INTERFACING FRIEDMAN AND STRING COSMOLOGIES

J. TOWE

Abstract. Compactification and symmetry breaking events in theories of heterotic superstrings implicitly indicate five inflation events. Scales of $10^9$ ly and larger are modeled in terms of these events. The proposed model accounts qualitatively for recent observations (of galactic clusters that lie on "thin, semi-spherical shells") and motivates a calculation that accounts (approximately) for the observed number of galaxies.

1. Five Inflation Events

Traditionally it was believed that the distribution of mass-energy was homogeneous and isotropic on scales of $10^8$ light years and larger [J. A. Wheeler, 1974]. In recent years however, the homogeneity of the large-scale distribution has been challenged. After surveying more than 5000 galaxies, J. P. Huchra and M. Geller concluded that "galactic clusters lie on thin, sharply defined semi-spherical shells that surround vast, empty voids." They compared these phenomena with the "bubble-like structures that constitute the foam in a kitchen sink" [J. P. Huchra, 1986]. Thus, while the distribution of mass-energy is isotropic (established by observations indicating that the background radiation is isotropic), it is not homogeneous. These observational results have challenged traditional theories, but it is argued here that they can be understood in terms of a supersymmetric gauge theory that indicates multiple symmetry breaking events: i.e. multiple inflation events.

In the theory of superstrings, one avoids anomalies and contradictions if the dimension of spacetime is 10. Moreover, one rids the ground state of tachyons and introduces spacetime supersymmetry through GSO projections. Periodic GSO projections involve Ramon boundary conditions, which produce a Type IIA theory, containing spin-1 fields and fermions. Anti-periodic GSO projections involve Neveu-Schwarz boundary conditions, which produce a Type IIB theory, containing scaler fields and fermions. Neither theory is physical. The first is not chiral and the second contains no gauge fields. One can solve this problem however, by combining the two theories into a mixed or 'heterotic' theory. One approach to this involves compactification of 16 dimensions from the 26 dimensional bosonic theory, which imposes a symmetry $E_8 \times E_8$ onto the 10-spacetime that corresponds to the heterotic theory.

One $E_8$ symmetry characterizes the observable sector while the other characterizes the hidden sector (where coupling with gauge fermions in the observable sector is strictly in terms of supergravity). When 10-spacetime is compactified to produce $M_4 \times K_6$, each $E_8$ is broken to yield SU(5)$\times$SU(3). Guth inflation [A. Guth, 1981] is a theoretical device that maintains large scale flatness by compensating (by rapid expansion) for the fattening of the vacuum that is due to a Higgs event (an event in which Higgs scalers are swallowed by other particles, imparting mass to the latter and therefore breaking the initial symmetry). Clearly however, a Guth inflation event is also called for by a compactification that increases mass-energy density;
i.e. fattens the vacuum by reducing the number of spacetime dimensions. Thus one Guth event is generated by compactification itself. A second Guth event is generated by the breaking of $E_8$ to yield SU(5)$\times$SU(3). A third inflation event is generated by the breaking of the other $E_8$ symmetry to yield a second version of SU(5)$\times$SU(3). And finally fourth and fifth inflation events are generated by the breaking of the two SU(5) symmetries. In the proposed theory then, a single Guth event is replaced by five such events.

The proposed additional inflation events complement the original shock wave that is attributed to the big bang with secondary, tertiary etc. shock waves as prescribed by Huygens' principle. Specifically, the first inflation event is regarded as spherically symmetric. The second inflation event is associated with secondary shock waves that emanate from the points of the initial, spherically symmetric wave front. Similarly the third inflation event is associated with tertiary shock wavelets, emanating from the points of the secondary wave fronts etc. Because these are inflation events, scales on the secondary, tertiary etc. wavelets are much larger than the scales on the wave fronts from which they emanate. In this context, it is argued that the five inflation events that are produced by compactification and symmetry breaking account for the large scale. A hypothesis relating numbers of galaxies to inflation events will now be considered.

2. A THEORETICAL NUMBER OF GALAXIES

The original inflation event, is attributed here to compactification of 16 dimensions onto a torus and is interpreted as the big bang. It is argued that this event formed a radially symmetric distribution of mass-energy that can be identified as a pre-galaxy. It is assumed that this initial pre-galaxy is a generic phenomenon that subsequently became part of every galaxy. The second inflation event; i.e. the first Huygens event is associated with the fattening of the vacuum that corresponds to compactification from 10 spacetime dimensions to $M_4 \times K_6$. It is argued that this inflation event produced a cluster of pre-galaxies; that the third inflation event; i.e. the second Huygens event (that associated with the second compactification from 10 spacetime dimensions to $M_4 \times K_6$); e.g. the compactification associated with the hidden sector generated a supercluster of pre-galaxies; that the fourth inflation event; i.e. the third Huygens event (that associated with the breaking of one SU(5) symmetry) generated a cluster of superclusters; and finally, that the fifth inflation event; i.e. the fourth Huygens event (that associated with the breaking of the second SU(5)) generated a supercluster of superclusters. In the context of this hypothesis and of boundary conditions that are determined from observations of local clusters, one can calculate the number of galaxies that populates the universe as modeled.

Based upon observations of local clusters, one adopts the following boundary conditions: 1. A typical galaxy means that this galaxy is contained in a typical basic cluster; i.e. a basic cluster containing an average number of galaxies. To ascertain the nature of a typical basic cluster in the local group of thirty five or so galaxies, it is observed that the large and small Magellanic clouds form a pair of satellites about the Milky Way, and that the Andromeda Nebula is at the center of a basic cluster that includes satellite galaxies M-32, NGC-205, M-33, NGC-47 and NGC-185. Based upon this and several similar observations, it is concluded that the average number of galaxies constituting a basic cluster in the local group
is five; 2. *Separations of galaxies are about ten times the diameters of the galaxies; separations of galactic clusters are about ten times the diameters of the clusters; separations of superclusters are about ten times the diameters of the superclusters etc.*

The iterative counting process, which is based upon the above stated hypothesis and boundary conditions, is as follows: It is determined (from observation) that the typical galaxy is about $c_t_0=10^5$ light years (ly) in diameter. The diameter $c_t_N$ of the global state that has resulted from the $N^{th}$ inflation event is, by provision number 2, designated:

$$c_t_N = c_t_010^N : N = 0, 1, 2, 3, ...,$$

where the $N=0$ state corresponds to a single, typical galaxy.

Because five galaxies populate the typical basic cluster and because, up to a scale of about $10^9$ ly, the number of galaxies can be enlisted as units in terms of which to express volume (up to this scale, galaxies appear to fill a volume rather than to populate the surfaces of semi-spherical shells), one can establish the following equation to describe the $N=1$ cluster of galaxies:

$$\frac{4}{3}\pi R_1^3 = 5,$$

which implies that

$$R_1 = 1.06.$$

From 2.1 the radius of this galactic cluster in light years is about

$$c_t_1 = c_t_010 = 10^5\times10^0 ly = 10^5$ly.$$

One now determines the approximate radius (as a number of galaxies) of the $N=2$ state. Given the counting device that is italicized above, it is argued that the radius of the $N=2$ state (the separation of the $N=1$ cluster and a second cluster is ten times the diameter of the local cluster), in terms of a number of galaxies, is given by

$$10(diameter(local\ cluster)) = 10(2\times1.06) \approx 21.$$

The radius in light years of a typical $N=2$ state is (consulting equation 2.1)

$$c_t_2 = c_t_010^2 = 10^5\times10^1 ly = 10^6$ly.$$

Proceeding in this way, one determines the radius (as an approximate number of galaxies) of the $N=3$ state. By analogy with the above calculations, the radius of the $N=3$ state, in terms of a number of galaxies, is given as a multiple of a typical separation of $N=2$ systems:

$$10(diameter(N=2\ state)) = 10(2\times21) = 420.$$

The radius of the $N=3$ state in light years is (according to 2.1) about

$$c_t_3 = c_t_010^3 ly = 10^5\times10^3 ly = 10^8$ly.$$

One now determines the radius (as an approximate number of galaxies) of the $N=4$ state. The radius of this state, in terms of a number of galaxies, is given by

$$10(diameter(N=3\ state)) = 10(2\times420) = 8400.$$

The radius in light years of the $N=4$ state is, according to equation 2.1, given by

$$c_t_4 = c_t_0(10^4) = (10^5)(10^4) ly = 10^9$ly.$
Finally, one determines the radius (as an approximate number of galaxies) of the N=5 state. The radius of this state, in terms of a number of galaxies, is given by

\[ 10(diameter(N=5 state)) = 10(2(8400)) = 168000. \]

Thus, since galactic clusters populate the surfaces of semi-spheres on scales larger then \(10^8\) ly, the number of galaxies in the N=5 state is (summing areas of opposite semi-spherical shells) given by

\[ 4\pi(R_4)^2 = 4(3.14)(168000)^2 = 3.54 \times 10^{11}. \]

The radius in light years of the N=5 state is, according to equation 2.1,

\[ ct_5 = c t_0 (10^5) ly = 10^{10} ly. \]

In summary, the proposed large scale hypothesis is based upon compactification and symmetry breaking events that are associated with string theory. It is argued that five inflation events result from these, and that the resulting inflations account qualitatively for the radial inhomogeneity of the large scale structure as recently observed. Based upon this structure moreover, and upon locally determined boundary conditions, an iterative calculation predicts the approximate number of galaxies that is indicated by observation.

References

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Department of Physics, The Antelope Valley College, Lancaster, CA 93536

E-mail address: jtowe@avc.edu