Research proposal: Modeling neutron excesses on the arrival direction data of the Pierre Auger Observatory

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1 Introduction

Even though the first ultra-high energy cosmic ray (UHECR) observations were made over 60 years ago [1], the origin of ultra-high energy cosmic rays remains unknown. Experiments such as Telescope Array [2] and the Pierre Auger Observatory [3] are designed to detect the highest energy cosmic rays.

Neutral particles can be an important tool to study sources of cosmic rays. Since they are not deflected by magnetic fields, they point directly to their sources. Neutrons and photons are expected to be produced in the vicinity of their sources in nuclear interactions and pion-production processes. Neutron production exceeds photon production in hadronic interactions because photons gain only a small fraction of the proton energy.

The Pierre Auger Collaboration has stipulated upper limits for neutron fluxes for declination values between -90° up to $+20^\circ$ in a blind search in 2012 [4]. Two years later, the Collaboration established the upper limits for candidate sources of neutrons [5]. An upcoming work of the Pierre Auger Collaboration led by one of the authors of this proposal will update the results of these searches. The candidate sources were classes of extreme astrophysical objects such as millisecond pulsars,

γ-ray pulsars, sources detected by the H.E.S.S. experiment, microquasars, and magnetars. Besides that, the Galactic plane and the Galactic center were tested as possible sources.

The main goal of the neutron search was to identify sources of UHECRs. Stipulating the upper limit on the neutron fluxes from candidate sources opens the possibility of constraining models for cosmic ray production in the EeV range.

2 Aims

The main aim of this research project is to study models of UHECR production, investigate propagation effects, and compare the results with the upper limit neutron fluxes established by UHECR experiments.

3 Methodology

Using different cosmic ray compositions in the propagation framework CRPropa [6], we aim to investigate the resulting neutron flux and compare it with the upper limit on the neutron flux estimated by UHECR experiments. Due to the neutron decay, we will restrict our analysis to Galactic sources. The main idea is to consider different neutron fractions and spectra for sources located at different positions and distances and investigate the remaining imprint of these neutrons after propagation under different assumptions to estimate what kind of scenarios could be tested by an experiment such as the Pierre Auger Observatory.

The feasibility of the project is plausible, given that two of the authors are experts on UHECR propagation and modeling using the CRPropa Monte Carlo package, and the other one is the leading author in the Pierre Auger searches for such signal. And the timing of the proposal is pertinent, given that the new result from the Pierre Auger Observatory is soon to be published, and interest in modeling it will quickly arise.

References

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