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One star could finally reveal the nature of what does lie at the Milky Way center

Press release

A new study deepens on the nature of the compact object sitting at our Galaxy center, SgrA*, by analyzing the astrometric data of one of the closest and long-studied stars that orbit around it. The international team of researchers from ICRA-ICRANet and CONICET-UNLP has found that besides the traditional black hole (BH) hypothesis, a dense concentration of dark matter (DM) made of fermions (called *darkinos*) can explain the detailed data (positions and velocities) of the star S2. The work provides a way to distinguish observationally between these two scenarios using the precession of the S2 orbit, very much in the same way that the theory of general relativity was proven using the precession of Mercury's orbit around the Sun. This new article, published in the Monthly Notices of the Royal Astronomical Society Letters [1], holds relevant implications about the nature and mass of the dark matter particles.

For about three decades, two independent observational campaigns have monitored a cluster of young and bright stars orbiting the central parsec of our Galaxy to constrain the mass and nature of the massive object harbored at the center. These precise and accurate measurements have been possible thanks to the most powerful telescopes on earth. This achievement led to the Nobel Prize in Physics in 2020 awarded to Reinhard Genzel and Andrea Ghez: *for the discovery of a supermassive compact object at the center of our galaxy.*

Traditionally, a classical BH has been the most accepted hypothesis for the nature of SgrA*. The reason for this is that the orbits of the few detected S-stars are nearly perfect ellipses, implying the existence of a very compact object placed at its focus. Einstein's theory of general relativity predicts that the orbits cannot be Keplerian because there is a precession of the periapsis. The new work demonstrates that this effect is also present in the case of the DM core model and that its entity agrees with all publicly available data that shows the existence of this relativistic pattern in the S2 orbit. The article predicts that the two scenarios on the nature of SgrA* could be discriminated by measuring the precession of S2 around the next apocenter passage that will occur in 2026. The reason behind this difference is that while the BH predicts a unique prograde precession, in the DM scenario, it can be either retrograde or prograde, depending on the amount of DM filling the orbit, which depends on the mass of the *darkinos*.

A remarkable aspect of this novel DM interpretation of SgrA* is that the DM distribution is not constrained to the core of the Galaxy. The DM configuration extends to the outskirts of the Galaxy, forming a dilute halo that explains the circular velocity of far away objects as welll!. This result, together with a related study (see https://ras.ac.uk/news-and-press/research-highlights/new-study-suggests-supermassive-black-holes-could-form-dark) obtained by some of the research team, hints towards a paradigm shift in the field of DM halos and supermassive BH formation. It suggests that non-active galaxies as our own host dense DM concentrations at their centers, while more massive and active-galaxies, host supermassive BHs that has been formed from the gravitational collapse of these DM cores.

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[1] C. R. Argüelles, M. F. Mestre, E. A. Becerra-Vergara, V. Crespi, A. Krut, J. A. Rueda, and R. Ruffini, Monthly Notices of the Royal Astronomical Society: Letters **511**, L35 (2021), arXiv:2109.10729, URL `https://doi.org/10.1093/mnrasl/slab126`.
[2] T. Do, A. Hees, A. Ghez, G. D. Martinez, D. S. Chu, S. Jia, S. Sakai, J. R. Lu, A. K. Gautam, K. K. O'Neil, et al., Science **365**, 664 (2019), 1907.10731.

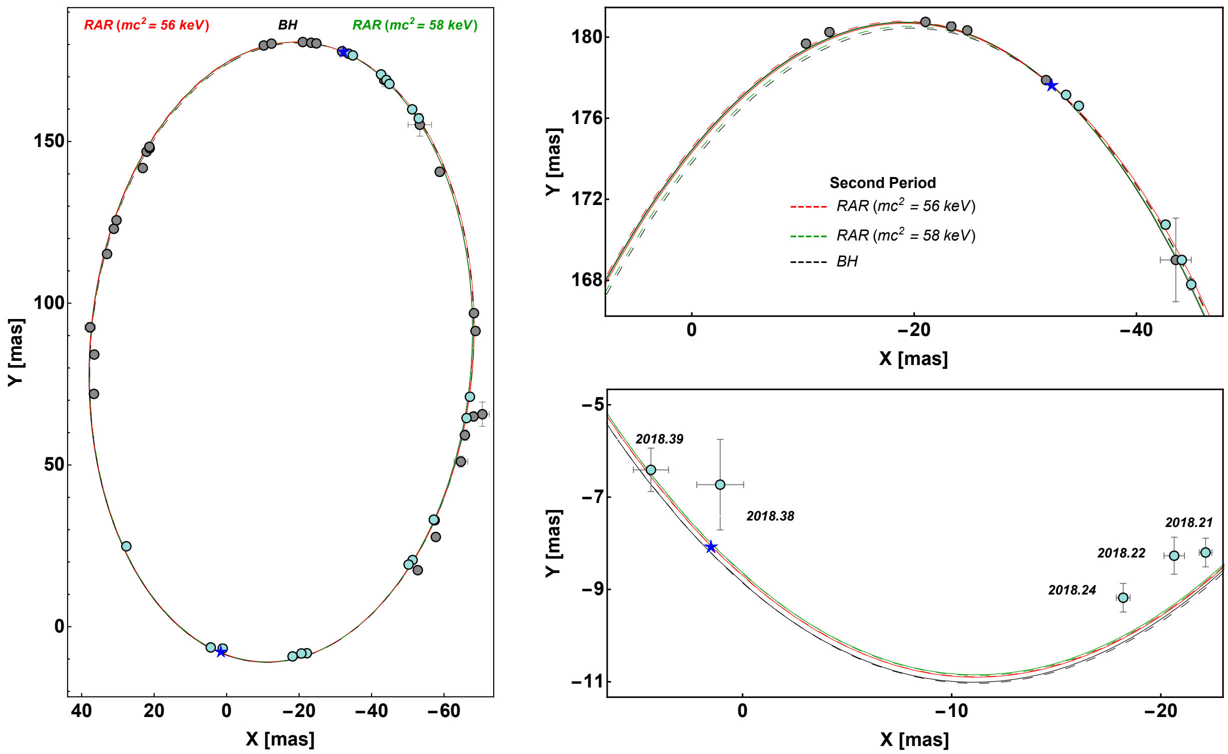

FIG. 1. Figure taken from [1] with the kind permission of the authors. Relativistic precession of S2 in the projected orbit on the plane of the sky as predicted in the BH and RAR DM models. While it is prograde for the BH and RAR ($m = 58$ keV/c^2) (in dashed black and green respectively), it is retrograde for the RAR DM model ($m = 56$ keV/c^2) (in dashed red). The solid (theoretical) curves and gray (data) points correspond to the first period (≈ 1994–2010) while the dashed (theoretical) curves and cyan (data) points to the second period (≈ 2010–2026). *Right panels*: zoom of the region around apocentre *(top panel)* and pericentre *(bottom panel)*. The astrometric measurements are taken from Do et al. [2].

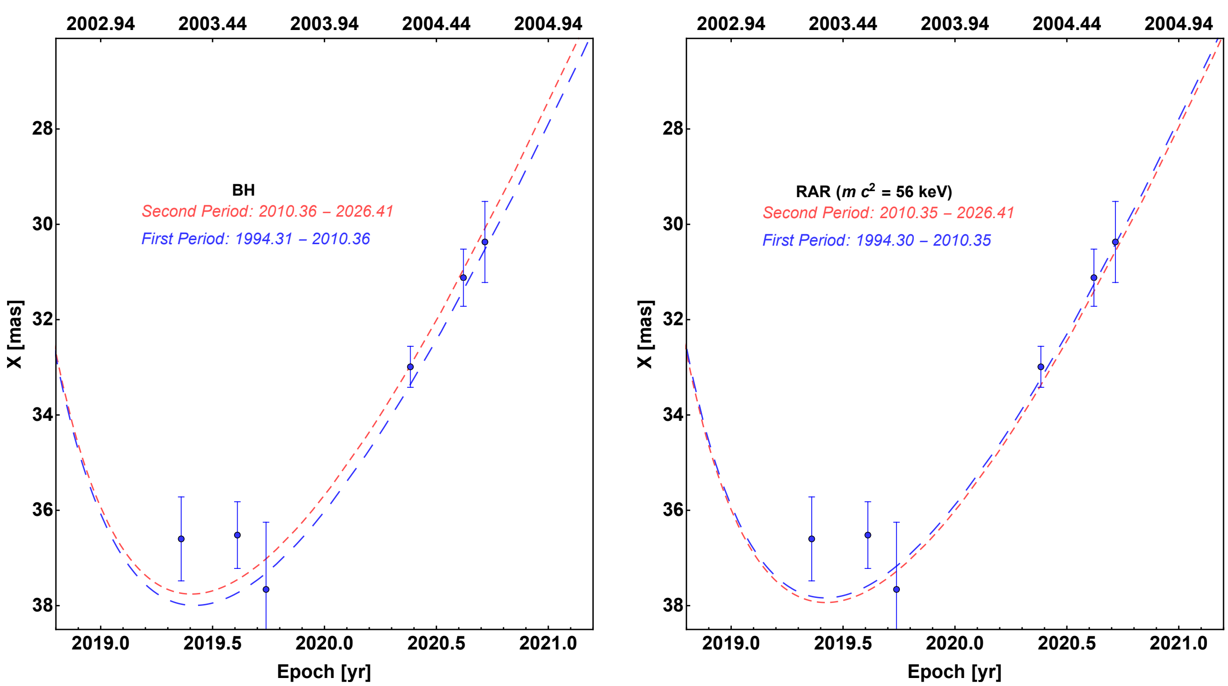

FIG. 2. Relativistic precession of S2 as manifested in the right ascension as a function of time after last pericentre passage, where effects are more prominent. BH model (*Left panel*) and RAR model for $m = 56$ keV/c^2 (*Right panel*).