# Dark Atoms and Dark Radiation

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Modern astronomical observations prove that dark matter and dark energy are the bedrocks of the modern theory of the Universe. These phenomena cannot be grounded in the known laws of physics and they call for hypothetical new particles and fields predicted by extensions of the Standard Model of particle physics. In the context of cosmology, dark matter stems from the processes in the early Universe that create this new form of matter, which is then sufficiently stable to survive to the present day. In the context of particle theory, the stability of dark matter implies new conservation laws, resulting from new fundamental symmetries.

The simplest candidates for dark matter, such as neutral Weakly Interacting Massive Particles (WIMPs), have difficulty explaining the results of direct and indirect experimental searches for dark matter particles as well as the astronomical observations of dark-matter distribution and structure. This is why a wide variety of other solutions for the dark-matter problem are being considered and composite dark matter, made of dark atoms, is of special interest among them, challenging both experimental studies and theoretical research.

We have invited investigators to contribute original research and review articles that seek to define the possible physical nature of composite dark matter and its constituents, to stimulate the experimental searches and to suggest astrophysical tests for their effects. The collected papers in this special issue represent only a first small step in the approach to the thorough investigation of the topic of dark atoms and dark radiation, demonstrating the wide but far from complete variety of possible aspects of this problem.

The papers in this volume discuss dark-atom candidates from black-hole or mini-black-hole bound systems to atom-like bound states of new stable electrically charged particles. Pending on their type, dark atom constituents may be bound by ordinary Coulomb interaction, mirror electromagnetism, gravitation or by some new forces. Even if dark atoms act on ordinary matter through its gravity only, as is the case for mirror matter or black holes, their presence in the Universe can lead to observable consequences. The signatures of their presence can be probed in the studies of cosmic rays and gamma radiation, if these constituents possess electric charge or can decay to ordinary charged particles. In particular, the excessive intensity of the positron annihilation line in the galactic bulge, observed by INTEGRAL, can find explanation by de-excitation of dark atoms, colliding in the central part of the Galaxy. Dark-atom content may be multi-component and the existence of even a strongly subdominant dark atom component can be probed in direct and indirect dark matter searches. Moreover, in the present issue, a possibility to explain the excess of cosmic high-energy positrons, observed by PAMELA, FERMI-LAT and AMS02, via decays of metastable doubly-charged-dark-atom constituents has been proposed. Such a possibility implies a restricted range of masses for (meta)stable doubly charged particles, challenging accelerator searches.

We thank all the authors for their contributions to the present issue and express the hope that its publication will stimulate further extensive discussion of this exciting topic.