New Constraints on Cosmic Particle Populations at the Galactic Center using X-ray Observations of the Molecular Cloud Sagittarius B2

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Located ~100 pc from the dynamic center of the Milky Way, the molecular cloud Sagittarius B2 (Sgr B2) is the most massive such object in the Galactic Center region. In X-rays, Sgr B2 shows a prominent neutral Fe Kα line at 6.4 keV and continuum emission beyond 10 keV, indicating high-energy, non-thermal processes in the cloud. The Sgr B2 complex is an X-ray reflection nebula whose total emissions have decreased since the year 2001 as it reprocesses what are likely one or more past energetic outbursts from the supermassive black hole Sagittarius A* (Sgr A*). The X-ray reflection model explains the observed time-variability of the Fe Kα and hard X-ray emissions, and it provides a window into the luminous history of our nearest supermassive black hole. In light of evidence of elevated cosmic particle populations in the Galactic Center, recent interest has also focused on X-rays from Sgr B2 as a probe of low-energy (sub-GeV) cosmic particles. In contrast to X-ray reflection, in this case we can assume that the X-ray flux contribution from ionization by low-energy cosmic rays (LECR) is constant in time, such that upper limits on LECR populations may be obtained using the lowest flux levels observed from the cloud.

In this contribution, we present the most recent and correspondingly least bright *NuSTAR* and *XMM-Newton* observations of Sgr B2, which were taken jointly in 2018. Using these observations, we aim to understand if the Fe Kα emissions have continued to decrease through 2018, consistent with still being dominated by X-ray reprocessing, or conversely if they have reached a constant level, consistent with the 2018 emissions predominantly arising from cosmic ray interactions. This work is based on both image analysis and spectral analysis of the dense core, the intermediate-density envelope, and diffuse regions of the cloud. Spectral analysis reveals that the total neutral Fe Kα emissions from the core and envelope have continued to decrease, down by ~50% since the next most recent XMM-Newton observation, from 2012. Thus the spectra and light curve are consistent with the 2018 emissions arising either primarily from cosmic ray interactions or primarily from X-ray reflection. Since the total flux in the 2018 observations is the lowest yet observed, we are able to set the best upper limits on cosmic ray interactions within Sgr B2.

The observations also reveal bright substructures within the diffuse region of the Sgr B complex, including features which are newly bright neutral Fe Kα emissions in the 2018 observations. This complicates the picture of a uniformly decreasing flux from Sgr B2, and highlights the reality that, at least for certain regions of the cloud, emissions will be dominated by X-ray reflection from Sgr A* into the future. These bright substructures must be accounted for in order to set best limits on LECR interactions.

After evaluating the Fe Kα line flux from different regions of the cloud, we considered models of ambient LECR transport into Sgr B2. Such transport is highly model dependent and the subject of much theoretic work, however decreased ionization rates inside dense clouds imply that LECR do not fully traverse clouds. The measured Fe Kα flux were comparable to that expected based on a model of ambient LECR populations and LECR transport that could simultaneously explain the relative ionization inside and outside of Sgr B2.