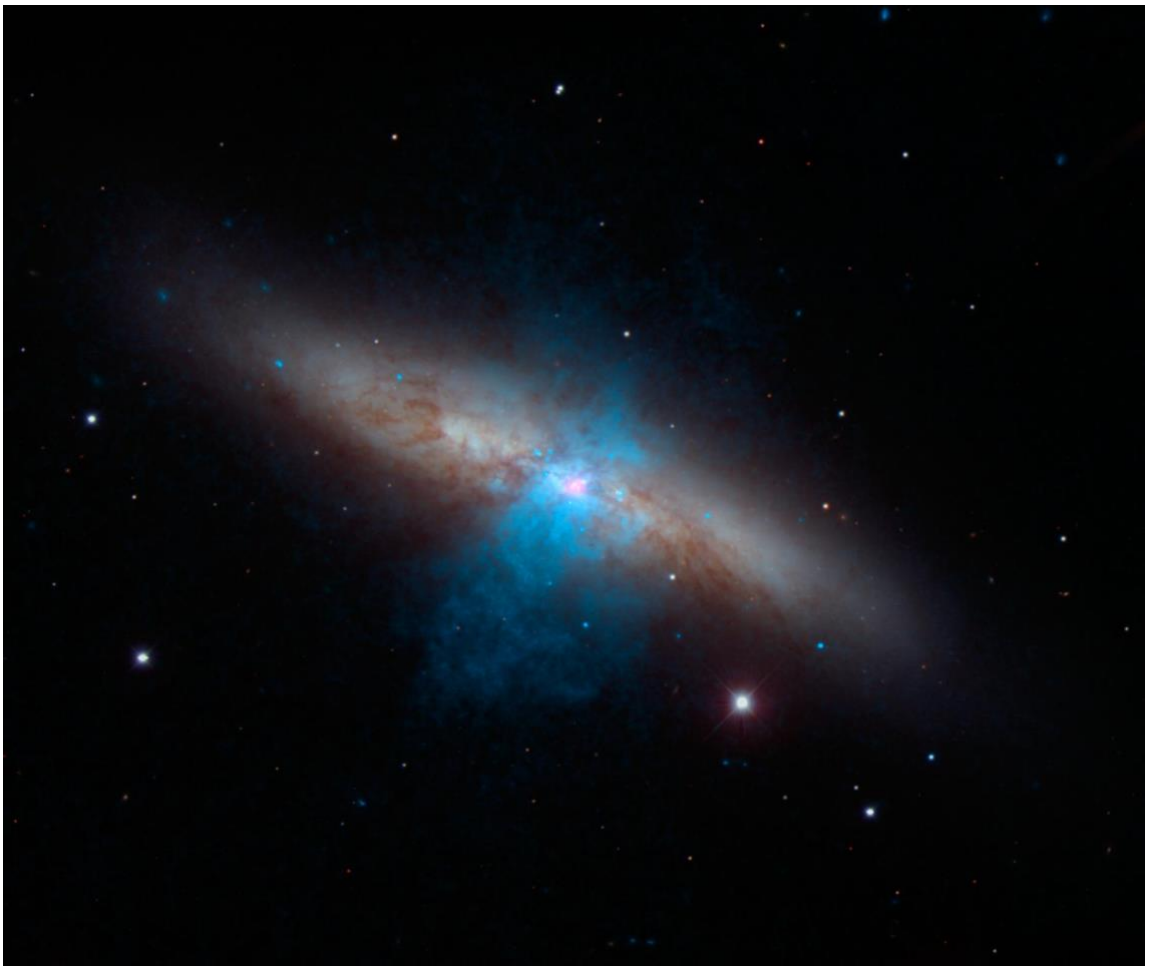
A New Type of Low-Mass Dark Matter Could Be Behind Two of the Most Mysterious Phenomena in Our Galaxy

- A recent study led by the IFT suggests that the annihilation of low-mass dark matter, below the gigaelectronvolt range, may be responsible for an unusual hydrogen ionization phenomenon in the Milky Way.

- Additionally, researchers propose that this "sub-GeV dark matter" could be related to another mysterious anomaly associated with electron-positron annihilation in the Center of our Galaxy.



High-energy X-rays emitted by a pulsar in the Messier 82 galaxy illustrate the type of extreme phenomena that could be related to the ionization of hydrogen in the center of our galaxy. / NASA/JPL-Caltech/SAO/NOAO

Madrid, January 16th, 2025.- A recent investigation with Spanish participation has proposed an innovative explanation for a mysterious phenomenon occurring in the center of our galaxy. **A specific type of low-mass dark matter could be behind the anomalous ionization of hydrogen**, which is usually observed in a neutral state and cannot be explained by other phenomena, such as cosmic rays.

The study has been led by Pedro De la Torre Luque, a researcher at the Institute of Theoretical Physics (UAM-CSIC); Shyam Balaji, from King's College London; and Joseph Silk, an emeritus member of New College, Oxford, and even considered as Nobel Prize candidate

Specifically, the researchers suggest that this ionization could result from the annihilation of low-mass dark matter, particularly, with sub-GeV mass (below the gigaelectronvolt range).

The phenomenon of hydrogen ionization in the center of our galaxy, in the so-called Central Molecular Zone of the Milky Way, has puzzled scientists for years. In this region, hydrogen is found in high proportions, which should normally be in a neutral state. However, **scientists have detected that this hydrogen is in an ionized state in amounts much higher than expected: that is, its atoms have lost electrons**, implying the presence of a constant energy source. This ionization cannot be explained by usual processes, such as cosmic rays, leading researchers to seek new explanations. The study concludes that **the cause could be low-mass dark matter**, a mysterious form of matter that we have yet to directly observe, in a much lower mass range than traditionally considered.

Unlike WIMPs (weakly interacting massive particles), the traditional candidate for dark matter, this research focuses on lower mass dark matter, in the range of megaelectronvolts (MeV). This "sub-GeV dark matter" **could emit light particles such as electrons and photons.**

The Mysterious Connection with Electron-Positron Annihilation in the Galactic Center

Another fascinating aspect of this study is the possible connection with the 511-kiloelectronvolt (keV) emission line, associated with positron annihilation in the galactic center. Positrons are the antiparticles of electrons, and when a positron encounters an electron, both annihilate, producing two photons, each with an energy of 511 keV. This line is like a specific "signature" indicating the presence of positrons in large quantities.

The study suggests that the same low-mass dark matter that could be ionizing hydrogen in the Central Molecular Zone **might also be responsible for generating pairs of electrons and positrons that annihilate to produce the 511 keV emission line.** If low-mass dark matter annihilates in the galactic center, it could produce electron-positron pairs. These positrons would then annihilate with electrons, thereby generating the characteristic 511 keV emission line.

This enigma has been a source of debate in the scientific community, and the hypothesis that both observations (hydrogen ionization and the 511 keV emission line) could be related adds a new level of interest to the study.

Compatibility with Other Theoretical Models

According to Pedro de la Torre Luque, IFT researcher and one of the study's main authors, the proposed hypothesis has no limitations or restrictions: "The model is consistent with certain dark matter distribution profiles that differ from the standard Navarro-Frenk-White model. Moreover, this approach avoids cosmological constraints and does not generate detectable secondary emissions at other wavelengths, such as radio, X-rays, or gamma rays, making it even more attractive from a theoretical standpoint."

De la Torre Luque, P., Balaji, S., & Silk, J. (2024). Anomalous ionization in the central molecular zone by sub-GeV dark matter. arXiv preprint arXiv:2409.07515. https://doi.org/10.48550/arXiv.2409.07515

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The IFT is part of the strategic line `Theoretical Physics and Mathematics´ of the Campus of International Excellence (CEI) UAM+CSIC established in 2009. Since 2012, it is credited as Severo Ochoa Centre of Excellence. Besides purely scientific activity, in the IFT is also conducted intensive training tasks of young researchers and professionals through the graduate program in Theoretical Physics with mention of excellence from the CEI and the Ministry of Education. In addition, the Institute carries out the important task of transferring knowledge to society through several outreach programs.

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