APR16-2016-000349

Abstract for an Invited Paper
for the APR16 Meeting of
the American Physical Society

NuSTAR results from the Galactic Center – diffuse emission

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The Nuclear Spectroscopic Telescope Array (NuSTAR) was launched in June 2012. It carried the first true, hard X-ray (>˜10 keV-79 keV) focusing telescopes into orbit. Its twin telescopes provide 10 times better angular resolution and 100 times better sensitivity than previously obtainable in the hard X-ray band. Consequently NuSTAR is able to resolve faint diffuse structures whose hard X-rays offer insight into some of the most energetic processes in the Galactic Center. One of the surprising discoveries that NuSTAR made in the Galactic Center is the central hard X-ray emission (CHXE). The CHXE is a diffuse emission detected from ˜10 keV to beyond 50 keV in X-ray energy, and extending spatially over a region ˜8 parsecs x ˜4 parsecs in and out of the plane of the galaxy respectively, and centered on the supermassive black hole Sgr A*. The CHXE was speculated to be due to a large population of unresolved black hole X-ray binaries, millisecond pulsars (MSP), a class of highly magnetized white dwarf binaries called intermediate polars, or to particle outflows from Sgr A*. The presence of an unexpectedly large population of MSP in the Galactic Center would be particularly interesting, since MSP emitting at higher energies and over a much larger region have been posited to be the origin of the gamma-ray emission that is also ascribed to dark matter annihilation in the galaxy. In addition, the connection of the CHXE to the ˜9000 unidentified X-ray sources in the central ˜100 pc detected by the Chandra Observatory, to the soft X-ray emission detected by the Chandra and XMM/Newton observatories in the Galactic Center, and to the hard X-ray emission detected by both the RXTE and INTEGRAL observatories in the Galactic Ridge, is unclear. I review these results and present recent NuSTAR observations that potentially resolve the origin of the CHXE and point to a unified origin for all these X-ray emissions. Two other noteworthy classes of diffuse structures in the Galactic Center will be discussed. The first class are the giant molecular clouds, which are strong hard X-ray emitters. These hard X-rays are believed to be produced when one or more giant outbursts from the supermassive black hole Sgr A*, more than a century ago, resulted in hard X-rays being reflected from the clouds, and detected only today. I discuss how these hard X-rays are used to elucidate the past history of the supermassive black hole, and to compare and contrast these past giant outbursts with those observed from the supermassive black hole more recently. The second class are non-thermal filaments, magnetized structures with both radio and soft X-ray emission that have now been shown by NuSTAR to be hard X-ray emitters. The electrons generating the hard X-rays observed in one of these filaments are the most energetic that have been observed in the galaxy. The filaments are a heterogeneous class of hard X-ray emitters, and the various mechanisms by which they produce hard X-ray emission will be discussed. Future NuSTAR observations of the Galactic Center with NuSTAR will also be discussed.