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Albert Stebbins

NASA/Fermilab Astrophysics Center
Fermi National Accelerator Laboratory
Batavia, IL 60510

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ALBERT STEBBINS
FERMI NATIONAL ACCELERATOR LABORATORY
BATAVIA, ILLINOIS

As has been illustrated in Simon White's talk, much progress can be made in understanding the formation of galaxies if one has *a priori* knowledge of the initial inhomogeneities leading to galaxy formation. While observational cosmology may be successful in making implausible certain theories of the initial conditions (White *et al.* 1983) we are a very long way from being able to read off the initial conditions from our observations of the positions and radial velocities of stars and gas. This is only feasible on very large scales where we can be fairly confident that gravity is the only important force acting. This has lead cosmologists to study certain *ansatzes* for the initial inhomogeneities, such as overdensities with a power law spectrum (Peebles 1982). Recently two plausible physical mechanisms have been proposed for producing inhomogeneities in our universe, inflation and cosmic strings. Both scenarios give predictions for the inhomogeneities. One of them (inflation) predicts a power law initial spectrum which researchers were well prepared to study, and to some extent had already studied. The other mechanism involved production of very large and massive one dimensional objects called cosmic strings. The gravitational field of the strings produce inhomogeneities in the other matter in the universe. One must first understand the "kinetic theory" of strings in an expanding universe, and then one may proceed to study the nature of the inhomogeneities they induce. While it cannot be said that this program of research is nearly complete, much progress in all stages of this program has been made.

Here I will discuss what I call the Standard String Scenario (SSS). This is the scenario with a significant cold dissipationless (non-baryonic) component. This scenario is "Standard" because it has been the most studied (Bertschinger 1986, Stebbins 1986, Turok and Brandenberger 1986, and other references mentioned elsewhere in this paper). String scenarios with no non-baryonic component or with hot non-baryonic matter have not received much attention. Other scenarios involving explosive amplification have been proposed, with the usual cosmic strings (Rees 1986) and with superconducting cosmic strings (Ostriker *et al.* 1987).

Basicly the idea of the SSS is that individual astrophysical objects are accreted around loops of cosmic string. Loops which were created at $z \sim 10^5$ accrete galaxies, while larger and less numerous loops accrete groups and clusters of galaxies. As the details of loop production is not yet fully understood, there still remain many unknowns. Hopefully, these unknowns will eventually be determined by string simulations, leaving us with "the single parameter of the theory", the mass per unit length, μ.

The cosmic string scenario has been shown to have several qualitative and quantitative successes since its inception. We list these in the context of the SSS

"Natural" Amplitude: For the correct amplitude of the inhomogeneities, the string tension corresponds to a natural scale in particle physics, the GUT scale. This can be stated in terms of the velocity dispersion of galaxies in rich clusters:

$$\frac{v_{\rm cluster}}{c} \approx \sqrt{\frac{G\mu}{c^2}} \approx \frac{M_{\rm GUT}}{M_{\rm Planck}}.$$

This was first pointed out by Vilenkin and Shafi (1983).

Inherent Biasing: The distribution of inhomogeneities gives a larger frequency of "rare peaks" in the mass distribution than a Gaussian distribution. These large density fluctuations supplant the *biasing* needed in most Gaussian models. The reason for this is that even during linear growth the perturbation created by a loop is very centrally concentrated. The overdensities in the central regions of these perturbations are much larger than the r.m.s. These inhomogeneities naturally leads to isolated large regions of virialized mass such as is suggested by rich clusters of galaxies.

Cluster Correlations: The observed correlation function of clusters of various richness classes as well as groups are predicted by the string scenario (Turok 1985). We should be somewhat wary of this "prediction" as it is not well understood in terms of an analytical theory. I did not mention the correlation function of galaxies because it has not been demonstrated that the initial r^{-2} distribution is not destroyed by the non-linear clustering of galaxies around themselves.

Isothermal Haloes: The initial density profiles of the dark matter halos of objects accreted around loops have density profiles r^{-2}-$r^{-9/4}$ (Sato 1986). This is *roughly* what is observed for galaxies (Rubin *et al.* 1985).

These successes have encouraged many people to look more closely at the string scenario. Indeed, if one examines more closely the simple models that have been used to describe the formation of structure with strings one finds problems. Peebles is among those to have scrutinized the string picture and has formalized his complaints by writing them down and distributing them in the form of a "privately circulated screed", and in a revised version known as "Screed II". I now proceed to list what I consider the potentially serious problems which have been raised.

The Biased Galaxy Problem: If one loop produces one galaxy then why are there so many galaxies in clusters. The SSS says that clusters are produced by large loops, and one would not naively expect a concentration of small, galaxy-seeding loops around a large cluster-seeding loop.

The Core Radius Problem: Given the spherical infall model one would naively expect density profiles of galactic halos to be $\rho \sim r^{-9/4}$ with $r_{core} \sim 100\,\mathrm{pc}$. The core radii of galaxies are more like a few kpc! Furthermore if baryons have collapsed to the center, as appears to have happened, then we would expect the rotation curve rise above its halo value as one approaches the center. Neither the $r^{-1/8}$ dependence of rotation velocity nor a significant rise due to baryonic dissipation are observed in galaxies.

The Maximal Rotation Velocity Problem: Why is there such a sharp cutoff in the observed velocity dispersion within galaxies? Shouldn't bigger loops produce bigger galaxies with bigger velocity dispersions?

The Small Galaxy Problem Where are all the small galaxies? The mass distribution of small loops goes as $n(>M) \sim M^{-3/2}$ and in the simplest string picture the mass accreted is proportional to M. Yet the luminosity function of small galaxies goes as $n(>L) \sim L^{-1/4}$.

The Angular Momentum Problem: If spirals are formed by isolated accretion then where do their baryons get the angular momentum with which to form spirals?

The Large-Scale Structure Problem: Recent observations suggest that most field galaxies lie on surfaces surrounding voids (de Lapparent, Geller, and Huchra 1986). There is nothing in the SSS to suggest that loops reside on such surfaces.

At present, none of these problems seem fatal for the SSS. String pundits can easily come up with ways in which the SSS can avoid these problems. However we should not take these explanations as resolutions of these problems but rather as a list of excuses. Usually these explanations will assert that the initial formulations of the SSS were too crude and in more sophisticated treatments these problems *may* not exist. Indeed the initial formulations of the formation of structure with strings have involved many crude approximations and it will take some time for more sophisticated treatments to appear. For example, until loop production is understood more completely all results concerning the number density of objects must be considered preliminary. These claims of ignorance are no guarantee that the aforementioned problems will not persist. Still the proposed resolutions of these problems bear mentioning.

One reply to the **Biased Galaxy Problem** is that what we are seeing in clusters is not an increased density of loops but rather an increased luminosity of galaxies forming around loops. Such an environmental effect would explain the large number of bright galaxies per unit mass in clusters. Another potential resolution to this problem could come from some as yet undiscovered propensity of loop fragmentation to produce many much smaller loops around a big loop. This does not seem very plausible as loop fragments are likely to travel very far from their place of origin due to their initial peculiar velocity.

The **Core Radius Problem** is somewhat fallacious as stated above. Numbers of order 100 pc comes from assuming the galaxy seeding loop is stationary which is known not to occur in practice. Loops will move due to both their initial velocity and thrust they produce via gravitational radiation. However, if we are required to explain halo core radii as large as 10 kpc as typical (Blumenthal *et al.* 1986), then this problem may persist.

One excuse for the **Maximal Rotation Velocity Problem** is to mumble something about primordial star formation and cooling. Clearly the "rotation velocity" for a halo is intimately related to the initial temperature of gas which collapses onto this halo and this may provide a dividing line between luminous galaxies and failed galaxies. This argument relies heavily on our ignorance of primordial star formation.

Biasing schemes (e.g. Dekel and Silk 1986) could easily cause condensations around very small loops to have such small surface brightness as to make them largely unobservable. In addition the velocity of very small loops are likely to be very large (at z_{eq}) which should further decrease the binding energy of the accreted haloes and thus make them even more fragile. Another important excuse for the **Small Galaxy Problem** is merging. These small condensations will certainly undergo much merging among themselves and with larger objects. It is, of course, not clear that merging will produce just the right number of small galaxies.

As for the **Angular Momentum Problem,** merging may provide the answer to the origin of angular momentum. However, whether merging is important for L^* galaxies depends strongly on the precise value of several parameters, such as μ, and H_0. It is not unlikely that merging is totally unimportant for these large galaxies in which case some other resolution is needed. An example of which is given by Zurek (1986).

The **Large Scale Structure Problem** is the problem I have the least excuses for. There is no reason to think that loops should arrange themselves in sheets. One can appeal to strong environmental biasing of galaxy luminosities in the wakes of long strings (Silk and Vilenkin 1984, Vachaspati 1986, Rees 1986, Stebbins *et al.* 1986), but hiding the loops may be a problem. If the recently reported large scale peculiar velocities (Burstein *et al.* 1986, Collins *et al.* 1986) persist, these may also be a problem for the SSS (Shellard *et al.* 1986, van Dalen and Schramm 1987). However we should also be careful not to overinterpret the observational data. Detailed comparisons, such as has been done for Cold Dark Matter (S. White this volume) will ultimately determine how serious a problem the observations are for string scenarios.

In summary, as the theory of structure formation with cosmic strings becomes more fully developed it will face more severe tests from observational cosmology. Several potentially serious problems with the theory have already been pinpointed. Whether a more mature theory of strings can resolve these problems is yet to be seen. Failure to resolve these problems in a "natural" way will probably not result in complete abandonment of the theory, but will decrease many peoples' interest. On the other hand, resolution of these problems in a more sophisticated treatment is unlikely to convince everyone of the existence of cosmic strings. Fortunately, the standard string hypothesis may be tested in a more direct fashion through the peculiarities of the MBR anisotropy they produce (Kaiser and Stebbins 1984), or they may be ruled out in a relatively straightforward fashion by the timing of the millisecond pulsar (Hogan and Rees 1984).

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