AST 381 (also PHY 394T)
The Formation of Galaxies and Large-Scale Structure in the Universe

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Our universe at large is well-described, on average, by the standard Big Bang model of cosmology, in which a homogeneous distribution of mass-energy expands uniformly and isotropically from an initial space-time singularity, in accordance with the expectations of Einstein's General Theory of Relativity. Shortly after its birth, our observable universe was extraordinarily smooth on all scales. Today, however, it is highly structured, populated by galaxies, clusters, and superclusters of galaxies surrounded by huge regions devoid of galaxies, with most of the volume permeated by a clumpy intergalactic medium of diffuse gas. How this cosmic structure arose over the last 14 billion years from an otherwise smooth, featureless beginning at the initial moment of the Big Bang will be the subject of this course.

We will start by reviewing the basic observed characteristics of cosmic structure – the galaxies and intergalactic matter, their clustering in space and peculiar motions with respect to the universal expansion, and their evolution, including the evidence for dark matter. A brief self-contained summary of the current standard cosmology framework – the Big Bang model and the properties of the evolving homogeneous background universe – will be included. The formation of galaxies and large-scale structure by gravitational instability which results when this expanding homogeneous universe is perturbed by initially small-amplitude density fluctuations will then be studied in depth. We will trace the growth of such primordial fluctuations from linear to nonlinear amplitude and its dependence on the mass-energy content of the universe and on the nature of the dark matter which is believed to dominate the present matter density. The current status of theories of galaxy and large-scale structure formation in comparison with data will be assessed, with a special focus on the well-known Cold Dark Matter model. Topics to be addressed will range from the formation of galaxies from dwarfs to giants to the formation of X-ray clusters of galaxies to the cosmic history of star formation to the reionization of the intergalactic medium, from the origin of galactic rotation to the origin of the Lyman alpha forest of quasar absorption-lines, to the origin of the statistical pattern of large-scale structure observed today in the spatial distribution and motions of galaxies in the universe.