Axions and HAYSTAC Experiment

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Axions and HAYSTAC Experiment Latest News

The HAYSTAC results, published in Physical Review Letters, marked a technological advance, even though no axions were detected. The experiment significantly expanded the parameter space of axion mass and coupling strength.

What are Axions?

- **Axions** are **hypothetical subatomic particles** originally proposed in the **late 1970s** to explain the **strong CP problem** in quantum chromodynamics (QCD). They later emerged as one of the **most promising candidates for dark matter**.
- The axion's role was to **suppress CP-violating terms** in QCD by dynamically adjusting the **theta parameter (θ)** to nearly zero.

Axions as Dark Matter Candidates

- Over time, **axions emerged as a leading dark matter candidate** due to their unique properties:
    - **Electromagnetically neutral**,

    - **Extremely light**,
    - **Very weak interaction** with ordinary matter and radiation.
- They are hypothesised to make up **Cold Dark Matter (CDM)**—the dominant form of dark matter thought to constitute ~85% of the universe's matter content.
- Pioneering work by **Sikivie, Wilczek, Dine, Preskill**, and others showed that **cosmological production of axions** in the early universe could match observed **dark matter density**.

What is HAYSTAC?

- The **HAYSTAC experiment** (**Haloscope At Yale Sensitive To Axion Cold dark matter**) is a collaborative initiative between **Yale, Berkeley, and Johns Hopkins**, aimed at **directly detecting axions** by exploiting their potential to convert into photons within a **strong magnetic field**.
- The experiment uses a **haloscope**—a special type of detector designed by **Pierre Sikivie**—which incorporates a **microwave cavity** inside a **powerful magnetic field**.
- In its **Phase II**, HAYSTAC conducted the **widest frequency search** for dark matter axions to date. It introduced **quantum squeezing techniques** to reduce **quantum noise**, thereby enhancing the **sensitivity** of its haloscope detector.
- The **HAYSTAC experiment and Advanced LIGO** are currently the only two major physics experiments utilising **quantum squeezing** to improve precision in measurements.
- **Quantum squeezing** involves manipulating the uncertainty in quantum states to suppress **random fluctuations**, which improves the signal-to-noise ratio in **weak signal detection**, especially important for identifying rare particles like axions.

Axions and HAYSTAC Experiment FAQs

Q1: What are axions?
Ans: Axions are hypothetical subatomic particles proposed as a solution to the strong CP problem in quantum chromodynamics and are considered candidates for dark matter.

Q2: What is the HAYSTAC experiment?
Ans: HAYSTAC (Haloscope at Yale Sensitive to Axion CDM) is a U.S.-based experiment designed to detect axions as a form of cold dark matter using a microwave cavity and magnetic fields.

Q3: How does HAYSTAC aim to detect axions?
Ans: It uses resonant conversion of axions into microwave photons in a strong magnetic field, leveraging the axion-photon coupling.

Source: PHY
