Beholding black hole power with the Accretion Explorer Interferometer (AEI)

PI & Contact: Kim Weaver (NASA/GSFC); 301-452-3065; **Kimberly.A.Weaver@nasa.gov**

Summary

AEI will revolutionize studies of black holes providing clear X-ray images of their accretion that compliment breakthrough radio images obtained with the event horizon telescope.

Innovation

- **Achieve:** μ arcsec resolution with interferometer design
- **Five to six orders of magnitude improvement:** over current state-of-the art X-ray imaging
- **Feasible:** formation flying solution

Why Now?

- A NIAC study for the Micro-arcsecond X-ray imaging mission (MAXIM) was led by W. Cash in the early 2000's; 450 km focus length and formation flying challenges.
- MAXIM proposed as a NASA Vision mission in ~2003 (PI: K. Gendreau). Not selected.
- Our architecture eliminates long focus lengths, dramatically decreasing the distances between the formation-flying mirrors to the detector spacecraft.

Approach

- Mission Design Lab study complete (July 2025).
- Studied pointing stability, examined trade-offs for formation flying solutions.
- Science traceability matrix to calculate required sensitivity limits; observing plan.
- Goals: Optimize architecture for a feasible interferometer solution (w/ 7 spacecraft).

Mission Design

- Free-flying interferometer with ~20 to ~280 m baselines.
- 2 km array-to-detector distance.
- Three pairs of "collector mirror" satellites launched together.
- Achieve formation flying with ~100 picometer stability.

Results

- L2 orbit; payload packaging – total launch mass feasible
- Adequate capacity available in ~2040s for single launch
- Pointing knowledge requirements can be reached
- Observation exposure times are ~week+
- LISA telescopes provide100 picometer stability
- **Opportunities identified for further study.**
- **Architecture concept study meets goals. No show-stoppers!**

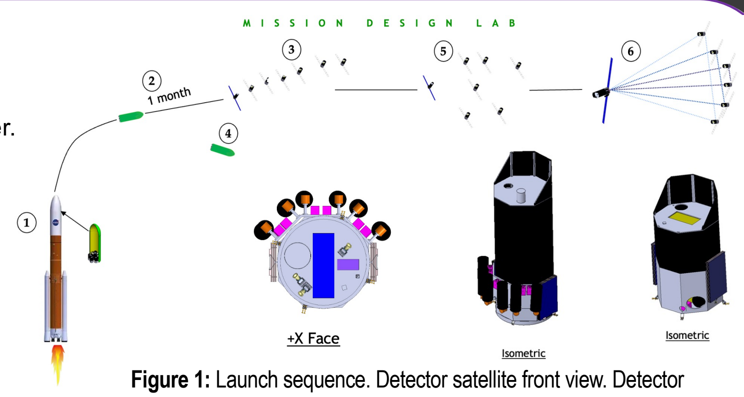

Figure 1: Launch sequence. Detector satellite front view. Detector satellite, stowed. X-ray collector satellite (one of six), stowed.

Supermassive Black Holes (SMBH)

- To know how SMBHs produce millions to billions of Suns worth of power, we must observe high energy photons (X-rays: E ~0.5 to ~20 keV).
- Inner accretion region is only ~6x10^{-5} arcsec across even for the closest X-ray luminous SMBH, M87 (Fig. 2 & Lu et al. 2023, Nature 616, 686).

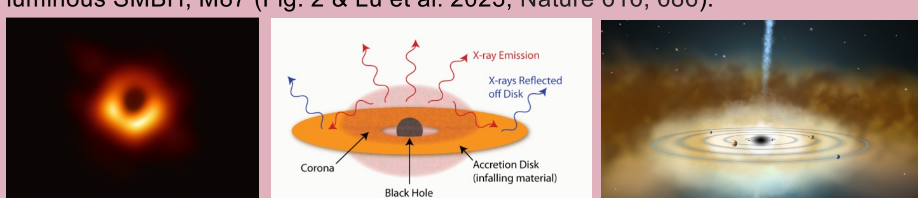

Figure 2: Left: Radio glow. This picture shows a reconstructed image of the very innermost regions surrounding the nearby SMBH in M87 (EHT collaboration). The image captures the glow of radio light tracing the black hole "shadow." **Center:** But to confirm theories about black hole accretion, we need to capture much more powerful X-ray light (Credit: D. Wilkins). **Right:** SMBH to scale compared with the solar system.

AEI NIAC Team

PI: Kimberly Weaver (NASA/GSFC)

Co-Is: Dr. Scott Rohrbach (NASA/GSFC), Dr. Kenneth Carpenter (NASA/GSFC) Dr. Jenna Cann (NASA/GSFC/UMCP), Dr. Maurice Leutenegger (NASA/GSFC), Dr. Takashi Okajima (NASA/GSFC) +GSFC Mission Design Lab engineers

Collaborators: Isabella Carlton (U. of Utah, PhD student), Dr. Webster Cash (U. of Colorado, Boulder), Emma Kleiner (Master's student, CUNY), Dr. John Krizmanic (NASA/GSFC), Dr. Erini Lambrides (NASA/GSFC/JHU), Miranda McCarthy (post-bac student, SURA), Dr. Teresa Monsue (Catholic U.), Kyla Mullaney (post-bac student, SURA), Dr. Ryan Pfeifle (NASA/GSFC/ORAU), Dr. Mainak Singha (Catholic U.), Dr. Melville Ulmer (Northwestern U.), Dr. Kelly Whalen (NASA/GSFC/ORAU)