The Origin of Structure:
Interestingly, it is also believed that cosmic structures such as cosmic strings, or other “seeds’ that triggered the creation of present-day’s superstructures, such as galactic super-clusters, and galactic voids were generated during this time, to account for the non-uniformity of matter-energy distribution that could have caused the creation of the above-named present-day structures. Other hypotheses for such a phenomena include the spontaneous generation of primordial gravitational singularities or bodies, as proposed by the great British cosmologist Stephen Hawking. This. however, leads to other problems, such as the question of the cause of these singularities. Attempted explanations include the possibility of the primary singularity being non-ideal. However, other scientists argue that at that time, effects of the Uncertainty Principle would probably smear out these non-ideal effects. There are a few models that attempt explain the origin of structure in our present-day Universe, and a few of them will be looked at.

1. The Hot Dark Matter Model: This model is a top-down approach; it is taken that inflation of the Universe amplified the density fluctuations during the epoch when radiation & matter were still coupled together and that baryonic matter is the primary constituent of the matter in the Universe. In this sense then the radiation is scattered by the baryons and this also smooths out any small enough adiabatic density fluctuations, but at the same time barely affecting density fluctuations that are $\sim 10^{15}$ solar masses as its mutual gravity will dampen this effect. As the Universe and the density fluctuations stabilize and the remaining radiation that has not scattered off the baryons fall below the value required to impede density fluctuation collapse this is what exactly happens. It must also be noted that after radiation-matter decoupling this radiation scattering effectively ends, at a time of $\sim 3 \times 10^{5}$ years. After the collapse along a single axis, according to this particular model the fluctuation fragments and the proto-galaxies start to emerge. This model however, does not account for why galactic clusters are currently observed to be still forming after the galaxy formation. In fact according to this model galaxies should still be forming, since the top-down approach is being used. Running this model in computer simulations the results show that such a Universe is scarce in small-scale structures but very inhomogeneous in terms of density.
2. The Cold Dark Matter Model: This model works in reverse to the Hot Dark Matter Model except that it uses the same explanation to account for the origin of density fluctuations; it postulates that most of the Universe’s dark matter is non-baryonic, cold and is not affect by radiation scattering. In this scenario then, isothermal density fluctuations form from the non-baryonic dark matter while baryonic matter is still coupled to radiation. Putting all of these factors together, one gets plenty of small-scale density fluctuations in the cold dark matter, and correspondingly a lot of small-scale gravitational wells. As radiation & matter fall out of thermal equilibrium after about $\sim 3 \times 10^{5}$ years after the Big Bang the baryonic matter falls into these numerous small-scale gravity wells and we have numerous small cosmic structures. Modern empirical data agrees more with the results of computer simulations running the Cold Dark Matter Model rather than the Hot Dark Matter Model. However it must be noted that this model was perhaps it was too successful; it produced too much small-scales structures than currently observed, and the Cold Dark Matter Model predicts galaxy velocities two to three times of what is observed.

Galaxies, clusters of galaxies and super-clusters - clusters of clusters of galaxies - are not the only large-scale cosmological structures, though of course they are by no means trivial in terms of their scientific information potential. There are also large-scale topological defects above-mentioned: domain walls, monopoles, cosmic strings and the like. All of these interesting theoretical entities result from the breaking of a particular type of symmetry, and they [these cosmological defects] usually form (Kibble mechanism) at the boundaries of sections in the Universe which settle into the lowest possible energy states, the domain walls, for example. This is the primary reason why these topological defects are theorized to be gigantic. Monopoles are basically 0D entities, and they are the result of the breaking of sphere-symmetry, while textures are the results of more complex symmetries being broken in the vacuum manifold.

Cosmic strings are the theoretical result of axial symmetry breaking, and they develop at “points” on one vacuum manifold. Cosmic strings are interesting entities; they display inter-commutating behaviour (as do some liquid crystals) and produce loops. Since many of them vibrate energy is released in the form electromagnetic or gravitational radiation. Such entities also display vibrational modes, and as mentioned earlier they release energy in the process. The quadrupole radiation field is characteristic of cosmic strings. Cosmic loops are theoretically also possible, and they too display inter-commutating behaviour during loop interactions.

The primary reason why this digression is made is that many believe these entities and their decay products could be the gravitational seeds for the initiation of the evolution of large-scale cosmic structures observed today, galactic clusters for example. Only time will tell however, which model(s) will be correct.