difficulty of occurrence of unrealistically large-sized holes does not arise either. This is because there is a maximum possible size, $r_{cr}$; and this comes out as a natural consequence of the development of the theory in the case of the Reciprocal System—not as an arbitrary constraint imposed on the model to make it conform to the reality.

# 11 Summary

The astronomical observations of the recent decade have brought to light the large-scale distribution of galaxies in the universe and the near perfect uniformity of the cosmic microwave background to an extent that has not been possible earlier. An unexpected fact that has come to be established is the ubiquitous occurrence of spherical voids of gigantic proportions throughout space. Current theories are nonplussed.

Larson has shown that galaxies, on reaching an age limit, explosively eject fragments of their cores, imparting to them ultra high speeds. These fragments are quasars. When gravitation is attenuated by distance (time) the net speed of quasars reaches two units, the limit of the material sector. Then gravitation—which always acts inward—ceases to act in space and starts operating in time. This leaves the outward progression of space unchecked and all the constituent matter of the quasar, which hitherto stayed put, is dispersed in all directions in space at the speed of the progression. Thus, centered at the location of the original quasar, a spherical void starts growing.

Since the ejection of quasars and their exit are inevitable stages in the evolution of material aggregates these voids ought to be a universal phenomenon. Preliminary calculations demonstrate that their observed sizes and other parameters are in consonance with the theoretical predictions.

All these latest observational findings that the current theories are at a loss to account for, are logically explained by the Reciprocal System starting from the foundation of its Fundamental Postulates. This paper, thus, demonstrates once again the cogency and power of the Reciprocal System as a general physical theory.