Analysis of NuSTAR X-ray Observations of Galactic Center Filament F.0173-0.413

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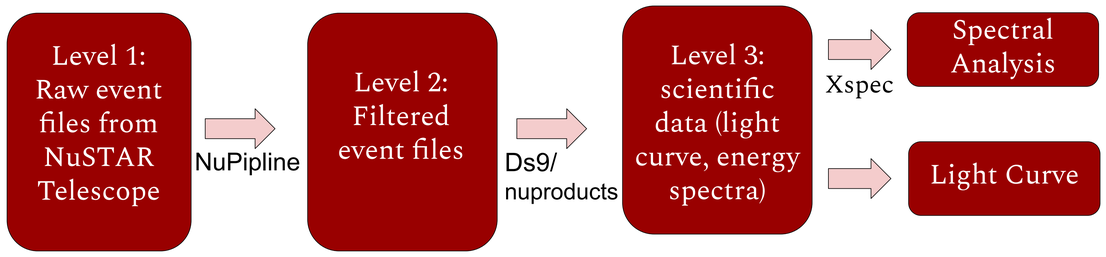
Abstract: At the center of our galaxy there is a lot of activity happening, including a supermassive black hole: Sagittarius A*, massive stellar clusters, and a molecular cloud. Among these objects are threads of light known as filaments. Galactic center filaments were first discovered through radio observations by Farhad Yusef-Zadeh in 1984. They have typically only been observed in either the radio or the X-ray energy bands, and only a handful have been observed in both. This summer, we analyzed data from the NuSTAR X-ray telescope observation of filament F.0173-0.413, as well a joint spectral analysis of the NuSTAR data combined with Chandra telescope data. The results show that the filament, which was uniquely linear and observed in both energy bands, fit the optically thin thermal model, assuming collisionally ionized plasma.

Methods and Procedure:

We analyzed data produced by the NuSTAR telescope. The procedure used to clean our raw data files is shown in the chart below:



As shown above, we ran the raw event files into a tool called NuPipeline which filters the data. Then we put them through an imaging tool (shown in Figure 1) to select our filament region and background region. This is what was then run through a coding package to produce scientific data.

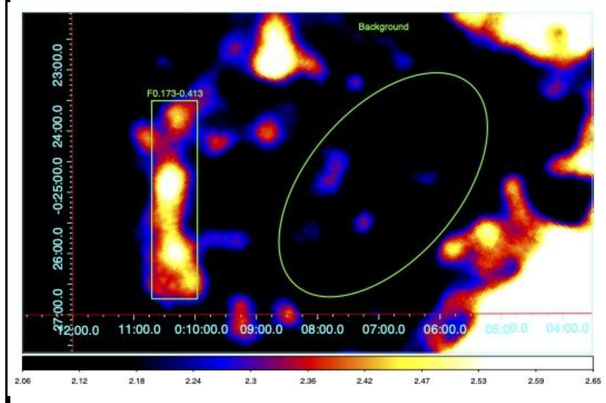


Figure 1: DS9 imaging of the NuSTAR X-ray observation of the filament.

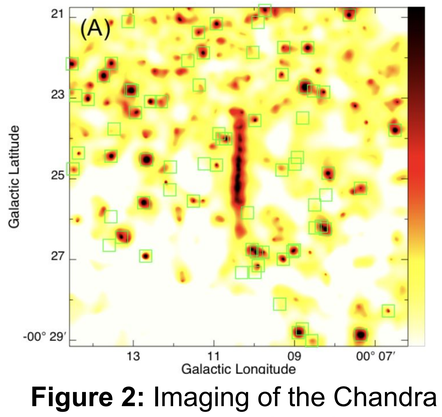


Figure 2: Imaging of the Chandra X-ray observation of the filament.

We were now able to extract the light curve files (measuring the intensity of the photons) and do a spectral analysis to understand the relationship between photon intensity and energy.

Results:

The spectral analysis of the NuSTAR data showed a fit with the optically thin thermal model known as APEC. This model assumes collisionally ionized plasma within the source. The joint spectral analysis with the Chandra data was consistent with the initial NuSTAR results.

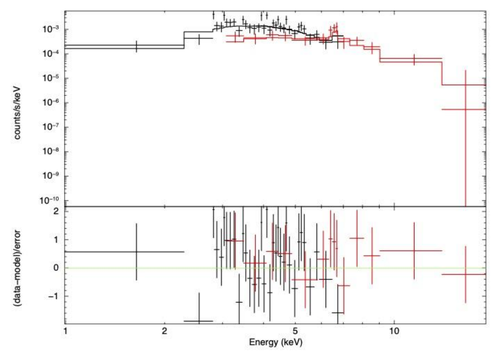
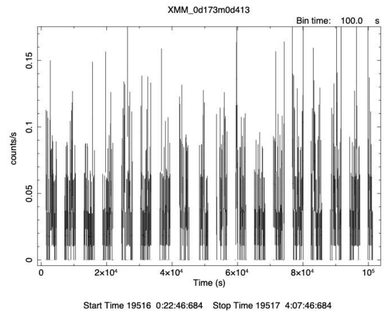


Figure 3: Spectral Plot of joint analysis. The red represents the NuSTAR data while the black represents Chandra data.

Parameter:	Value:	Error:
Constant factor: (nustar)	0.90	0.65 to 1.20
nH (10^{22}cm^{-2})	11.92	8.46 to 17.41
kT(keV)	4.17	2.42 to 7.67
Abundance	0.32	0 to 0.87
Flux(chandra): 2-10 keV (ergs/cm^2/s)	1.32e-13	8.54e-14 to 1.39e-13
Flux(nustar): 2-10 keV (ergs/cm^2/s)	1.19e-13	7.252e-14 to 1.24e-13
Flux(chandra): 1-20 keV (ergs/cm^2/s)	1.38e-13	8.498e-14 to 1.41e-13
Flux(nustar): 1-20 keV (ergs/cm^2/s)	1.40e-13	8.236e-14 to 1.46e-13
Luminosity (ergs/s): 2-10 keV (nustar)	9.35e32	5.695e32 to 9.739e32
Luminosity (ergs/s): 1-20 keV (nustar)	1.099e33	6.469e32 to 1.147e33
χ^2/dof	94.99/94	–

Figure 4: Joint Spectral Analysis results. Hydrogen abundance, temperature, Flux, and Luminosity of the source is shown.

The light curve below shows that this source is a stable source.



χ^2	559.1
Average count rate	0.357e-01

Conclusion:

The results of our research showed that F.0173-0.143 is a thermal source with collisionally ionized plasma activity. We don't know where exactly the filament comes from, but we can rule out a Pulsar Wind Nebula (PWN) source scenario due to no point source. The most likely explanation is the cosmic ray outflow scenario from the nearby supermassive black hole Sgr A*. Observations of these galactic center filaments are still relatively new, so our research adds to a much larger effort to understand these objects.