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A revised view of the ultra-high energy cosmic ray-neutrino connection: the case of gamma-ray bursts

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The origin of ultra-high energy cosmic rays (UHECRs), with energies above 10^{18} eV, remains unknown fifty years after their discovery. Gamma-ray bursts (GRBs) are arguably among the most likely sources: their high luminosities (> 10^{52} erg/s) hint at the possibility that strong magnetic fields in them are able to shock-accelerate protons to the high energies that are necessary to explain the UHECR observations. Interactions of these protons with photons in the source would lead to the production of UHE neutrinos, the detection of which would be the smoking gun of the occurrence of hadronic acceleration in the sources. Recently, km-scale neutrino telescopes such as IceCube have finally reached sensitivities that put pressure on the neutrino predictions of some of the existing GRB models. On that account, we present here a revised, self-consistent model of joint UHE proton and neutrino production at GRBs that includes a state-of-the-art, improved numerical calculation of the neutrino flux (NeuCosmA); that uses a generalised UHECR emission model where some of the protons in the sources are able to "leak out" of their magnetic confinement before having interacted; and that takes into account the energy losses of the protons during their propagation to Earth. In doing so, we also compute the production of cosmogenic neutrinos created in the interaction of the protons with the cosmological photon backgrounds. We use our predictions to take a close look at the cosmic ray-neutrino connection and find that the current UHECR observations by giant air shower detectors, together with the upper bounds on the flux of neutrinos from GRBs and of cosmogenic neutrinos, are already sufficient to put tension on several possibilities of particle emission and propagation, and to point us towards some requirements that should be fulfilled by GRBs if they are to be the sources of the UHECRs.

Author: BUSTAMANTE, Mauricio (DESY Zeuthen / Universität Würzburg)

Co-authors: Dr BAERWALD, Philipp (Penn State University); Dr WINTER, Walter (Wurzburg University)

Presenter: BUSTAMANTE, Mauricio (DESY Zeuthen / Universität Würzburg)

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