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New Constraints on Dark Matter from Cosmic Rays and Stars

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We explore novel astrophysical probes of Dark Matter in the dense spike environments surrounding supermassive black holes. First, we analyze the effects of elastic DM scattering with protons and electrons on the energy budget of observed stars near Sagittarius A*. By suppressing or enhancing their luminosity, we derive constraints on DM-electron and DM-proton cross sections. These constraints apply robustly across a broad DM mass range and halo profile assumptions, offering complementary sensitivity to parameter space relevant for freeze-in production and cosmic-ray boosted DM. Second, we introduce a method leveraging the survivability of ultra-high-energy cosmic rays accelerated near supermassive black holes: large DM–nucleon cross sections would fragment heavy nuclei, preventing them from reaching observed energies. Applying acceleration requirements, we set stringent bounds on DM–proton interactions for DM masses between 100 keV and 1 GeV. Together, these approaches highlight the potential of extreme astrophysical environments to place competitive and complementary constraints on dark matter interactions beyond current terrestrial and cosmological limits.

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