PROCEEDINGS OF SCIENCE

Beyond the Standard Model with HAWC

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The High Altitude Water Cherenkov (HAWC) Gamma-ray Observatory, located in the mountains of Mexico, has been performing an unbiased survey of the Northern sky at energies above 300 GeV since becoming fully operational in 2015. HAWC's wide field-of-view enables indirect searches for TeV-scale dark matter from diverse targets including galaxy clusters, dwarf spheroidal galaxies, the Milky Way galactic halo and the Sun. Beyond dark matter, sensitivity to transient bursts of gamma-rays provides a window into the early universe through searches for evaporating primordial black holes and its high energy reach enables searches for violations of the Lorentz symmetry. I will present an overview of beyond-the-Standard-Model searches with HAWC and present some of the world's strongest constraints on these processes at the TeV scale.

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1. HAWC

Gamma-ray astrophysics at TeV energies has the ability to constrain physics Beyond the Standard Model of particle physics (BSM) to a level not achievable with Earth-based experiments. The High Altitude Water Cherenkov (HAWC) observatory is sensitive to gamma-rays from 300 GeV to >100 TeV. It has a duty cycle of >95% and can observe 2 sr of the sky at any one time, covering 2/3 of the sky each day. This enables searches for BSM physics in rare transient events and in source regions extended across large regions of the sky. Below, we discuss 3 of the BSM searches HAWC has performed: dark matter, primordial black holes, and Lorentz invariance violations.

2. WIMP Dark Matter

HAWC has placed competitive constraints on dark matter models which annihilate or decay into Standard Model particles. These dark matter models, called Weakly Interacting Massive Particles (WIMPs), are a leading dark matter candidate and one of the best-studied dark matter models in the literature. HAWC in particular is sensitive to WIMPs with masses from TeV - hundreds of TeV.

Due to its wide field-of-view and large sky coverage, HAWC has been able to search for signals of WIMP dark matter in many astrophysical objects, including:

- Dwarf Spheroidal Galaxies [6, 9]
  - Including targeted searches for gamma-ray lines [9] and joint analysis between HAWC and 4 other gamma-ray observatories [1]
- Dwarf Irregular Galaxies [11]
- The Virgo Galaxy Cluster [13]
- The Milky Way Galactic halo [2, 10]
- Dark Matter structures [3]
- The Andromeda Galaxy [7]
- Diffuse gamma rays [4]
- The Sun [5]

Particularly for WIMP masses above 100 TeV, the HAWC searches provide some of the strongest constraints on WIMP annihilation and decay.

3. Primordial Black Holes

Primordial Black Holes (PBHs) are thought to be produced during the early universe and may be a candidate for dark matter. As these objects age, they emit Hawking radiation which increases in intensity until they finally evaporate. By searching for these evaporating PBHs, which would be observed as TeV transient events, HAWC can place strong limits on the density of PBHs in the Galaxy [8].

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4. Lorentz Invariance Violations

Violation of Lorentz Invariance (LIV) are often features of BSM models for Grand Unified Theories which combine gravity with the Standard Model. Even if LIV is realized at an energy scale above the Plank scale, the long distances to astrophysical objects can produce observable effects at TeV energies. By looking for TeV photons up to the highest energies, HAWC is able to constrain the energy scales at which LIV may be possible [12].

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