Finally, we come to the constellation of issues associated with dark matter and the very early universe. The observational situation is quickly summarized: 90 percent or more of the stuff in the universe that contributes to gravitational potentials does not emit (or absorb) its fair share of electromagnetic radiation. Dark matter unquestionably exists and outweighs the luminous matter in stars, galaxies, and the gas between them. But we haven't a clue what it is.

Colleagues often object to this second statement. What they mean, however, is not that we have any very definite information about what the dark matter is, but only that we know quite a lot of things it is not. This is progress only if the number of ideas generated by theorists is finite (not by any means a safe bet). For starters, the requirement of not messing up big bang nucleosynthesis almost certainly means that the dark matter cannot all be ordinary stuff made of protons, neutrons, and electrons. Thus we are forced to hypothesize other stuff that is capable of, at most, gravitational and weak interactions, and not of electromagnetic or nuclear ones (again a few colleagues would disagree at some level).

Dark matter, structure formation, inflation, phase transitions, etc. get mixed up together in several ways. First, most obviously, galaxies and clusters live in potential wells made mostly of dark matter, and the nature of the stuff is bound to make a big difference to how galaxies form (and whether we can model them at all successfully, to which the present answer is no, not entirely). Second, galaxy formation might be aided (or impeded) by various topological singularities (cosmic strings, textures, . . .) left from the phase transitions associated with the four forces gradually separating themselves. The supersymmetry arguments that go with the forces having once been the same more or less automatically imply the existence of several kinds of nonbaryonic particles associated with assorted unfamiliar but conserved quantum numbers.

Third, the "inflaton field" responsible for early, exponential expansion of the universe (inflation) could possibly leave behind a small ghost of itself to act as a cosmological constant (Einstein's unloved Λ). Fourth, inflation, at least some kinds, is supposed to leave behind both the exact critical density required to stop universal expansion in infinite time and a spectrum of perturbations of that density with a definite form, well shaped to grow into galaxies and clusters. No obvious astronomical observation would seem capable of proving that inflation happened, but one could imagine definitive dynamical evidence for a total density less than the critical one or for a spectrum of not-yet-evolved density perturbations different from the inflationary prediction. But there are already variants of inflation in the literature that can live with one or both anomalies.

In some ways, this mess looks slightly simpler from the astronomical side. As far as we can tell, for the purposes of galaxy formation and creation of large-scale structure, everything nonbaryonic can be divided among four categories, and it doesn't much matter which example nature has chosen to favor. The four categories are non-zero cosmological constant, seeds (like the topological singularities), hot dark matter (consisting of particles light enough that they are relativistic at $T \approx 3000$K when baryonic matter and light stop talking to each other; ordinary neutrinos of 5–25 eV are the most obvious candidate), and cold dark matter (consisting of particles massive enough to be non-relativistic at the same temperature, like the lowest-mass supersymmetric particle and its cousins; or axions which are low mass but form at rest; and no, I don't know why).

You can, if you wish, have two of these or even three. I am not aware of any scenarios that involve all four simultaneously, but this may well come. The variety is welcomed because no current simulation of galaxy (etc.) formation simultaneously does a very good job of accounting for structures on relatively small linear scales (a megaparsec or less, promoted by CDM), the largest scales (up to 100 Mpc, promoted by HDM), the largest deviations from smooth cosmic expansion that we see, and the observed sizes of those deviations (for example, the dispersion of pair-wise velocity differences between nearby galaxies) as a function of scale length. Choosing a spectrum of initial density fluctuations different from the standard inflationary one allows yet another degree