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Application of Normalizing Flows for Detecting Rare Events in Gamma-Ray Astronomy

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Studying the fluxes of gamma quanta (gamma rays) of various energies generated in the vicinity of galactic and metagalactic sources is one of the most promising ways to study the sources themselves, and hence the important processes occurring in the Universe. The fact is that charged cosmic rays (elementary particles and atomic nuclei) are significantly influenced by galactic and intergalactic magnetic fields, which leads to a strong distortion of their trajectories and, as a result, to the loss of any information about the place of their origin. Gamma-ray astronomy does not have these shortcomings, since photons trajectories are not distorted because of their electric neutrality and therefore indicate the direction of their origin. In many ways, these reasons have contributed in recent years to the rapid development of experimental gamma-ray astronomy in the world, see, e.g., [1,2] and references therein.
An important fact that must be taken into account is that the flux of gamma rays is very small compared to the flux of cosmic rays (electrically charged particles), the ratio is not higher than 1:1000. Because of the large background its is crucial that the methods for classification of the recorded events perform well. For this aim new algorithms are explored to enhance the separation of gamma rays and charged cosmic rays including those based on deep learning [2]. In this work we suggest a new method for detecting rare gamma quanta against the background by heavily using normalizing flow-based deep learning models. The latter are generative models that explicitly models a probability distribution by leveraging normalizing flow, which is a statistical method using the change-of-variable law of probabilities to transform a simple distribution into a complex one (see, e.g., [3] and refs therein). We consider various versions of the method based both on one-class and two-class learning (classification). Moreover in the former case there exist the possibilities to choose as the training class both gamma quanta and the charged particles. The method is intended to be applied for processing the experimental data of the TAIGA (Tunka Advanced Instrument for Gamma Astronomy and Cosmic-Ray Physics) project [4].

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