PROCEEDINGS OF SCIENCE

# Beyond the Standard Model with SWGO

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Observations of very high-energy (>1 TeV) cosmic gamma rays are a powerful, unique tool to explore new physics beyond the Standard Model. The Southern Wide-field Gamma-Ray Observatory (SWGO), a next-generation experiment looking for cosmic gamma rays, will be situated in the Southern hemisphere with gamma-ray sensitivity up to hundreds of TeV. This observatory will have an order of magnitude better sensitivity than the current-generation High Altitude Water Cherenkov (HAWC) observatory. Because of its increased sensitivity and location in the Southern hemisphere, SWGO will be ideally situated to look for dark matter signals from the Milky Way. Specifically, SWGO will be able to search for dark matter signals a thousand times dimmer than those observable with HAWC. SWGO will also be well-situated to search for other phenomena Beyond-the-Standard-Model, including Primordial Black Holes, Axion-like Particles, and Violations of Lorentz Invariance. In this presentation, I will discuss the prospects for SWGO as a leading observatory in next-generation searches for physics beyond the Standard Model.

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## 1. SWGO

TeV-energy gamma-ray astrophysics can constrain Beyond the Standard Model (BSM) physics to a level not achievable with Earth-based experiments. In particular, wide field-of-view instruments have the capability to search for these BSM signals in a wide variety of sources and models. The Southern Wide-field Gamma-ray Observatory (SWGO) is an upcoming TeV gamma-ray observatory with such a wide field-of-view, which will offer a unique and sensitive look into BSM physics in the cosmos.

SWGO, to begin construction in the mid 2020s in the mountains of South America, will be sensitive to gamma-rays from 500 GeV to >2 PeV [1, 4]. It will observe the overhead sky nearly continuously, covering its full observation range of the sky (with several sr instantaneous field-of-view) each day. The high energy reach and wide sky coverage of SWGO will be excellent for searches of BSM including signatures of particle dark matter, Primordial Black Holes, Axion-like Particles, and violations of Lorentz Invariance.

## 2. WIMP Dark Matter

SWGO will be situated in the Southern Hemisphere, which will provide a good location for dark matter searches in 2 ways. First, the Galactic center will be near the core sensitivity region of the sky for SWGO, which is where the largest, nearest dark matter overdensity exists in the sky. Second, the Southern sky has never been observed by a wide-field TeV instrument before, but hundreds of dwarf galaxies are expected to be found in the Southern hemisphere with current and upcoming observatories [2]. This means that SWGO will have the first TeV observations of most of these dark matter-dense regions, enabling unique discovery science.

The TeV energy range enables searches for signatures of Weakly Interacting Massive Particle (WIMP) dark matter, one of the best-motivated and most-studied dark matter models. With its observations of the Southern sky, SWGO will be able to probe thermal WIMP dark matter up to its theoretical maximum mass of $\sim$ 100 TeV [6]. This search is crucial to a well-informed understanding of the thermal WIMPs over their full theoretical range.

Additionally, with its wide field-of-view, SWGO will be able to look for signatures of WIMP dark matter in a large variety of regions of dark matter overdensities and astrophysical environments, including:

- Dwarf Spheroidal Galaxies
- Dwarf Irregular Galaxies
- Galaxy Clusters
- The Magellanic clouds (depending on the chosen SWGO site location)
- The Milky Way Galactic halo and its Dark Matter structures
- Diffuse gamma rays
- The Sun

## 3. Primordial Black Holes

Primordial Black Holes (PBHs) are black holes created during the early universe, some of which would be evaporating today in bursts of short, intense transient emissions of gamma rays. More massive, stable counterparts to these evaporating PBHs are a candidate for some of the dark matter density of the universe. With its wide field-of-view, SWGO will be uniquely capable of seeing these evaporating transients over several sr of the sky at any one time. These searches will be 1-2 orders of magnitude more sensitive to PBH signals than those from current-generation TeV observatories [5].

## 4. Lorentz Invariance Violations

Violation of Lorentz Invariance (LIV) often arises in some String theories and other Grand Unified theories (GUTs). However, even though these violations occur at energies near the Planck energy, they do have some small energy dependence down to TeV scales. Due to the long distances and correspondingly long propagation times of the cosmic sources of TeV gamma-rays, these tiny effects can make an observably large difference in the timing, flux, and even the existence of cosmic gamma rays at TeV energies. By pushing the search for gamma ray up to multiple PeV and its ability to search in many locations across the sky for these small observable effects, SWGO will be able to place stringent limits on these GUT and String theory models of the universe [1, 3].

## 5. Axion-like Particles

Axions are particles theorized to exist which solve the so-called Strong CP Problem of the Standard Model. Though axions have a well-defined relation between their coupling constants and their mass, they also can imply the existence of Axion-like particles (ALPs) which do not have these relations but may be the dark matter content of the universe.

Similar to LIV searches, ALP searches in the TeV typically come from objects at extragalactic distances from which very few TeV photons are expected to propagate to Earth unimpeded. SWGO will have the ability to probe energies up to several PeV and look at many such extragalactic objects across a region of the sky which has never been probed up to such high energies. Therefore, SWGO has a unique discovery space in which to detect the effects of ALPs, often to a level unachievable with ALP searches in terrestrial laboratories [1, 3].

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