The Synergy between Cosmology and High Energy Physics

During the last two decades we have witnessed a revolution in cosmology, primarily because of a variety of precise experimental data. Particularly important are the measurements of the temperature anisotropies of the Cosmic Microwave Background (CMB) radiation. Based on that, cosmologists constructed a standard cosmological model that is frequently referred to as the concordance model (or ΛCDM model) of big bang cosmology. It attempts to explain CMB observations, as well as large scale structure observations and supernovae observations of the accelerating expansion of the universe. It is the simplest known model that is in general agreement with observed phenomena. According to the model, the Universe is composed of only about 4% of baryonic matter (that is us), 22% of dark matter and 74% of dark energy (the component which is responsible for the observed accelerated expansion of the Universe). The Standard Model (SM) of particle physics explains (more precisely just describes) only the 4% (the baryonic matter) of the Universe. The nature of the two major constituents of our Universe, dark matter (DM) and dark energy, is so far unknown.

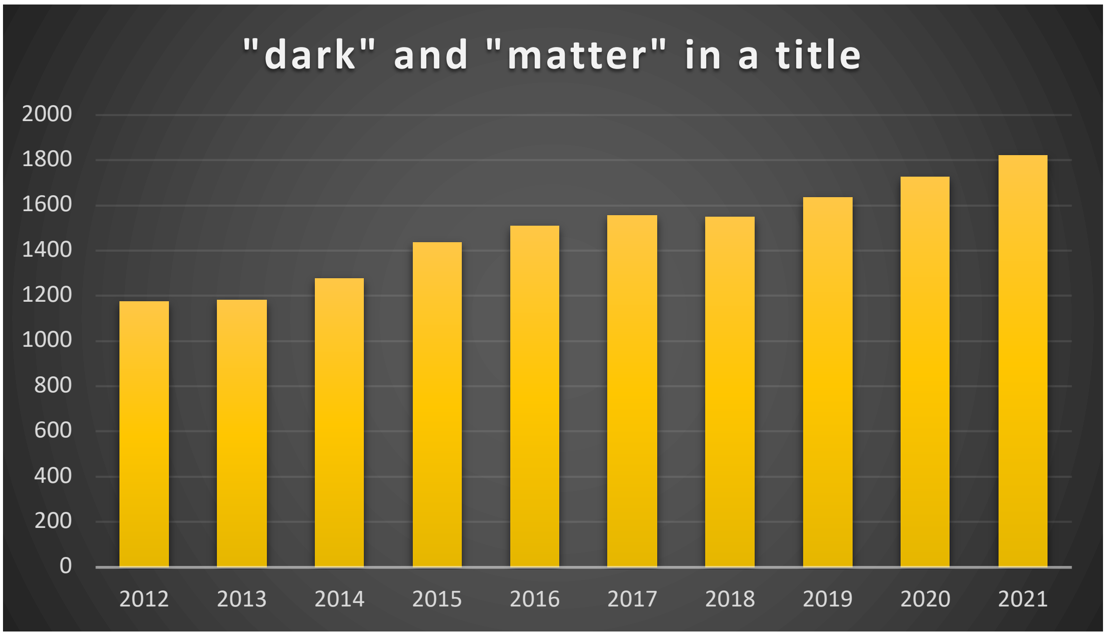

Figure 1: Number of papers containing “dark” and “matter” in a title published for last 10 years.

Particularly important is the absence of DM candidate in the SM. It is likely that the necessary modification of the SM that incorporates the DM will also lead to discovery (as a by-product) of the complete theory of fundamental (i.e. gravitational, electro-weak and strong) interactions.

It is commonly accepted that the early Universe went through a period of very fast expansion (called inflation), the mechanism responsible for the inflation is still uncertain. Vast majority of existing models of the inflation rallies on an assumption of existence of scalar field, called inflaton, this is again an area where cosmology and fundamental interactions meet.

There exists another fundamental problem of cosmology, namely the baryogenesis; it is unclear why the Universe which we know is made entirely from matter. One necessary ingredient of possible solution of this problem is breaking of CP (so called combined parity, the approximate symmetry of electroweak interactions). It is known that the SM does not provide sufficient amount of the CP violation, so again cosmology requires a modification of our theory of fundamental interactions.

Summarizing, it is clear by now that the physics of fundamental interactions requires a major modification (at least it should explain the existence of 96% of matter in the Universe).

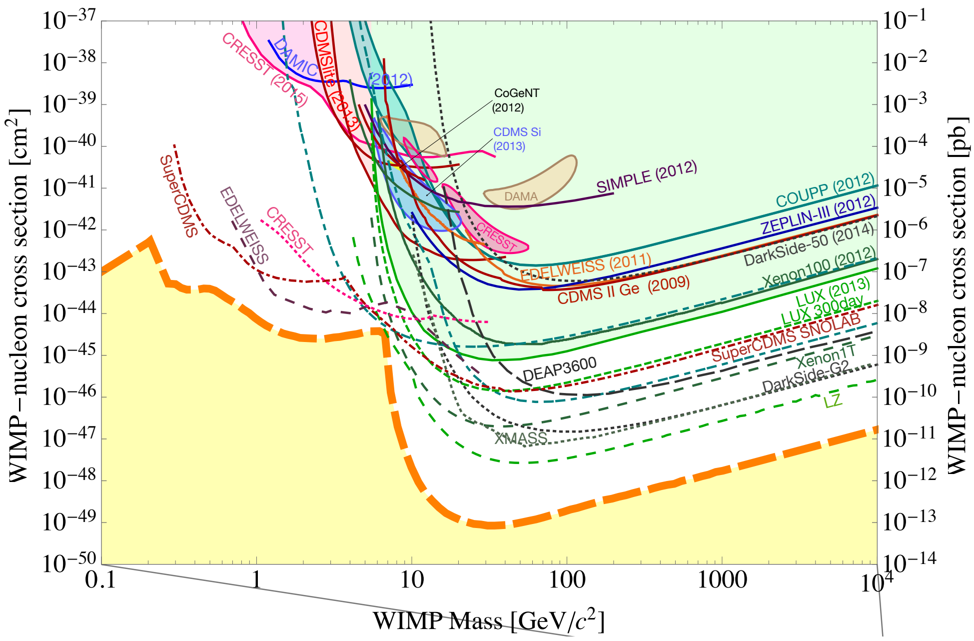

Figure 2: Limits or evidence (as claimed by the authors) for the cross section for DM-nucleon interactions, source P. Cushman et al., arXiv:1310.8327

It should be emphasized that postulated theories of DM could be tested also at particle colliders, for instance at Large Hadron Collider (LHC) indeed searches for DM are carried on by the two major collaborations, CMS and Atlas. The unquestioned synergy between particle physics and cosmology led to formation of a new discipline; the particle cosmology. The figure 1 illustrates the rate of expansion of the particle cosmology, it shows number of research papers published during recent 10 years as a function of time, it is clear that this is dynamically growing discipline of physics. On the other hand, in order to illustrate the experimental development of particle cosmology, the figure 2 contains results of measurements of the DM-nucleon scattering. It is absolutely clear that this region of physics is (and will be) investigated vigorously by very many experimental groups. New data available soon (within 1-2 years) will open an exciting period both in high energy physics and in cosmology! It is conceivable that within next decade we will be able to construct the consistent theory of particle physics and cosmology.

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