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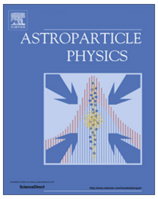

Editorial

Foreword: Dark energy and CMB

Maps of the Universe when it was 400,000 years old from observations of the cosmic microwave background and over the last ten billion years from galaxy surveys point to a compelling cosmological model. This model requires a very early epoch of accelerated expansion, inflation, during which the seeds of structure were planted via quantum mechanical fluctuations. These seeds began to grow via gravitational instability during the epoch in which dark matter dominated the energy density of the universe, transforming small perturbations laid down during inflation into nonlinear structures such as million light-year sized clusters, galaxies, stars, planets, and people. Over the past few billion years, we have entered a new phase, during which the expansion of the Universe is accelerating presumably driven by yet another substance, dark energy.

Cosmologists have historically turned to fundamental physics to understand the early Universe, successfully explaining phenomena as diverse as the formation of the light elements, the process of electron–positron annihilation, and the production of cosmic neutrinos. However, the Standard Model of particle physics has no obvious candidates for inflation, dark matter, and dark energy. The amplitude of the perturbations suggest that the natural scale for inflation is at ultra-high energies, so understanding the physics driving inflation could lead to information about the ultraviolet completions of our current theories. There are arguments that naturally link the dominant dark matter component to new physics hovering above the electroweak scale. Apart from the dominant component, neutrino oscillation experiments already inform us that neutrinos constitute a non-negligible fraction of the dark matter, and one of the key points of this chapter is that experiments usually associated with dark energy and inflation are ideally suited to pin down the sum of the masses of the neutrinos and the cosmic existence of any additional (sterile) species. The situation with dark energy is more complex. A cosmological constant (Λ) has effective pressure equal to minus its energy density (equation of state $w = -1$) consistent with preliminary measurements, but for example in supersymmetric theories the most natural scale for A is at least as large as 100 GeV. A cosmological constant with this value would produce a universe accelerating so rapidly that the tips of our noses would be expanding away from our faces at a tenth the speed of light. If Λ is responsible for the current epoch of acceleration, its value is many orders of magnitude smaller than this but curiously just large enough that it began dominating the energy density of the universe only recently. So the mechanism driving the current accelerated expansion of the Universe remains a profound mystery.

The quest to understand dark energy, dark matter, and inflation then is driven by a fundamental tension between the extraordinary success of the model that explains our Universe and the failure of the Standard Model of particle physics to provide suitable candidates for the dark sector that is so essential to our current view of the Universe. Cosmic surveys have demonstrated that the Standard Model is incomplete; the next generation of experiments can provide the clues that will help identify the new physics required.

The American Physical Society's Division of Particles and Fields initiated a long-term planning exercise over 2012–13, with the goal of developing the community's long term aspirations. The sub-group "Dark Energy and CMB" prepared a series of papers explaining and highlighting the physics that will be studied with large galaxy surveys and cosmic microwave background experiments. This Special Issue contains those papers.

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