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Magnetogenesis Induced by Streaming Cosmic Rays in the Early Universe

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Cosmic rays (CRs) and magnetic fields are ubiquitous and play important roles in various astrophysical phenomena in the current universe. Magnetic fields are observed for very wide size range, that is, from planetary scale to the scale of galaxy clusters. However, the origin of magnetic fields is not fully understood.

The scenarios to generate cosmic magnetic fields are roughly divided into two branches, that is, primordial and astrophysical origin. In the primordial scenario, magnetic fields are thought to be generated during the very early phase of the universe: inflation or electroweak or QCD phase transitions. In contrast, the astrophysical scenario treats magnetogenesis after the beginning of structure formation.

Based on the recent research which shows that the first generation of CRs are accelerated in the supernova remnants of the first stars, here we focus on astrophysical magnetogenesis induced by CRs. We introduce a new generation scenario where the Biermann battery is driven by resistive heating caused by streaming CRs[1]. The strength of magnetic fields achieved by this mechanism is estimated and it is sufficient for subsequent dynamo processes to amplify it up to the level of galactic magnetic fields in the current universe. This new mechanism is compared with other previously proposed ones[2], [3]. As shown in Figure 1, our mechanism works efficiently in small-scale, low-temperature, and strongly ionized regions.

References
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[2] F. Miniati and A. R. Bell, ApJ 729, 73 (2011)
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