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EDITORIAL

Focus on the origin of matter

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Abstract. The origin of matter in the Universe is a fascinating cosmological puzzle that has triggered a formidable intellectual enterprise, started in 1967 with the prescient paper by Andrej Sakharov (1967 *Pisma Zh. Eksp. Teor. Fiz.* **5** 32; 1967 *JETP Lett.* **52** 4; 1991 *Sov. Phys.—Usp.* **34** 392; 1991 *Usp. Fiz. Nauk* **161** 61) aimed at relating a cosmological observation to the fundamental laws of physics, the goal of baryogenesis. A successful model of baryogenesis should ultimately identify the required source of charge parity violation and the origin of the cosmological matter–antimatter asymmetry. This focus issue is not only a review of the main ideas that have been proposed in baryogenesis but should also bear witness to the great vitality of the field and to show how future experimental results could bring a breakthrough in baryogenesis during the coming years. For this reason we selected, out of the multitude of proposed baryogenesis models, those that will more likely experience a significant experimental test during the coming years.

Baryogenesis provides the first example of a theory suggesting an extension of the laws of physics tested in Earth laboratories in order to explain a basic cosmological property: the non-observation of primordial anti-matter in the Universe. This is seemingly at odds with a symmetric description of matter and anti-matter within the established fundamental laws elegantly encoded by the Dirac equation.

Forty-five years since Sakharov's paper [1], which established baryogenesis as a new field in particle cosmology, represents a good opportunity to review the state-of-the-art in the field, discussing the achieved result and what kind of advances we can expect in future years toward a solution of the problem.

However, this is not the only reason for this focus issue on baryogenesis. We have just entered a stage of experimental efforts in particle physics and cosmology that will likely have a tremendous impact on fundamental physics and specifically on baryogenesis. It is quite likely that at the end of this stage, probably at the end of this decade, we will have to abandon some of the ideas that have driven the investigation in baryogenesis so far. At the same time there are realistic possibilities that strong signals pinning down the correct model could emerge. Even the possibility that one of the existing models of baryogenesis will be established as the next pillar within the history of the early Universe together with big bang nucleosynthesis, the recombination era and, seemingly, inflation, is a legitimate hope. In this focus issue, we select, out of the multitude of proposed baryogenesis models, those that will more likely experience a significant experimental test during the coming years. There is robust observational evidence for primordial matter–antimatter asymmetry that cannot be explained either as a local effect or as a pre-existing initial condition [2] but should be explained in a dynamical way through a model of baryogenesis [1]. A successful model of baryogenesis should satisfy Sakharov's three famous conditions. Within the standard model (SM) these would all be fulfilled and electroweak baryogenesis [3, 4] provides a definite example of how the asymmetry could be explained within the SM. However, experimental measurements rule out electroweak baryogenesis as a viable scenario. For this reason the matter–antimatter asymmetry of the Universe is today regarded as evidence of new physics and a successful model of baryogenesis should rely on an extension of the SM. A typical example is provided by revisiting electroweak baryogenesis within supersymmetric models [3]. Another important model of baryogenesis based on a supersymmetric extension of the SM is the Affleck–Dine model of baryogenesis [5, 6].

The discovery of neutrino oscillations has opened up new opportunities, relating the matter–antimatter asymmetry of the Universe to neutrino properties. Leptogenesis [7] is based on extensions of the SM able to explain neutrino masses and mixing where the asymmetry is generated by the decays of very heavy right-handed neutrinos [7, 8, 9]. It has also been shown that the matter–antimatter asymmetry could be generated by the right-handed neutrino oscillations [2].

Interestingly, the matter–antimatter asymmetry puzzle could also have a common explanation together with another long-standing cosmological puzzle, the existence of a dark matter component in the Universe [2, 10].

This focus issue should then be meant not only as a review of the main ideas in baryogenesis, but also as a witness to the great vitality of the field and to show how future experimental results could bring a breakthrough in baryogenesis during the coming years.

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