Lynx2030 SAG: Updates and Results II

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CENTER FOR ASTROPHYSICS
HARVARD & SMITHSONIAN

Lynx Concept Study Report, Niko Maisuradze

Lynx 2030 SAG

To revisit the Lynx Science portfolio and design model in the context of the current Astronomy landscape.

Lynx Concept Study Report

SAG Chairs

Name	Institution
Steven Ehlert	MSFC
Fabio Pacucci	SAO

Lynx2030 SAG: Website

About Lynx 2030 SAG

Lynx 2030 SAG Will Build On the Work of the Lynx Concept Study Report

The Lynx concept study report is an excellent baseline for what the flagship X-ray mission submitted to the 2030 Decadal Survey may look like.

The primary goal of this Science Analysis Group is to revisit the Lynx science portfolio and reference design model in the context of the current astronomy landscape.

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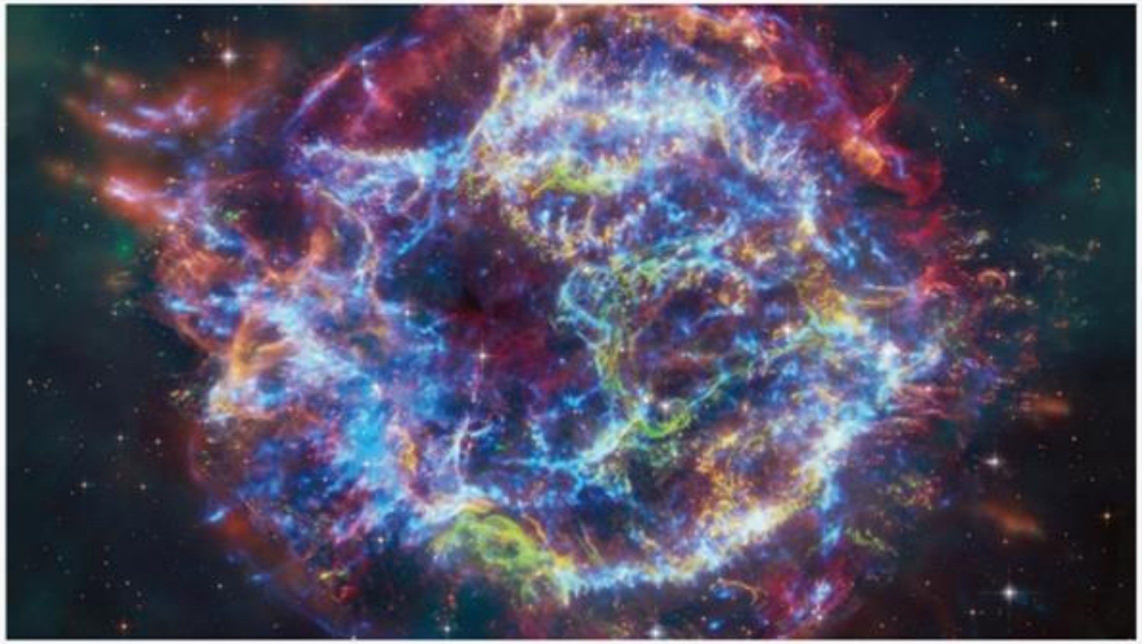


For the first time, astronomers have combined data from NASA's Chandra X-ray Observatory and James Webb Space Telescope to study the well-known supernova remnant Cassiopeia A (Cas A). This work has helped explain an unusual structure in the debris from the destroyed star called the "Green Monster," first discovered in Webb data in April 2023. The area of the Green Monster is outlined in the inset image. This composite image contains X-rays from Chandra (blue), infrared data from Webb (red, green, blue), and optical data from Hubble (red and white). The outer parts of the image also include infrared data from NASA's Spitzer Space Telescope (red, green, and blue).

Image and text credit: X-ray: NASA/Chandra X-ray Center (CXC)/Smithsonian Astrophysical Observatory (SAO); Optical: NASA/European Space Agency (ESA)/Space Telescope Science Institute (STScI); Infrared (IR): NASA/ESA/Canadian Space Agency (CSA)/STScI/Milisavljevic et al., NASA/Jet Propulsion Laboratory (JPL)/Caltech; Image processing: NASA/CXC/SAO/J. Schmidt and K. Arcand

LAUNCHING SOON

LYNX2030

www.HIDDENCOSMOS.org

Lynx2030 Working Groups

ANGULAR RESOLUTION

NEW CAPABILITIES

ENERGY BANDPASS

SURVEY GRASP

MICRO CALORIMETER

SAGs Timeline

October 2025:
SAGs begins operating

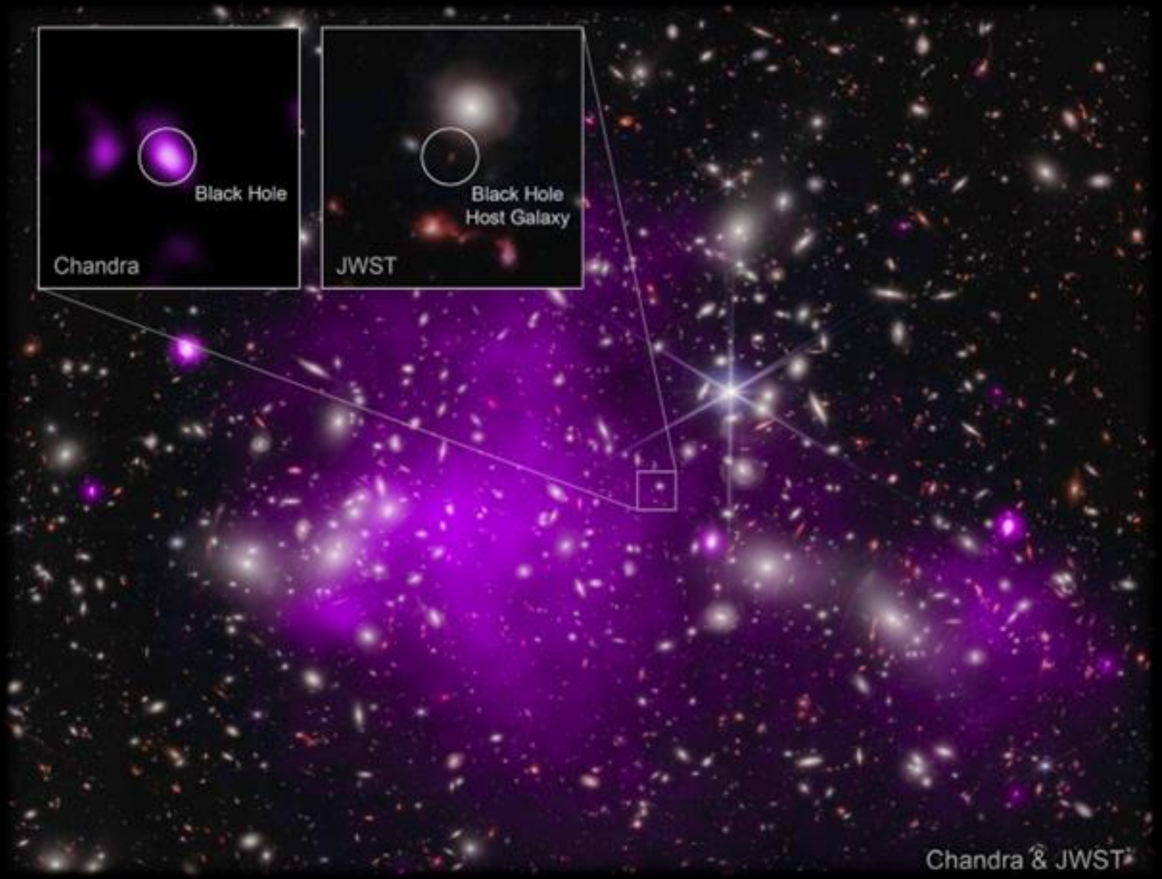
January 2026:
Working Groups Assembled

June 2026:
WGs report findings to SAG Chairs

July 31, 2026:
Final report to NASA APD

Why a Lynx2030 SAG?

A Quarter Century of Chandra Science



nature astronomy

Review article

https://doi.org/10.1038/s41550-025-02675-8

25 years of groundbreaking discoveries with Chandra

Received: 24 May 2025

Accepted: 2 September 2025

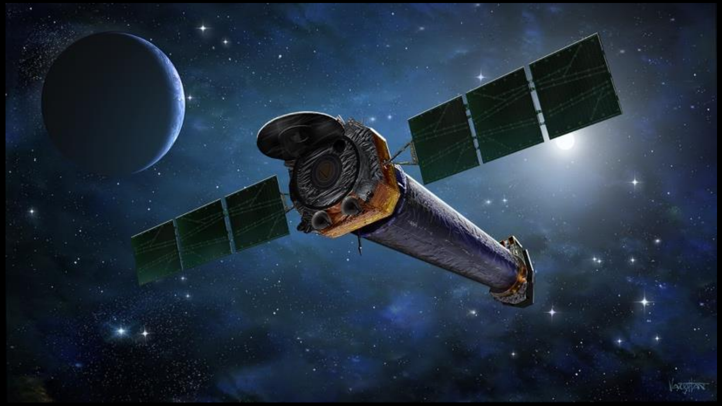
Published online: 10 October 2025

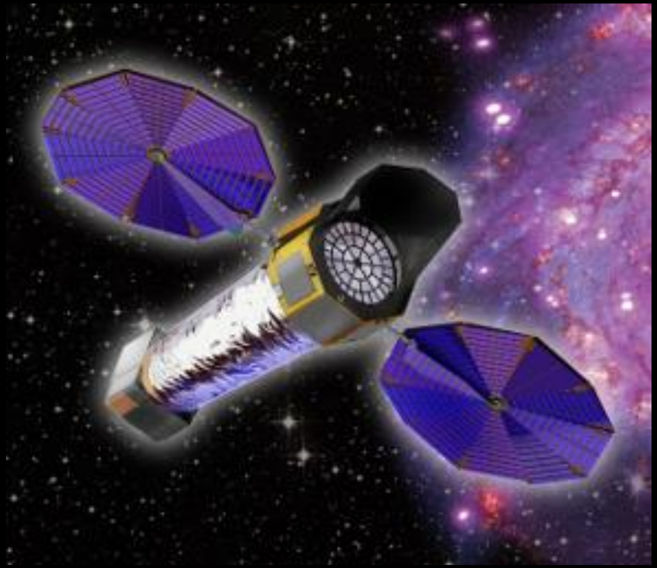
Check for updates

Patrick Slane[1], Ákos Bogdán[1] & David Pooley[2,3]

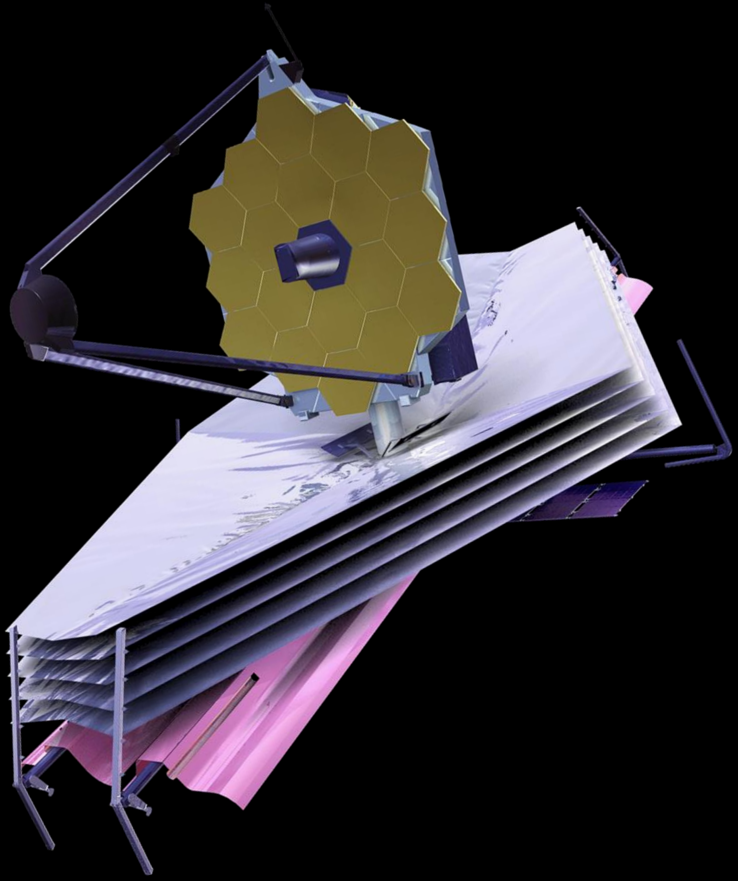
The Chandra X-ray Observatory is a mainstay of modern observational astrophysics. With the highest angular resolution of any X-ray facility, its imaging and spectral capabilities in the 0.5–10 keV band have led to both unique and complementary breakthroughs in nearly all areas of the field. Now, more than a quarter of a century into its mission, Chandra continues to provide invaluable information on the contributions of compact objects to the evolution of galaxies, the nature of supernova explosions, the impact of energetic jets from supermassive black holes on their host environments and the fate of exoplanet atmospheres in systems rich with stellar flares. Here we provide a summary of Chandra results—one that is embarrassingly incomplete, but representative of both the exquisite past and promising future of Chandra's contributions to high-energy astrophysics and all of mainstream astronomy.

UHZ1: Bodgan+ 2023
z ~ 10

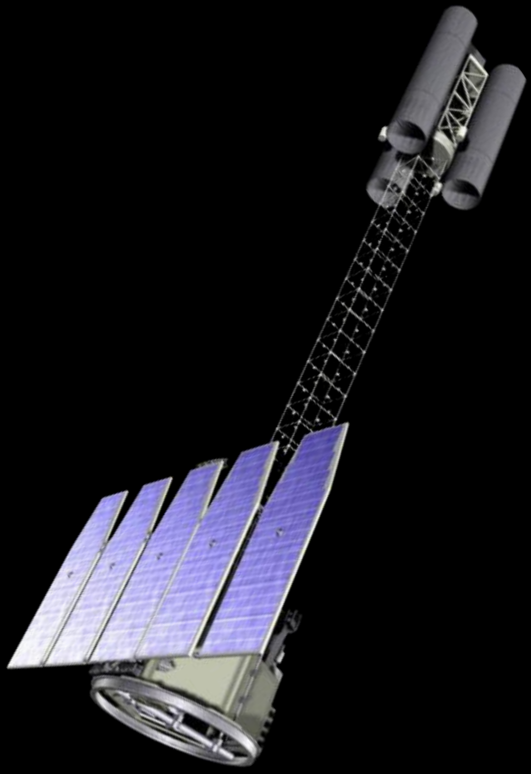




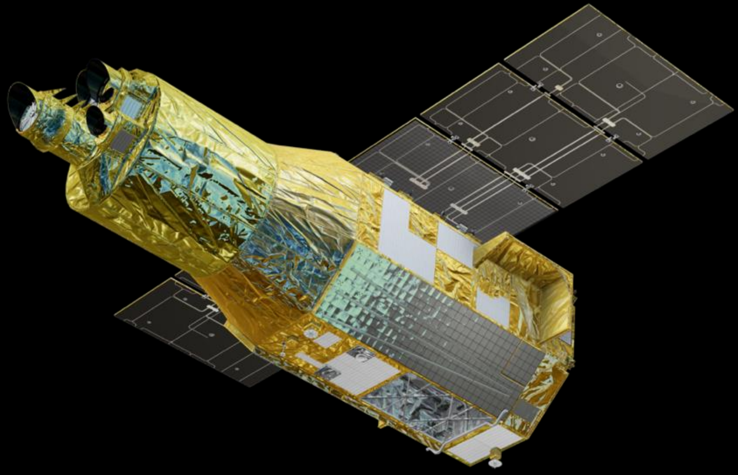
Beyond Chandra:
The Case for a Next-Generation X-ray Observatory



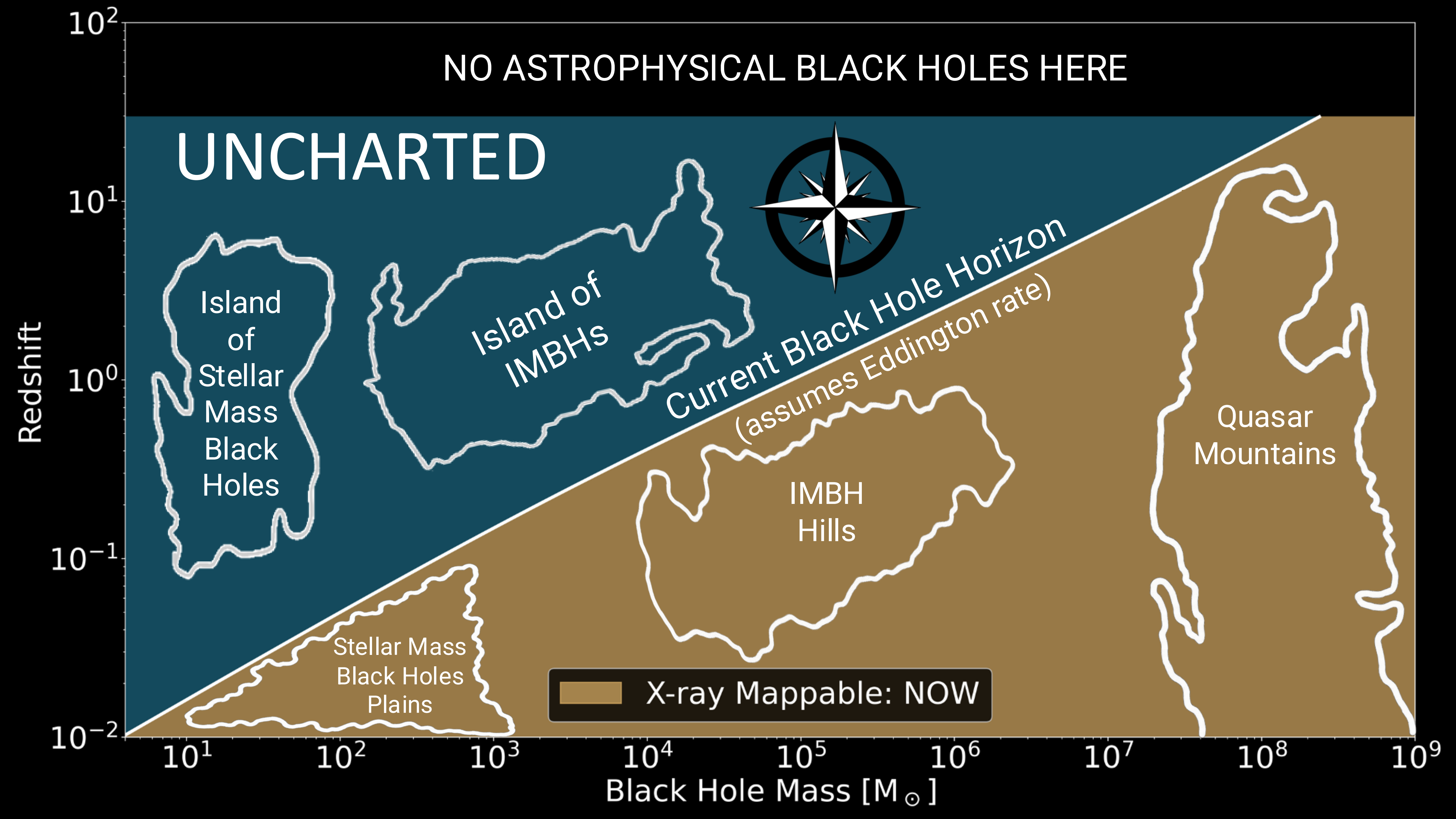
JWST



IXPE



XRISM



NO ASTROPHYSICAL BLACK HOLES HERE
UNCHARTED
Island of Stellar Mass Black Holes
Island of IMBHs
Current Black Hole Horizon
(assumes Eddington rate)
Stellar Mass Black Holes Plains
IMBH Hills
Quasar Mountains
X-ray Mappable: NOW
Redshift
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{1} 10^{2} 10^{3} 10^{4} 10^{5} 10^{6} 10^{7} 10^{8} 10^{9}
Black Hole Mass [$M_\odot$]

Updates from the Working Groups

ANGULAR RESOLUTION WG

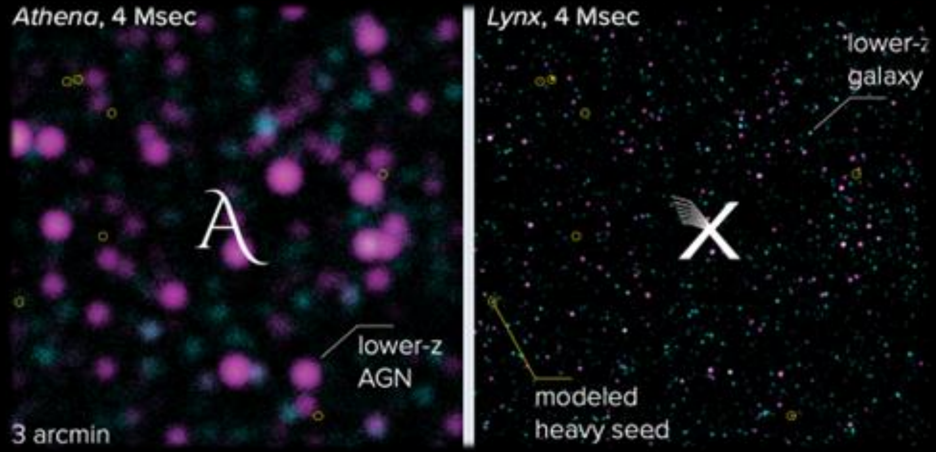
Lynx Design Requirement: 0.5”

Deep Field AGN

X-ray Binaries

Chair(s):

- Scott Randall



What Science can we unlock with a higher angular resolution?

Why Angular Resolution Matters

Lynx2020 Baseline: 0.5” resolution over 10-20’ FOV.

Goal: angular resolution of ~ 0.1" (likely the limit of what can be achieved with currently mature technology).

1 **First black holes seeding & growth**

Resolve faint AGN at z>8 and separate black holes from their host galaxies, enabling the first unbiased census of early black-hole growth.

2 **Resolving hot gas inside the Bondi radius**

Resolve hot gas near nearby black holes and directly constrain accretion physics.

3 **Black-hole feedback across cosmic time**

Map shocks, winds, jets, and cavities from the local Universe to cosmic noon, revealing how black holes shape galaxy evolution.

4 **Crowded, lensed and high-leverage fields**

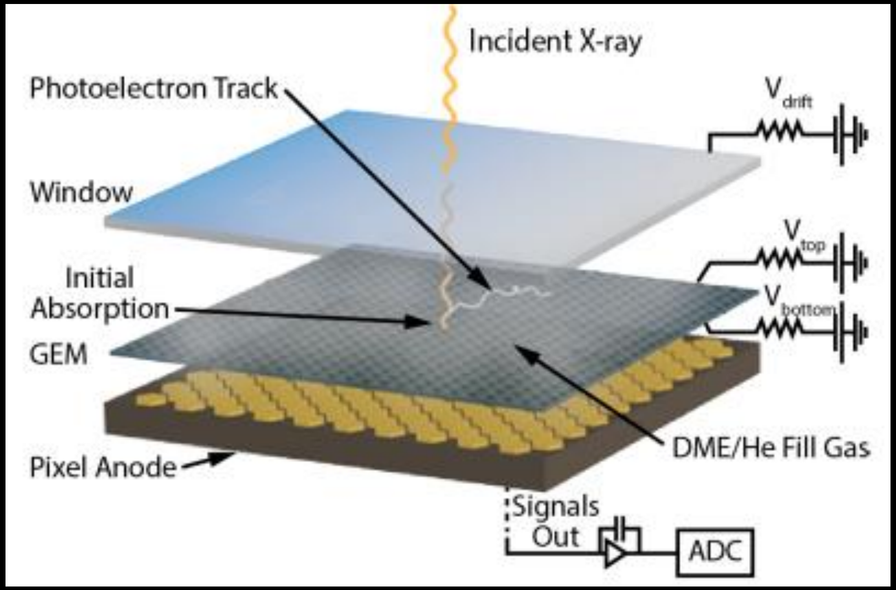
Resolve dual AGN, crowded stellar populations, and gravitationally lensed sources that are inaccessible at lower angular resolution.

NEW CAPABILITIES WG

Focus: new technologies

Chair(s):

- Grant Tremblay
- Peter Maksym



What Science can these new capabilities unlock if they are equipped on Lynx?

Transforming X-ray Polarimetry

Scaling from IXPE to Lynx-like area enables:

More Sources:

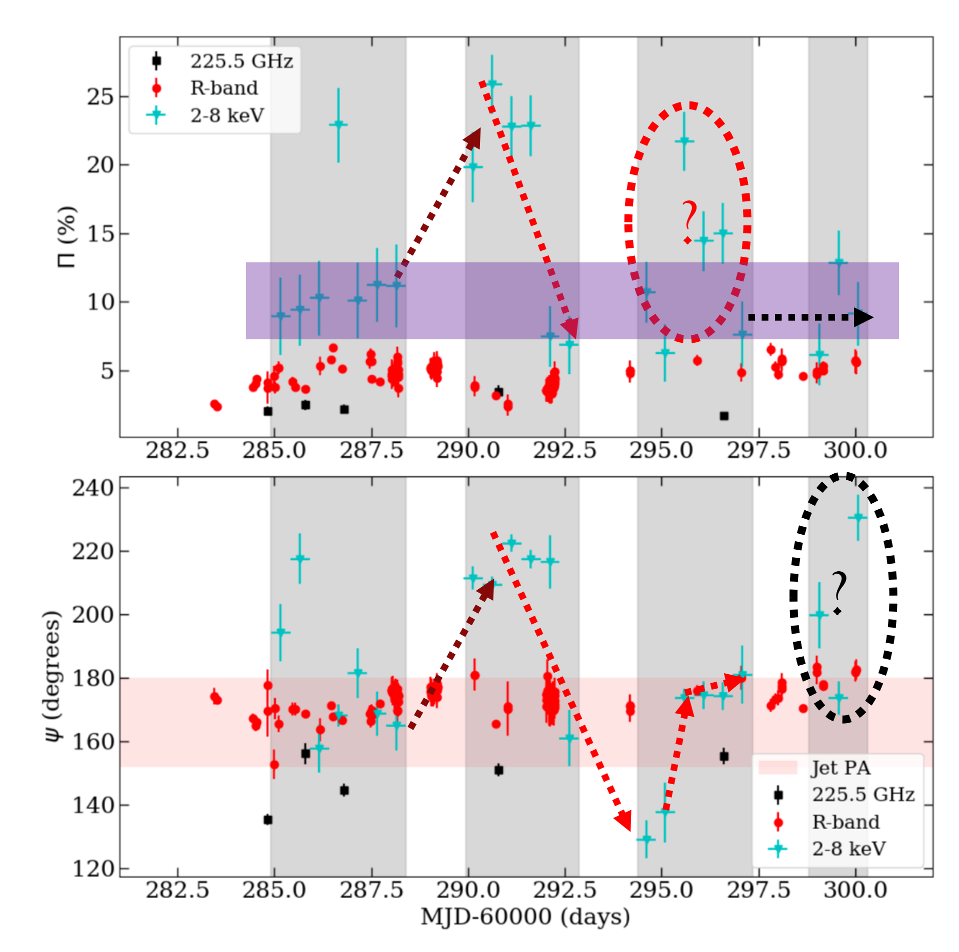
- ~500 times larger accessible sample.
- Statistical studies of BH/NS jets, shocks, disk/torus reflection, SNRs.

Faster Variability Studies:

- Current observations are photon-limited
- Probe much shorter timescales.

Technological Readiness:

- New gas pixel detectors: ~2x sensitivity, broader bandwidth (>30 keV).
- High technology readiness, modest cost.

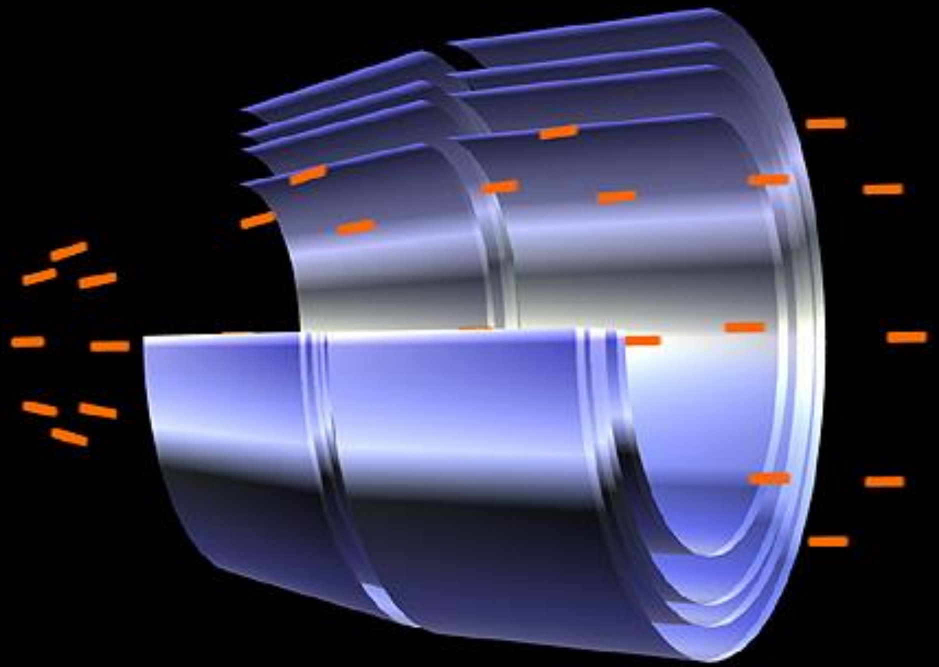


Polarization variations already hint at rich jet physics. (Maksym+ 25)

Future Technology Opportunities

Optics:

- Candidate mirror technologies:
  - Silicon meta-shell
  - Electroformed replication
  - Glass
- Scaling advanced mirror technologies to large collecting areas remains challenging.
- Hybrid optical designs offer greater flexibility.
- Advanced mirror coatings enhance sensitivity and broaden energy coverage.



Microcalorimeters:

- 0.33” pixels
- FoV up to 20
- Trade-offs between FoV and resolution

Future Technology Opportunities

Critical-Angle Transmission gratings:

- Baseline: R~7,500 (Lynx target)
- Potential: R~10,000

Flexible Mission Architectures:

- New launch vehicles
- Modular upgrades
- Robotic servicing

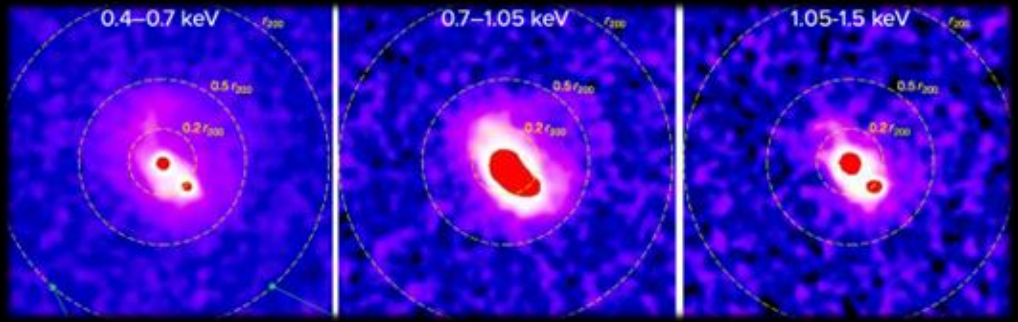
Advances in optics, detectors, spectroscopy, and mission design could extend mission performance beyond current concepts.

ENERGY BANDPASS WG

Lynx Design Requirement: 2 m^2 effective area @ 1 keV

↓

Deep Field AGN



Chair(s):

- Laura Brenneman
- Nico Cappelluti

What Science can we unlock with a larger effective area at 10 keV? What about 20 keV?

Science Drivers for a Broad X-ray Bandpass

Science goals:

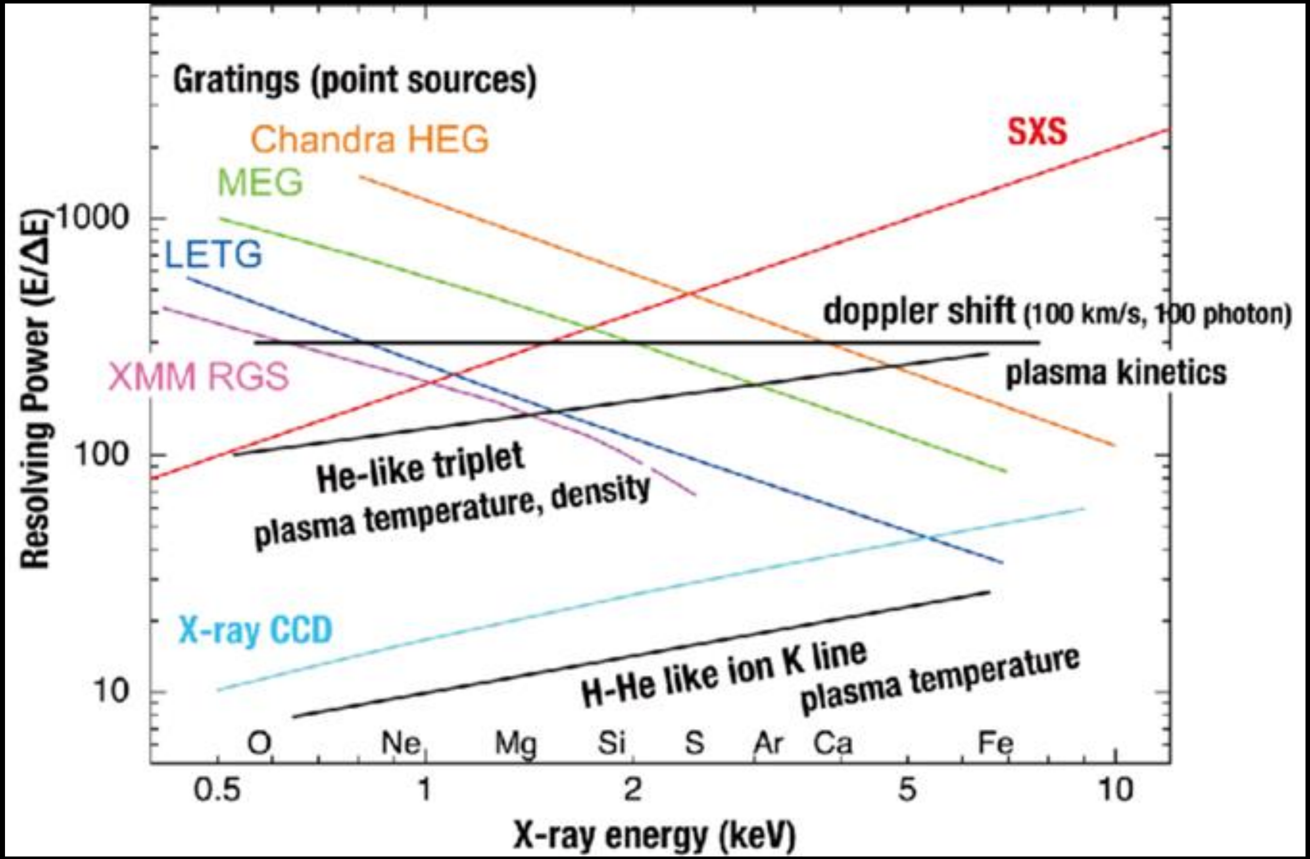
- First black holes and AGN evolution
- Cosmic web and AGN outflows
- Diffuse hot gas in galaxies and groups
- Obscured AGN and coronal physics

Low-Energy Coverage Limit: ~0.1 keV

- Redshifted AGN diagnostics at high redshift
- Cosmic web and outflow studies
- Cool diffuse gas in galaxies and groups

High-Energy Coverage: 12-15 keV:

- Coronal and Compton-hump science
- Obscured AGN surveys
- Compatibility with current X-ray missions



Instrumental Motivation for R > 2000:

Gratings: E < 2 keV

Microcalorimeter: E > 2 keV

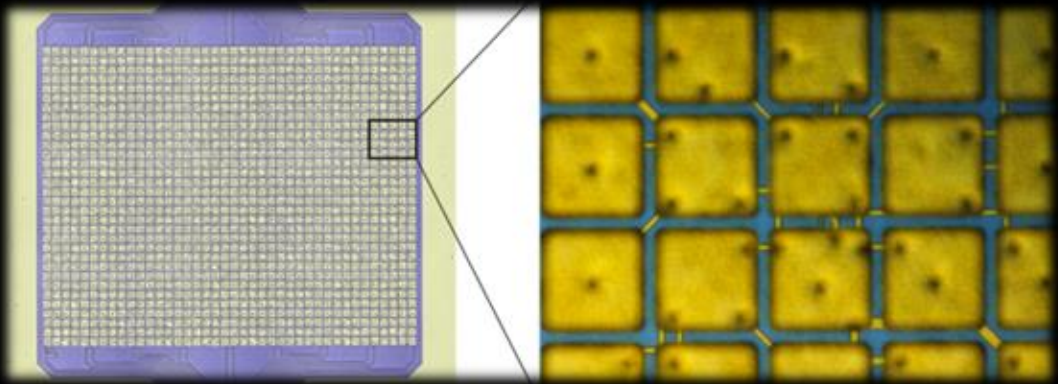
MICRO CALORIMETER WG

Lynx Design for LXM:

Field of View	Pixel Size	Energy Resolution
5' × 5'	1"	3 eV
1' × 1'	0.5"	2 eV
1' × 1'	1"	0.3 eV

Chair(s):

- John ZuHone
- Simon Bandler



What Science can we unlock with changes to this configuration?

Mapping the Dynamic X-Ray Universe

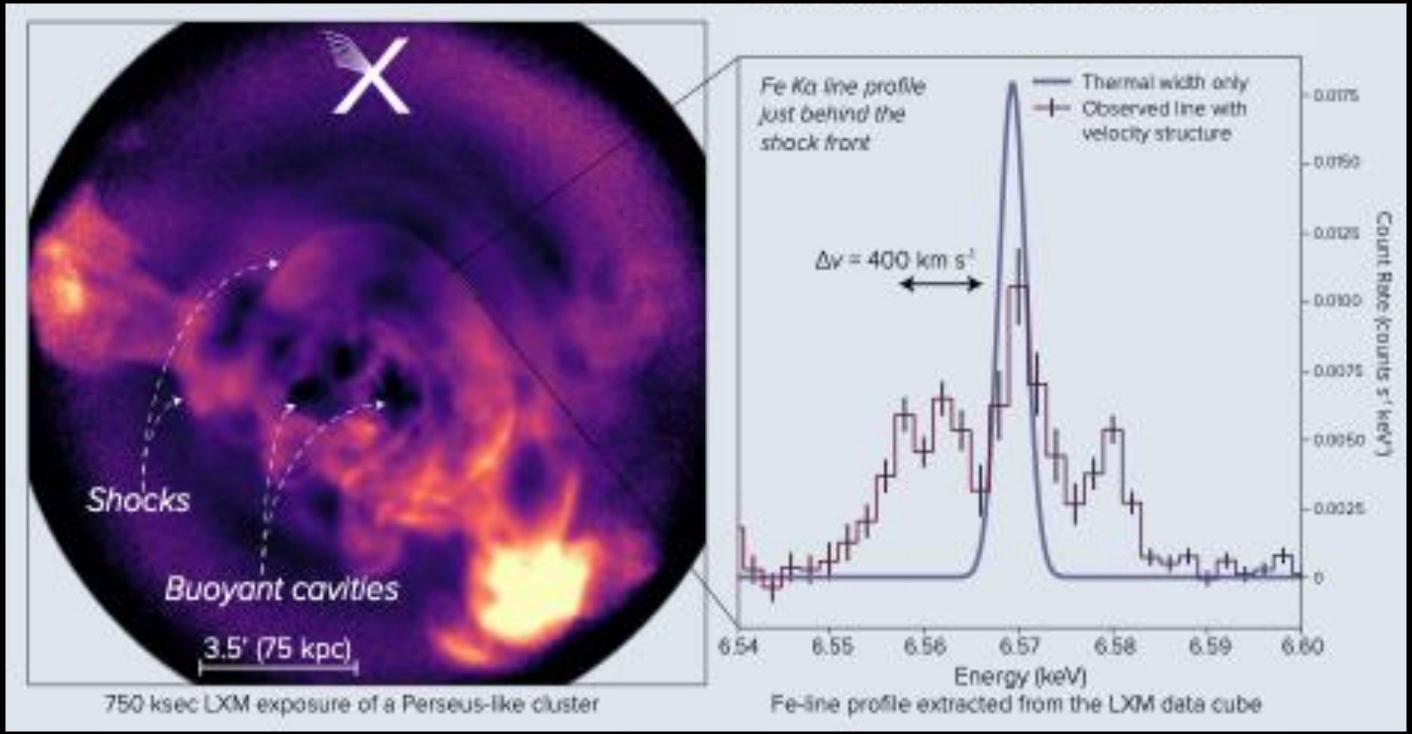
LXM will transform invisible, superheated gas around black holes and supernovae into spectacular 3D maps of the dynamic Universe.

XRISM has shown the power of high-resolution X-ray spectroscopy:

- Measures turbulence and gas motion in AGN, supernovae remnants, compact objects, and clusters

Lynx adds arcsecond imaging:

- < 3 eV spectral resolution
- Arcsecond spatial resolution
- Maps the structure, thermodynamics, kinematics, and chemical composition

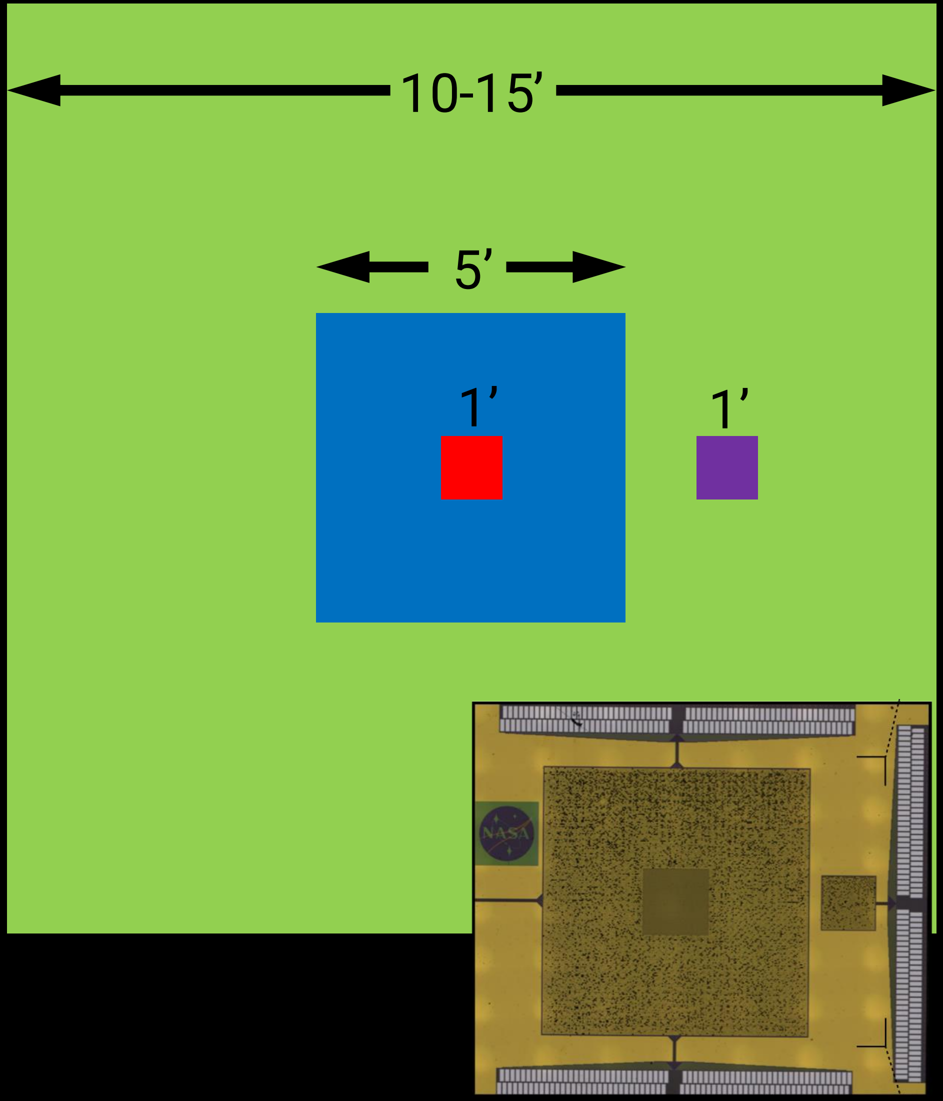


Mapping temperature and velocity structure in galaxy clusters reveals turbulence, shocks, and AGN feedback.

A Flexible Design for Diverse Science Goals

Sub-array	FoV	Pixel Size	Energy Resolution	Band	Science Case
Main Array	5'	1"	2 eV	0.2-12 keV	General Use
Enhanced Main Array	1'	0.5"	1-2 eV	0.2-7 keV	AGN, Compact Objects, Stars
Ultra-High-Res Array	1'	1"	0.3-0.4 eV	0.2-1 keV	AGN, Compact Objects, Stars
Extended Array	10-15'	2-5"	2-3 eV	0.2-2 keV	Large Diffuse Objects, Survey Science

Multiple arrays balance field of view, spatial resolution, and spectral resolution for different science applications.



Tracing the Hot Baryons that Shape Galaxies

Circumgalactic Medium:

- Maps thermal, chemical, and velocity structure

Galactic Winds:

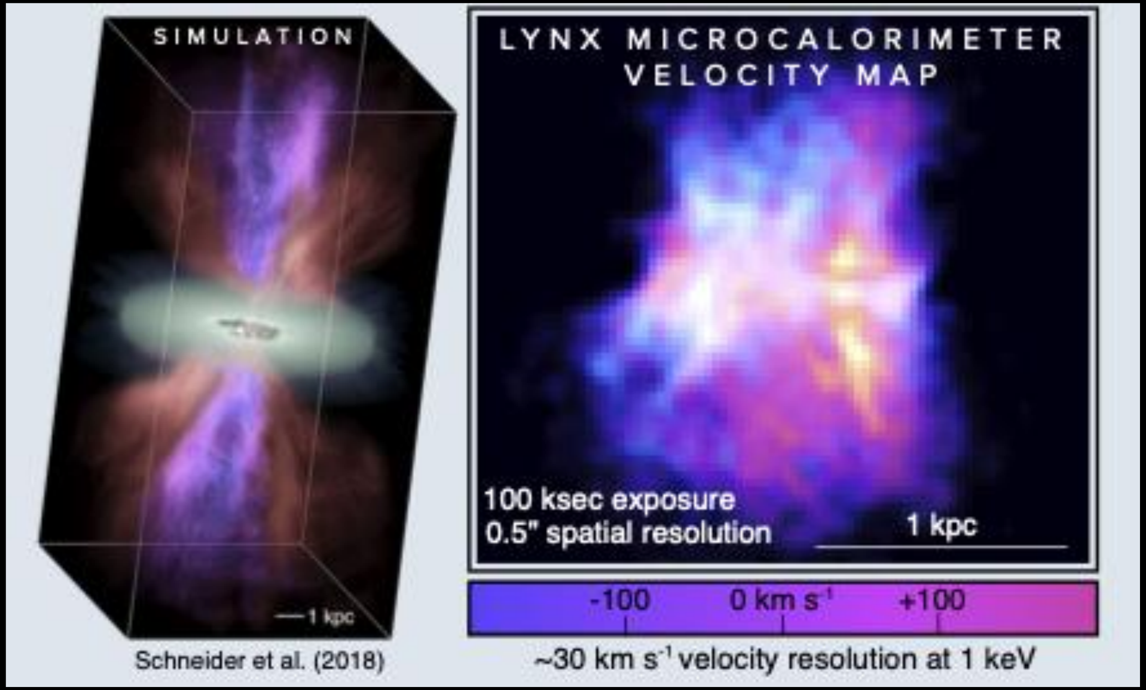
- Measure outflow energetics and mass loading
- Distinguish stellar and AGN feedback models

AGN Feedback:

- Quantify how black holes heat surrounding gas

Cosmic Web:

- Detect diffuse baryons in the Warm-Hot Intergalactic Medium



Velocity-resolved spectroscopy reveals how energy flows through galaxies and their environments

Probing Black Holes, Supernovae, and the Transient Universe

Black Hole Growth:

- Measure SMBH spins to z ~ 5 – 6
- Distinguish growth through accretion vs. mergers

AGN Feedback:

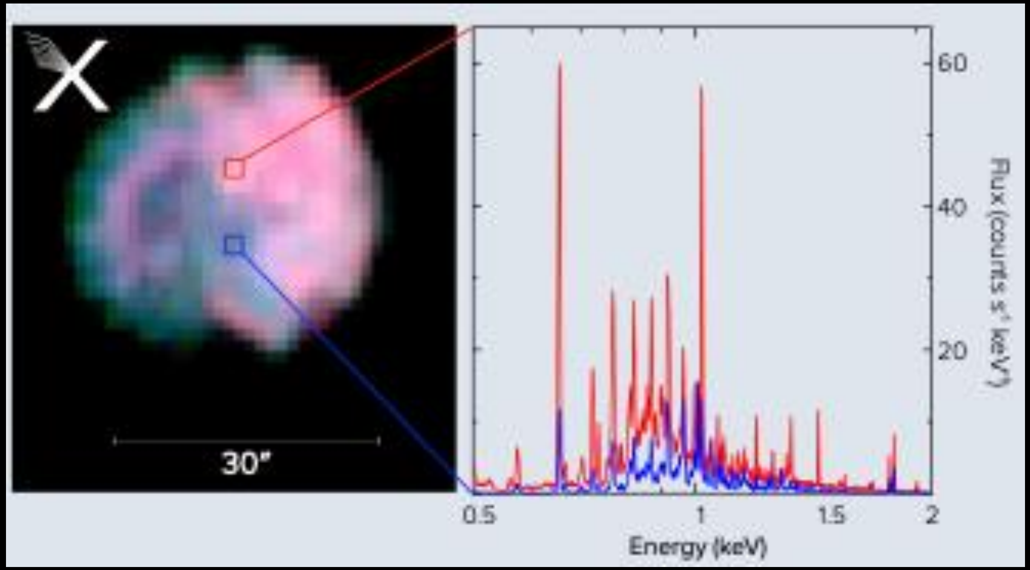
- Measure mass, momentum, and energy in AGN winds
- Map feedback from nuclear to galaxy scales

Supernova Physics:

- Map ejecta composition and kinematics
- Probe nucleosynthesis and explosion mechanisms

Time-Domain and Multi-Messenger (TDAMM):

- Identify LISA counterparts
- Enable studies of transient events



Kinematic and abundance mapping of SNRs to probe explosion mechanisms

Synergies With the 2030-2040 Astronomy Landscape

The Lynx 2030 microcalorimeter architecture is designed to be complementary to major multi-wavelength facilities of the next decades.

Optical and Near-IR (Roman & Rubin):

- Matched wide-field capabilities.
- Connect hot gas to galaxy structure and evolution

Radio (SKA & ngVLA):

- AGN feedback & cluster radio-mode studies
- Using FRB sightlines to map the WHIM

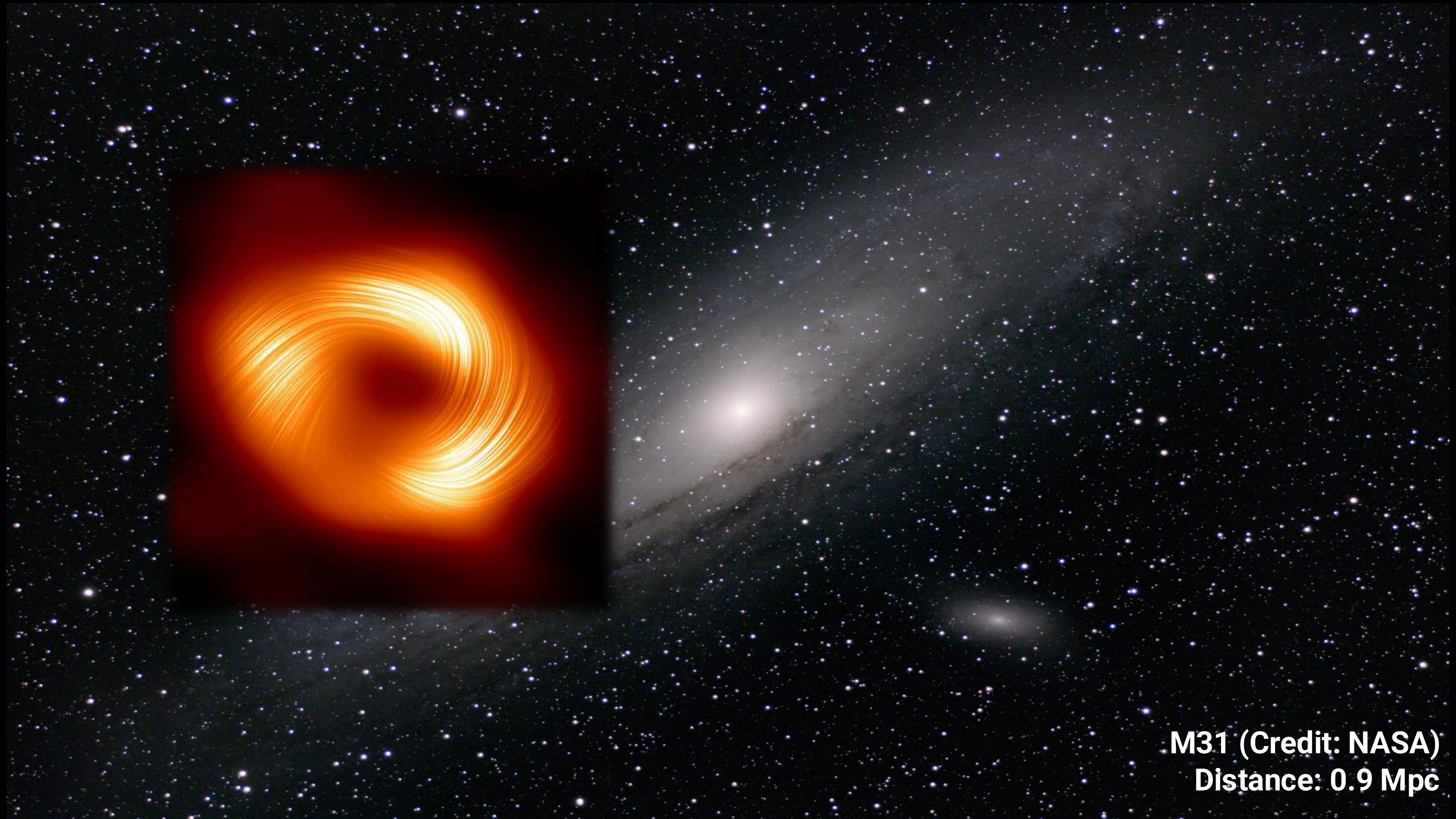
Infrared (JWST):

- Provide the high-redshift context

X-Rays (NewAthena):

- Complementary focus with sub-arcsecond pixels, wide-field spectroscopy, and coverage to ~0.3 keV

Why Are We Doing This?


M31 (Credit: NASA)
Distance: 0.9 Mpc

The High-Energy Luminarium

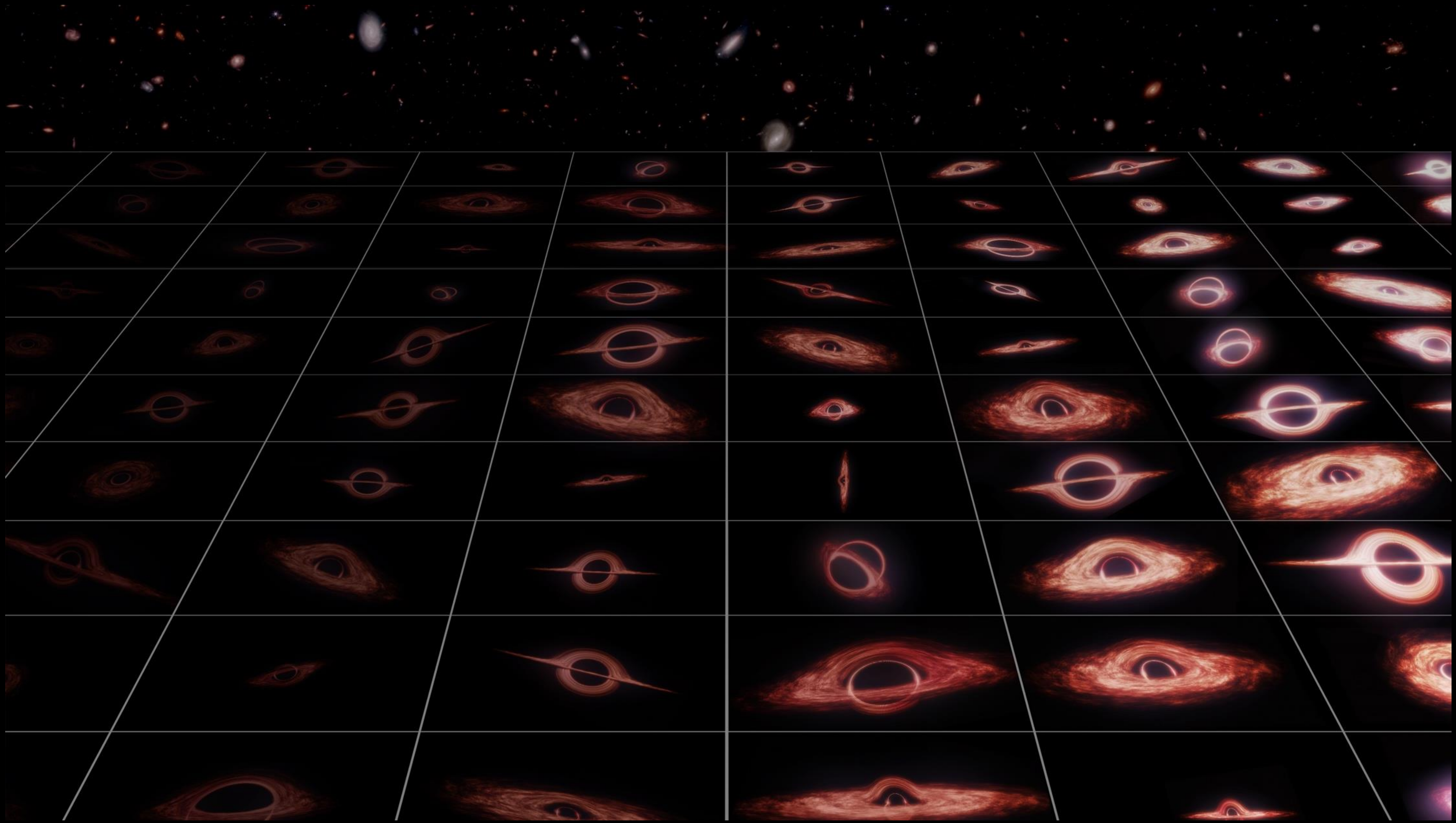
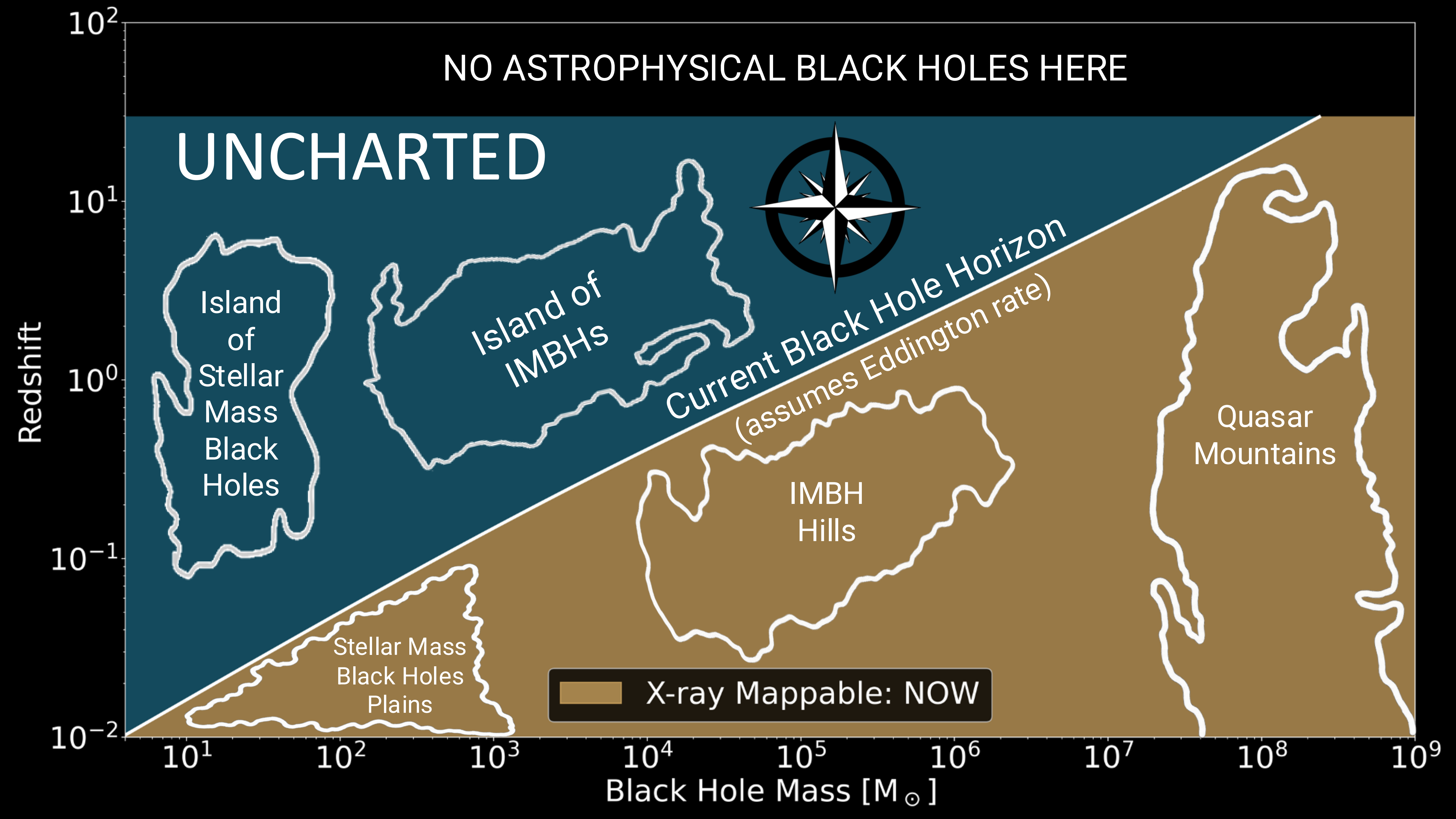


Illustration by CfA/Melissa Weiss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Current Black Hole Horizon
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IMBH Hills
Quasar Mountains
Stellar Mass Black Holes Plains
X-ray Mappable: NOW
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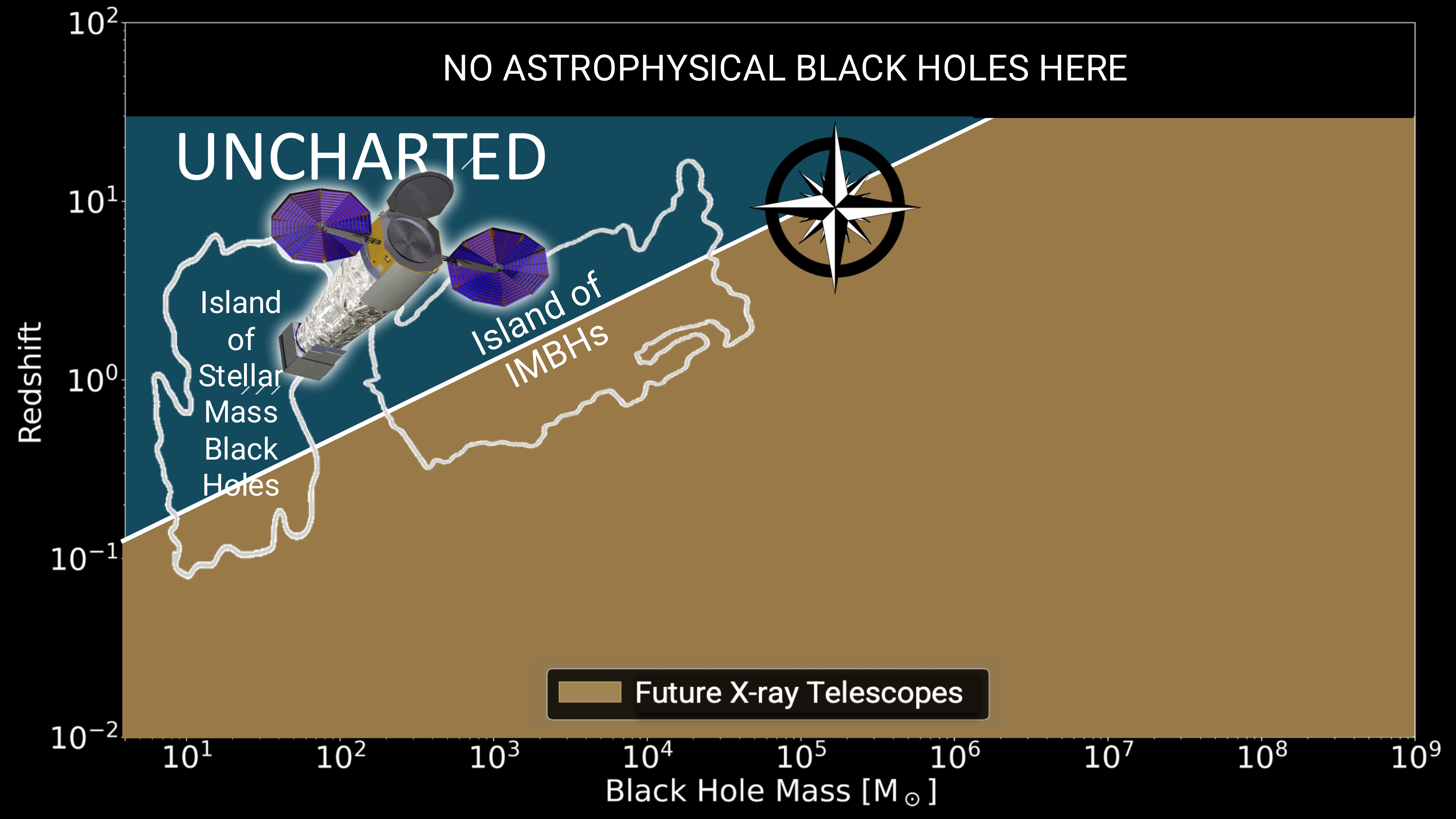
Black Hole Mass [$M_\odot$]



NO ASTROPHYSICAL BLACK HOLES HERE
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Island of Stellar Mass Black Holes
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Future X-ray Telescopes
Redshift
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
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Black Hole Mass [$M_\odot$]