Detection of Seven High-Energy X-ray Flares from the Galactic Center Supermassive Black Hole Sgr A*  

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Supermassive Black Hole Sagittarius A* (Sgr A*)

- Located at the dynamical center of the Milky Way Galaxy
- Closest supermassive black hole with 4 million times the mass of Sun
- One of the most inactive supermassive black holes known

Credit: Wide-field X-ray: NASA/CXC/SAO, Close-up X-ray: NASA/UMass/D.Wang et al., IR: NASA/STScI
Mysterious Sgr A* X-ray Flares

- Sgr A* flares occur on a daily basis.
- Each flare lasts up to a few hours.
- During a flare, X-ray luminosity of Sgr A* increases by a factor of up to ~600.
- Ideal probe of physical condition at merely a few gravitational radii from the black hole.

Physical origin: magnetic phenomena involving a plasma blob orbiting the black hole.

Haggard et al. 2019

NuSTAR Sgr A* Observation Campaign from 2012-2022

<table>
<thead>
<tr>
<th>Year</th>
<th>Instruments</th>
<th>NuSTAR Exposure</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012</td>
<td>NuSTAR + Chandra/Keck</td>
<td>335 ks</td>
</tr>
<tr>
<td>2013</td>
<td>NuSTAR</td>
<td>367 ks</td>
</tr>
<tr>
<td>2014</td>
<td>NuSTAR + Chandra/Spitzer/XMM</td>
<td>227 ks</td>
</tr>
<tr>
<td>2015</td>
<td>NuSTAR + XMM</td>
<td>92 ks</td>
</tr>
<tr>
<td>2016</td>
<td>NuSTAR</td>
<td>151 ks</td>
</tr>
<tr>
<td>2017</td>
<td>NuSTAR + EHT/Chandra</td>
<td>196 ks</td>
</tr>
<tr>
<td>2018</td>
<td>NuSTAR + EHT/Chandra</td>
<td>81 ks</td>
</tr>
<tr>
<td>2019</td>
<td>NuSTAR + Gravity/Chandra/XMM</td>
<td>466 ks</td>
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<tr>
<td>2020</td>
<td>NuSTAR + Gravity/EHT</td>
<td>72 ks</td>
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<tr>
<td>2021</td>
<td>NuSTAR + EHT</td>
<td>276 ks</td>
</tr>
<tr>
<td>2022</td>
<td>NuSTAR + EHT</td>
<td>157 ks</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2.3 Ms</strong></td>
<td></td>
</tr>
</tbody>
</table>
Seven New Sgr A* Flares Detected during 2016-2022

Flare 1 (8-20-2019)

Flare 2 (4-19-2022)

Flare 3 (4-24-2018)
Do Bright Flares and Faint Flares Share the Same Origin?

- Investigated flare spectra dependence on their brightness
- Found a trend that brighter flares have harder spectra at $2\sigma$ confidence level
- It suggests that bright and faint flares might have different origins, but it calls for more flare samples to confirm or reject this trend.

**Graph:**

- **Black:** 7 hard X-ray Sgr A* flares during 2012-2015 (Zhang et al. 2017)
- **Red:** 7 newly detected hard X-ray Sgr A* flares during 2016-2022 (this work)

**Equation:**

$$y = -0.11x + 2.51$$
Summary

• Detected 7 bright high-energy X-ray Sgr A* flares using NuSTAR X-ray observations from 2016 to 2022, totaling 1.3 Ms exposure time.
• Doubled previously known bright Sgr A* high-energy X-ray flares.
• Found a trend that bright flares have harder spectra compared to fainter flares, which needs more data to confirm.

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