

The Growth and Spin of Supermassive Black Holes

with a Broad-Band X-ray Observatory

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How did supermassive black holes grow?

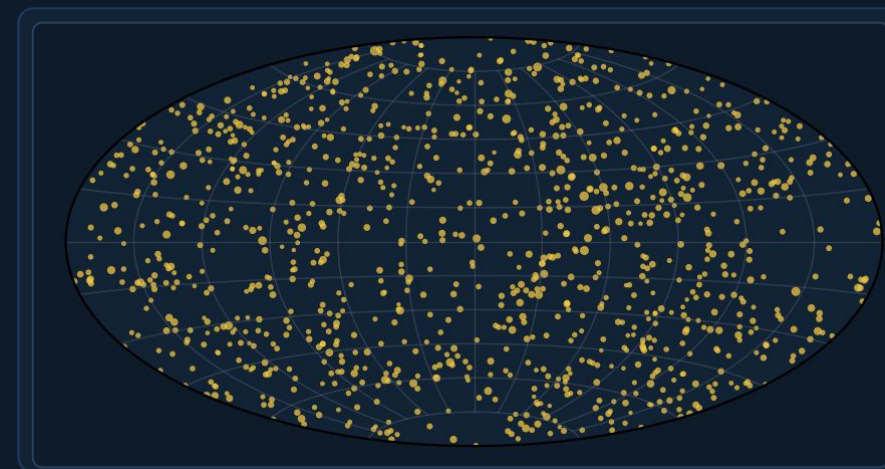
growth era ($z \geq 4$)



abundant early accretion — the JWST “little red dots” —
yet X-ray weak: hard to observe directly

JWST/NIRCam — NASA, ESA, CSA, STScI, D. Kocevski (Colby College)

present-day population



1,071 AGN in the local hard X-ray sky — Swift-BAT (14–195 keV)
the fossil record, readable now: spins + the cosmic X-ray background (CXB)

Swift-BAT 157-month catalog (Lien et al. 2025) · EHT Collaboration

- Every massive galaxy hosts a 10^6 – $10^{10} M_{\odot}$ black hole; its mass tracks the host — coevolution
- Growth dominated by radiatively efficient accretion (Soltan argument)
- JWST's little red dots: abundant accreting black holes surprisingly early — yet X-ray weak
- The growth record survives locally: the spin distribution and the cosmic X-ray background



one of them, up close:
M87* (EHT)

The 2030s map consequences, not the engine

what the surveys will map

the consequences of accretion

JWST · Euclid

hosts, environments, assembly

Rubin/LSST

transients, variability

Roman

wide-field demographics

far-IR · radio

obscured star formation, jets



what only X-rays measure

the engine itself

coronal power

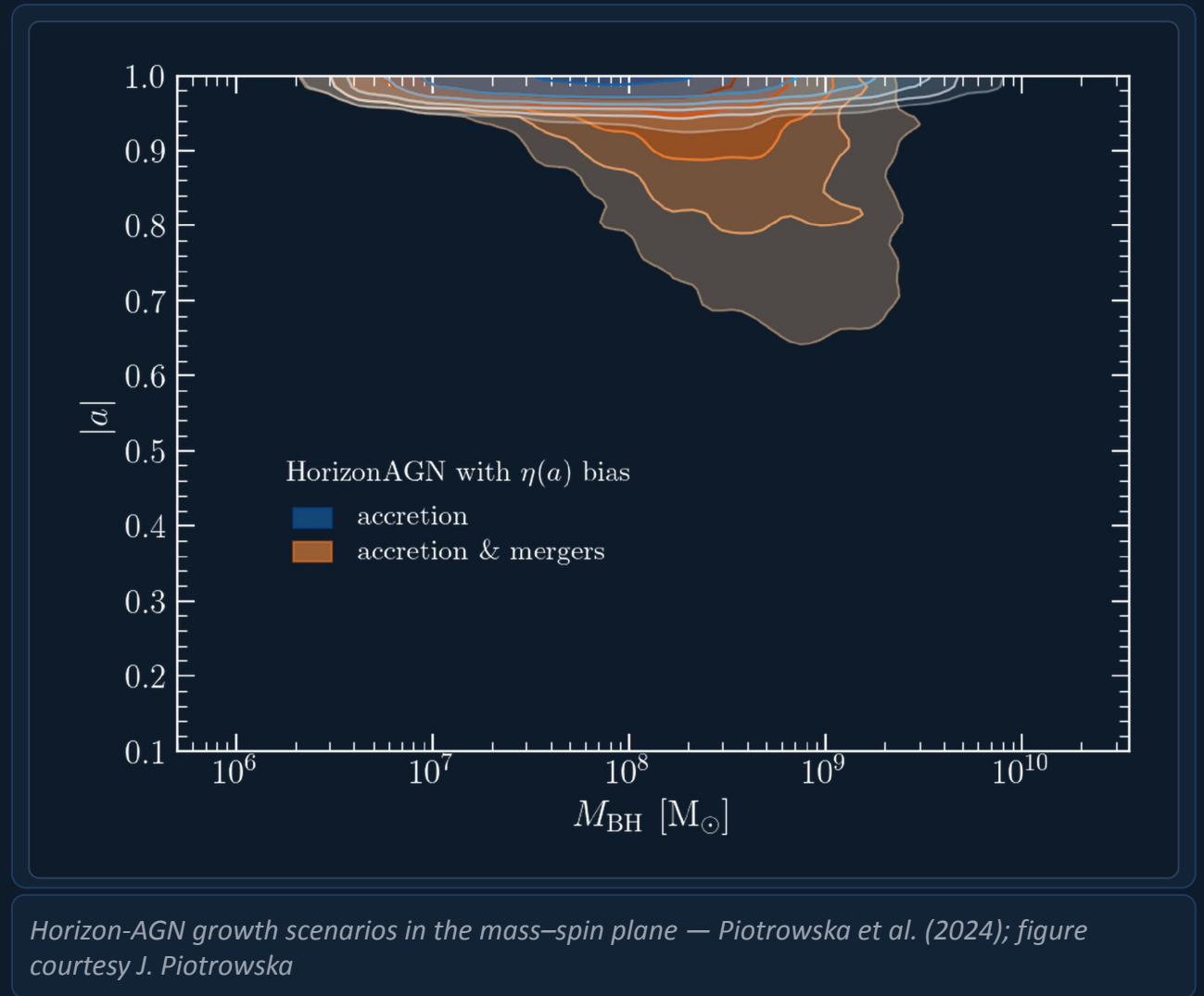
line-of-sight obscuration

black-hole spin

The accretion physics is encoded in the X-ray band — and requires broad spectral coverage

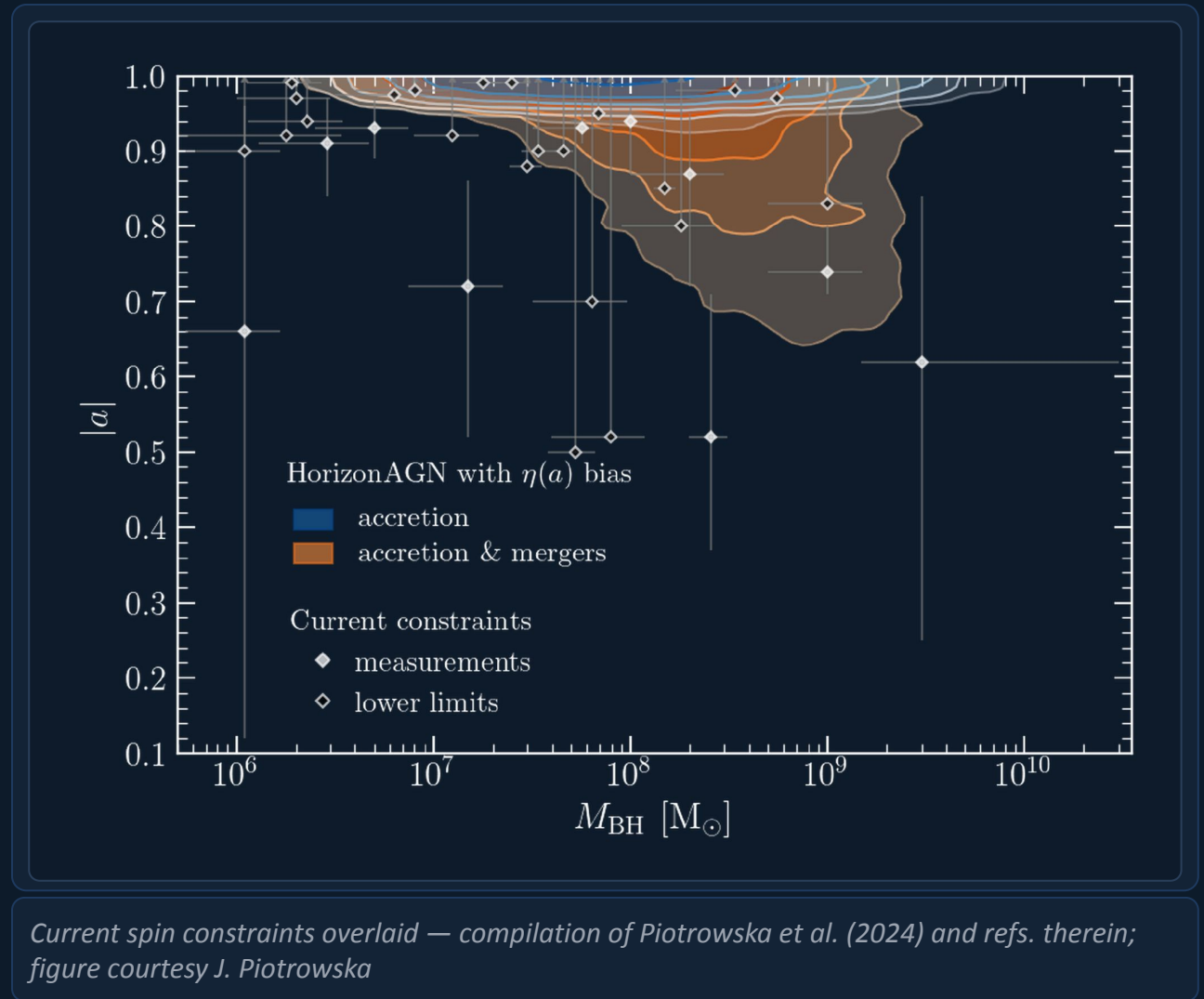
Spin records accretion history

- Horizon-AGN prediction: accretion-only vs. accretion + mergers — two distinct territories in the mass–spin plane



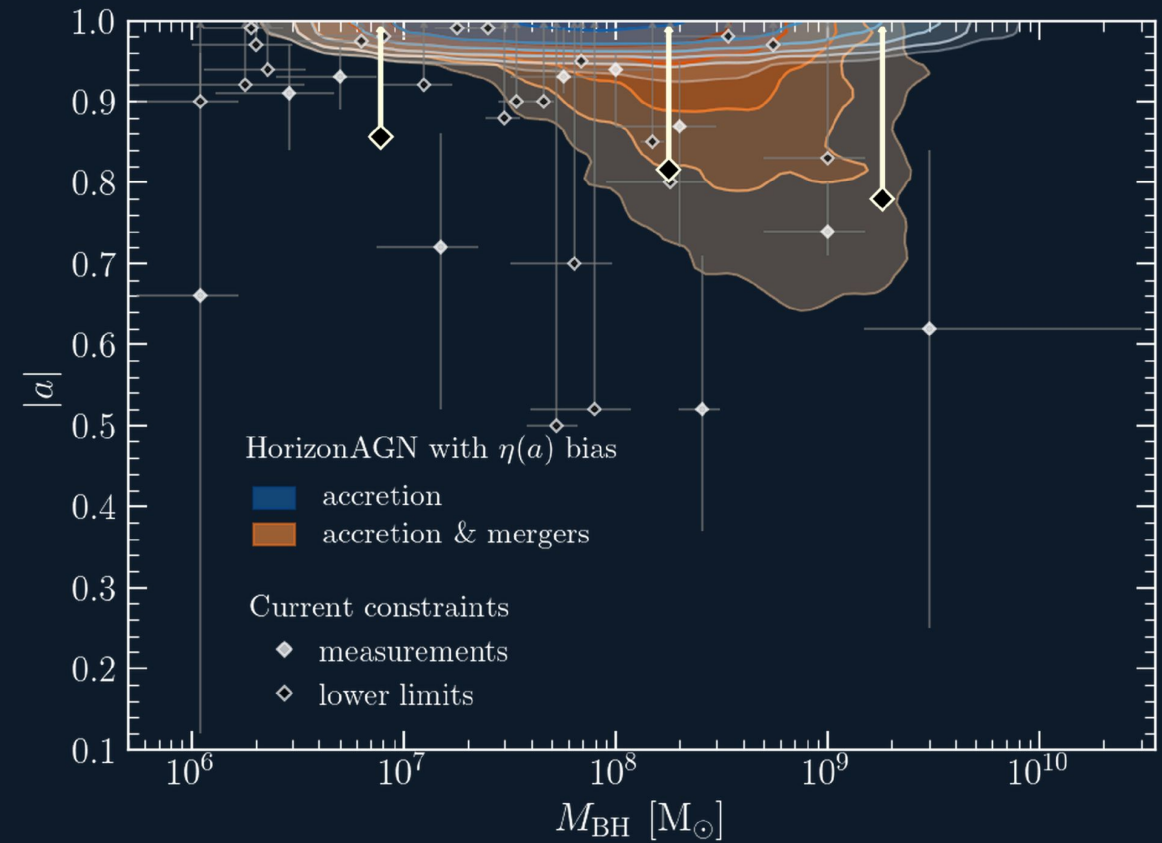
Spin records accretion history

- Horizon-AGN prediction: accretion-only vs. accretion + mergers
- Today's census: a few dozen objects — most only lower limits, models heterogeneous



Spin records accretion history

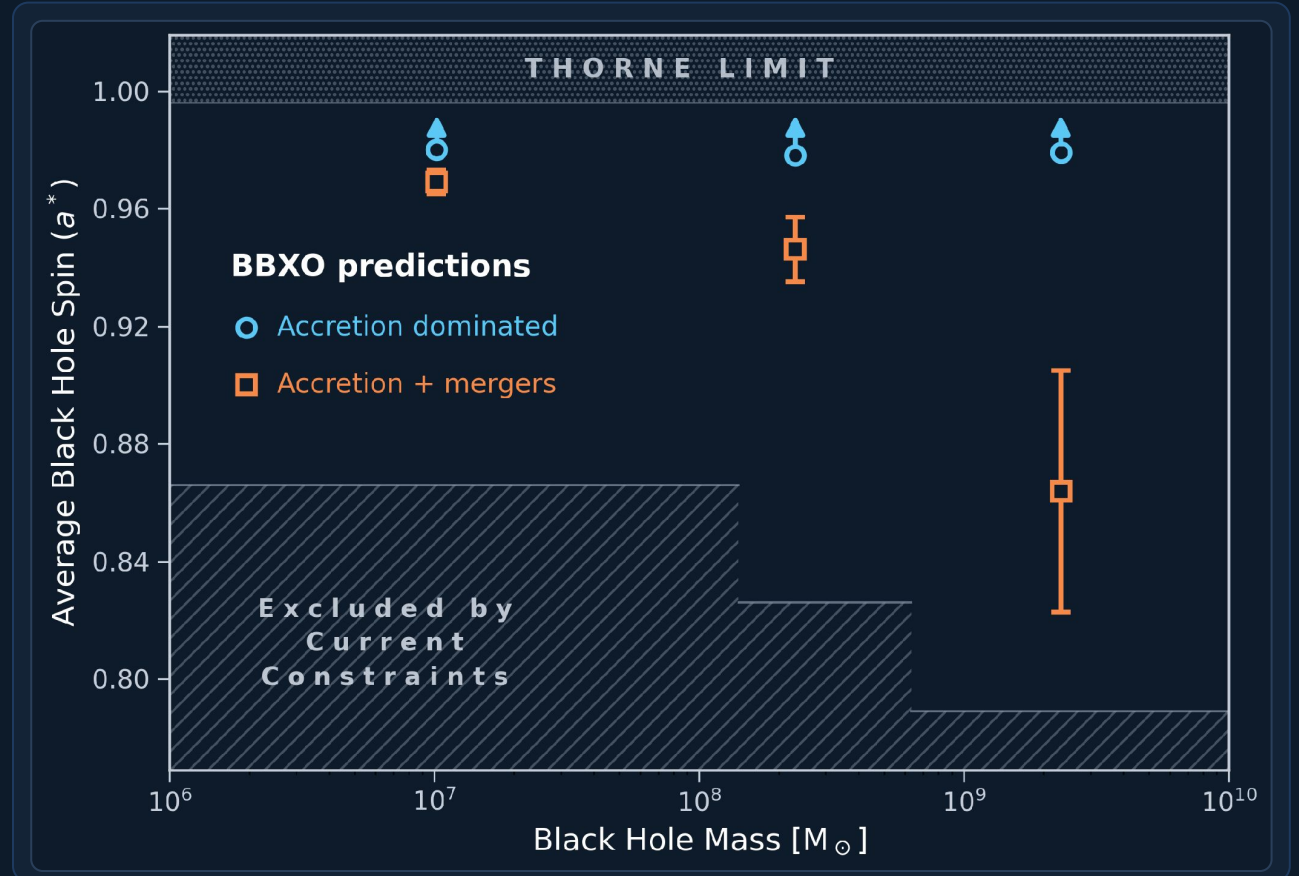
- Horizon-AGN prediction: accretion-only vs. accretion + mergers
- Today's census: a few dozen objects — most only lower limits, models heterogeneous
- Binned by mass: lower limits only — the two growth scenarios are indistinguishable today



Binned mean spins: lower limits in every mass bin — Piotrowska et al. (2024); figure courtesy J. Piotrowska

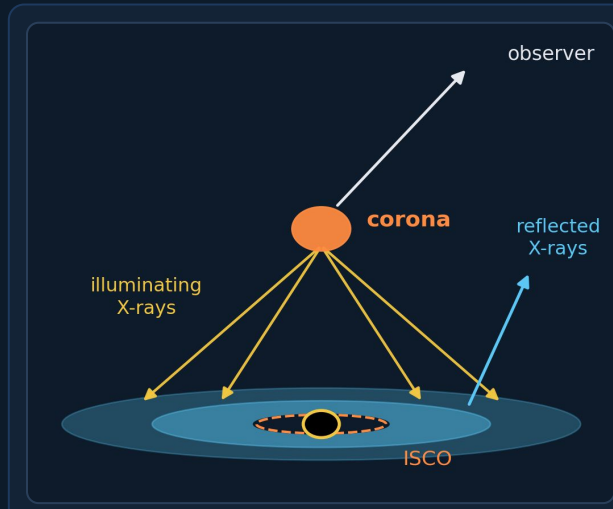
The transformative step: ~100 AGN, uniformly analyzed

- A few dozen heterogeneous constraints → ~100 AGN: one sample, one capability, one analysis framework
- Mean spin per mass bin becomes a measurement — accretion-only and accretion + mergers separate

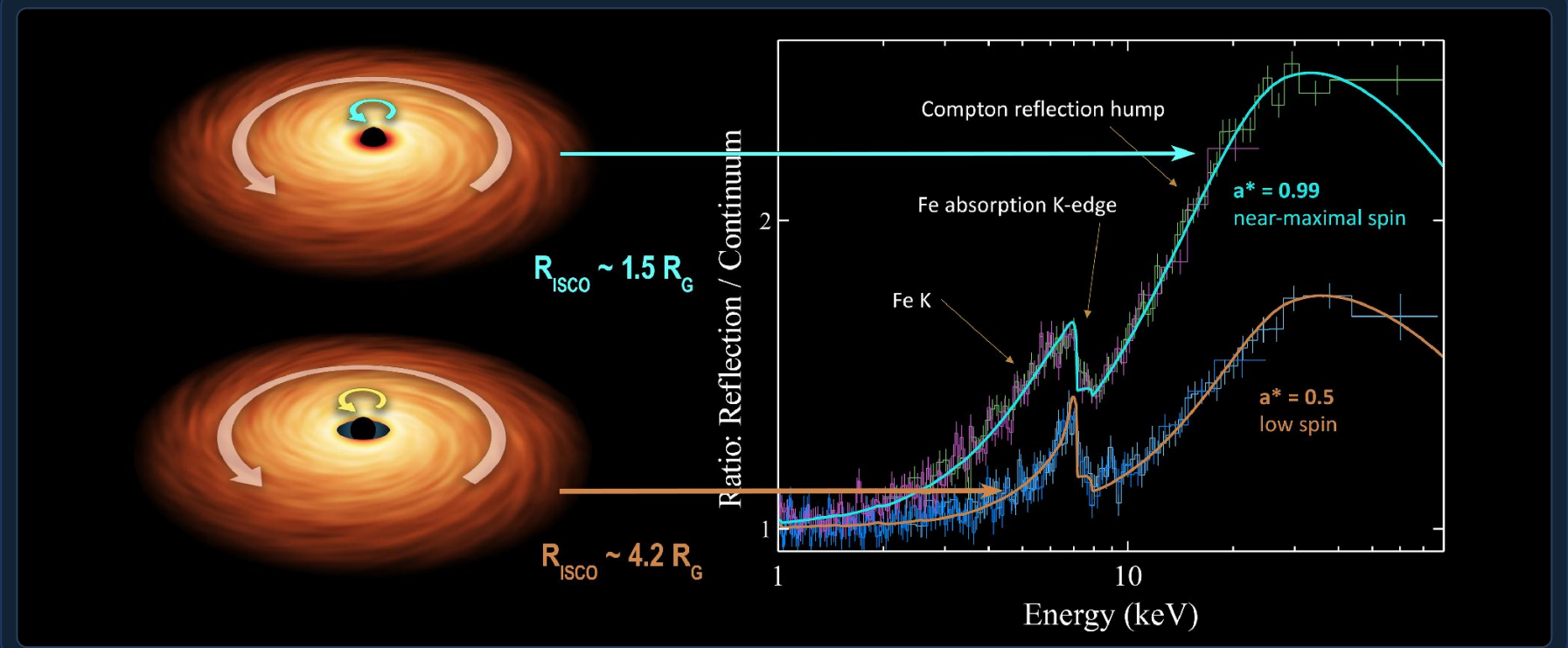


Mean spin per mass bin, simulated 2–80 keV survey of 100 AGN, vs. the region excluded by current constraints — simulations: Piotrowska et al. (2024); after García et al. (2024), Fig. 5B (heritage)

Reading the reflection spectrum needs the full band



Reflection geometry — García et al. (2014);
Dauser et al. (2014)



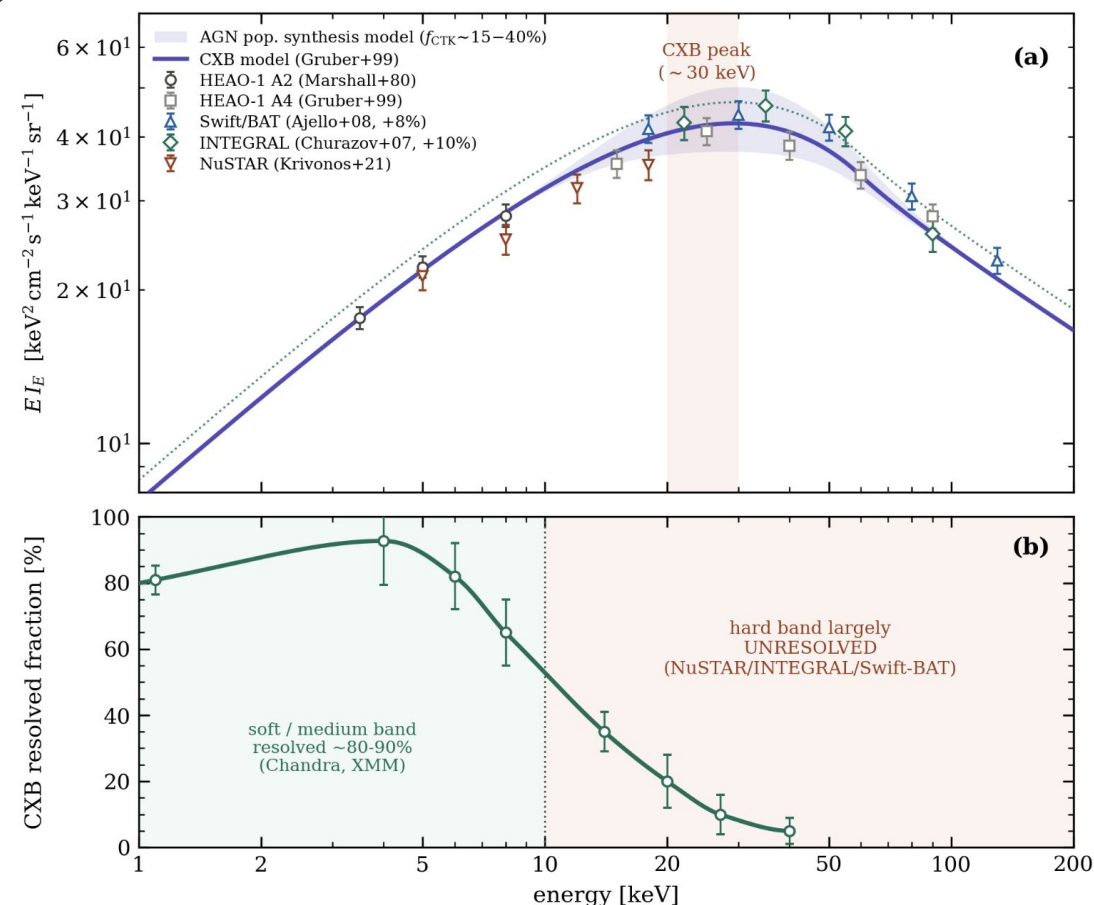
Two spins, one method: smaller R_{ISCO} , broader smearing of Fe K, K-edge, and ~30 keV Compton hump (simulated XMM-Newton + NuSTAR) — J. Piotrowska & J. García; art: NASA/JPL-Caltech

Three diagnostics, three decades in energy — measured in one spectrum, the degeneracies break

Obscured growth and the 30 keV CXB peak

- The CXB = integrated emission of all accreting SMBHs over cosmic history
- Soft band: ~80–90% resolved into AGN — the backbone of demographics
- At the ~30 keV peak: only ~10% resolved into sources
- The fastest growth hides behind heavy obscuration — visible only in the hard band

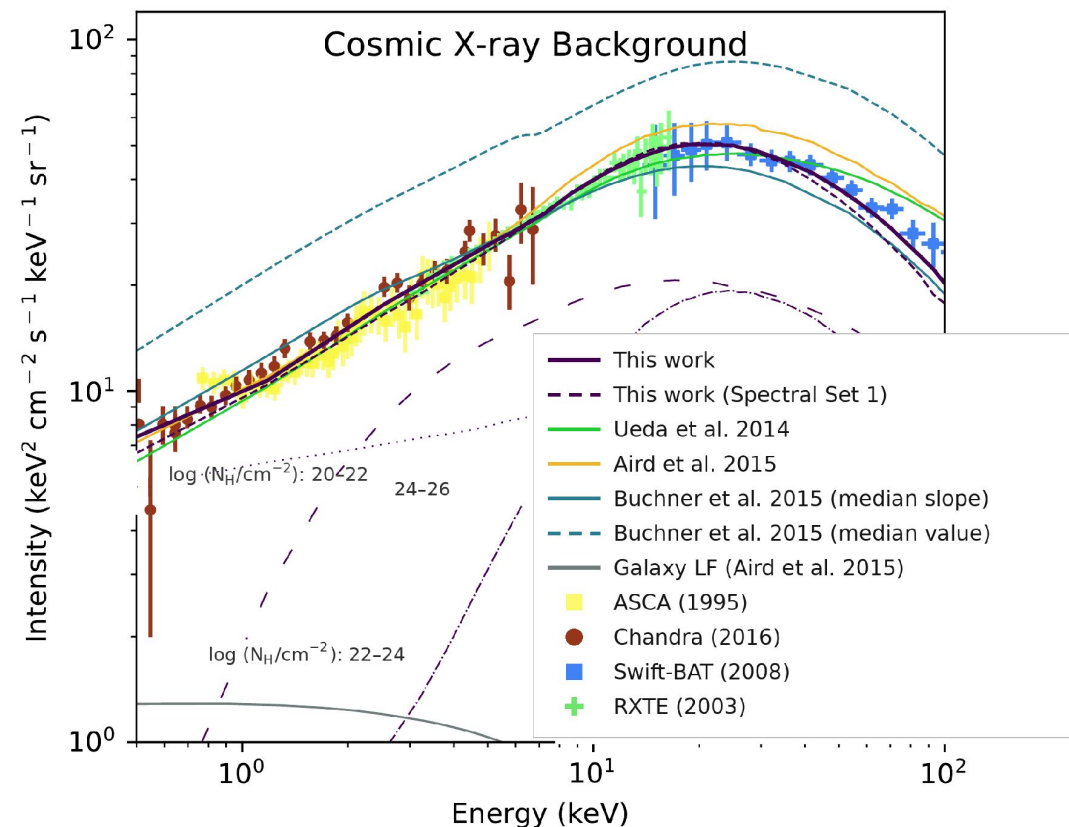
The CXB in depth → Chien-Ting Chen's talk



The CXB and its resolved fraction: at the ~30 keV peak, most of the background remains unresolved — BBX-SAG (2026); measurements as labeled

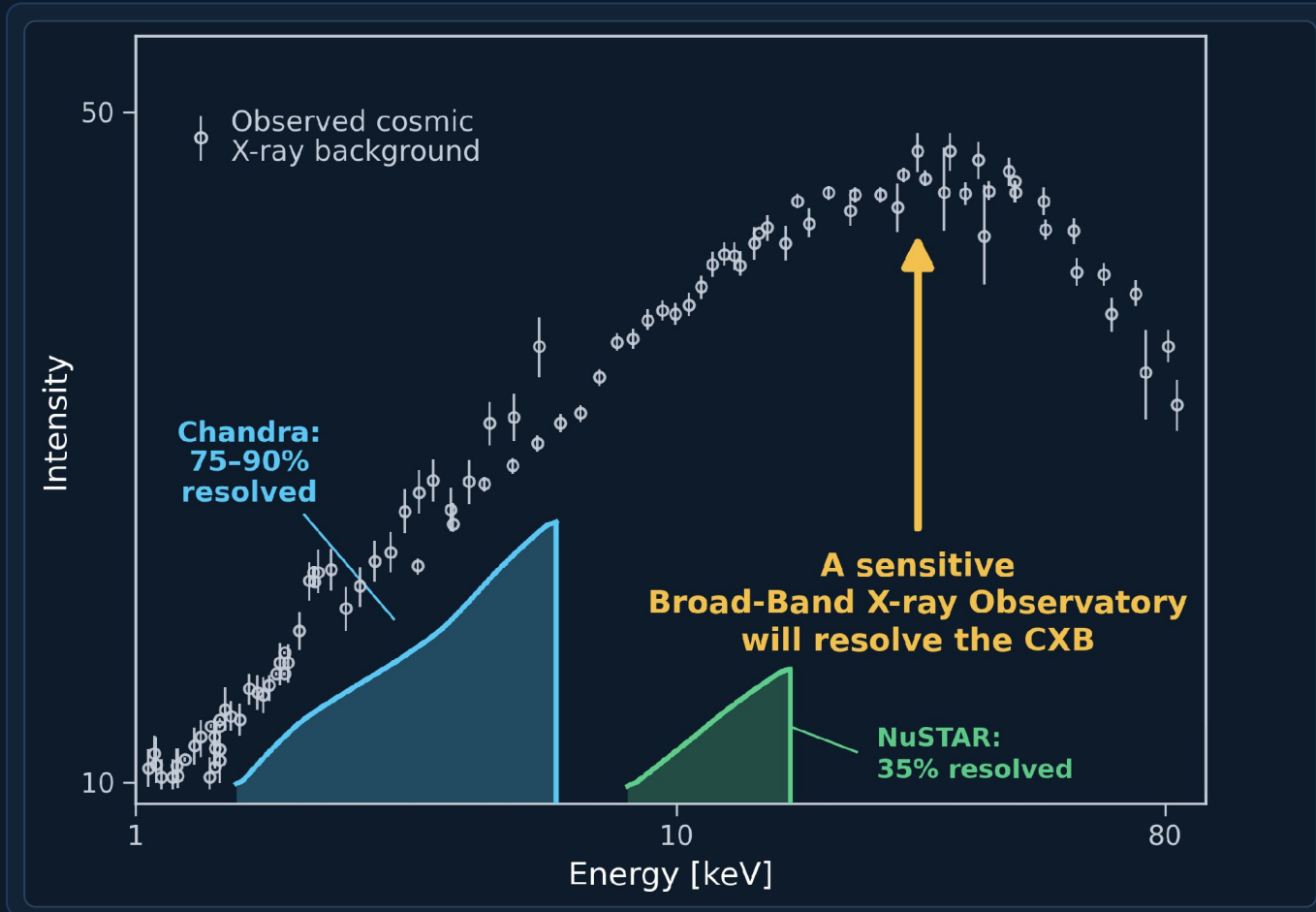
What the CXB peak is made of

- Synthesis models with very different Compton-thick fractions all match today's CXB
- The obscured fraction sets the accretion energy budget; obscured/unobscured $\rightarrow$ duty cycle, geometry
- Variable absorption probes the obscurer: clumps, covering fraction
- LRDs: if obscured AGN, a hard X-ray census finds them — or proves their absence



Many synthesis models, one dataset — Compton-thick fraction unpinned — Ananna et al. (2019)

Resolving the 30 keV peak



The X-ray background, dominated by accreting SMBHs, peaks near ~30 keV: half of SMBH growth is obscured and missed by low-energy surveys. Resolving that population into individual sources completes the cosmic census of SMBH growth.

What the X-ray measurement multiplies

JWST · Roman · Rubin/LSST · Euclid · FIR & radio

masses · hosts · environments · epochs — the sample and its context



high-resolution soft X-ray spectroscopy

**complementary —
same objects, same epochs**

XRISM today · NewAthena next (heritage) — line-by-line: winds, outflows, obscuring gas

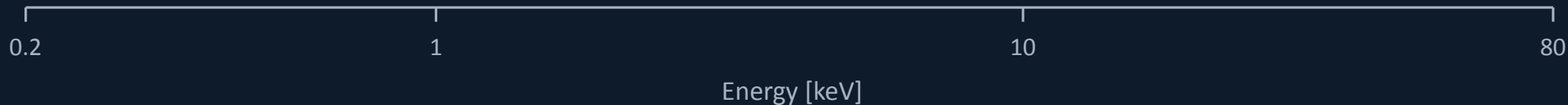
sensitive broad-band coverage — the requirement

continuum + reflection across three decades: spin, corona, obscured growth

soft excess
 $\lesssim 2$ keV

Fe K & wind lines
6–9 keV

Compton hump & CXB peak
~20–40 keV



Masses from the surveys, physics from the X-rays — neither is a census alone

What this science requires

THE QUESTION

How did supermassive black holes grow — and how does that growth shape their galaxies?

THE MEASUREMENT

The spin–mass distribution of supermassive black holes in the local Universe

THE REQUIREMENT

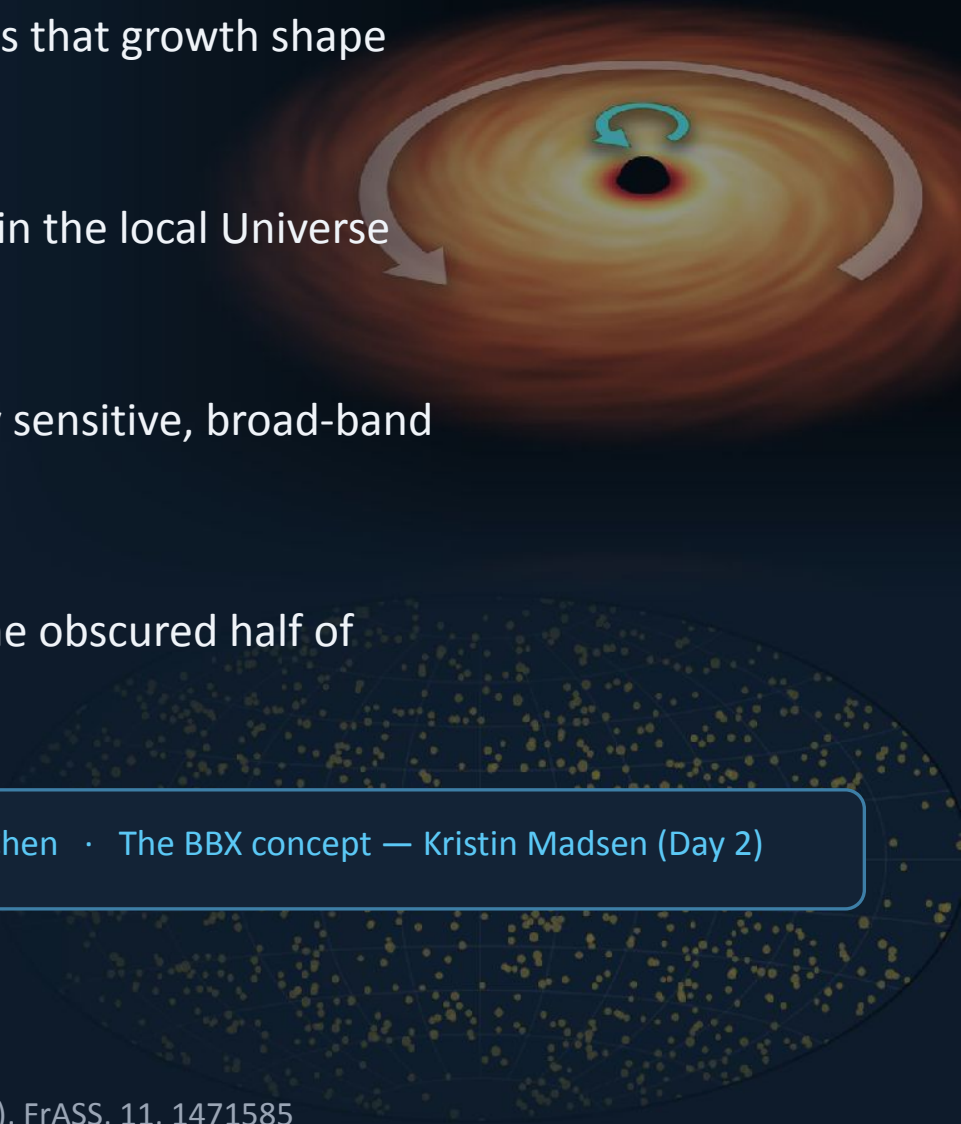
≥ 100 uniformly analyzed spins with $\sigma(a^*) \lesssim 0.05$ — only sensitive, broad-band reflection spectroscopy delivers this

AND

Resolve the cosmic X-ray background above 10 keV — the obscured half of growth

Compact objects & the time domain — Dan Stern (next) · The CXB in depth — Chien-Ting Chen · The BBX concept — Kristin Madsen (Day 2)

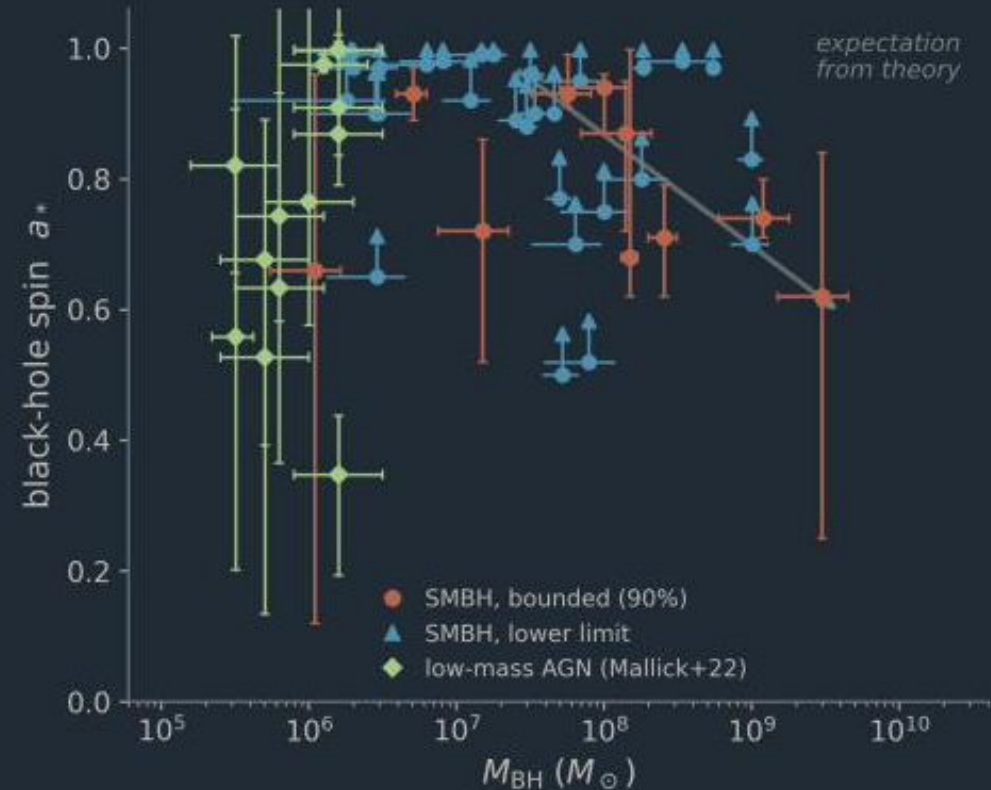
On behalf of the BBX Science Analysis Group — thank you



Backup

B1 — Today's census: few dozen, heterogeneous

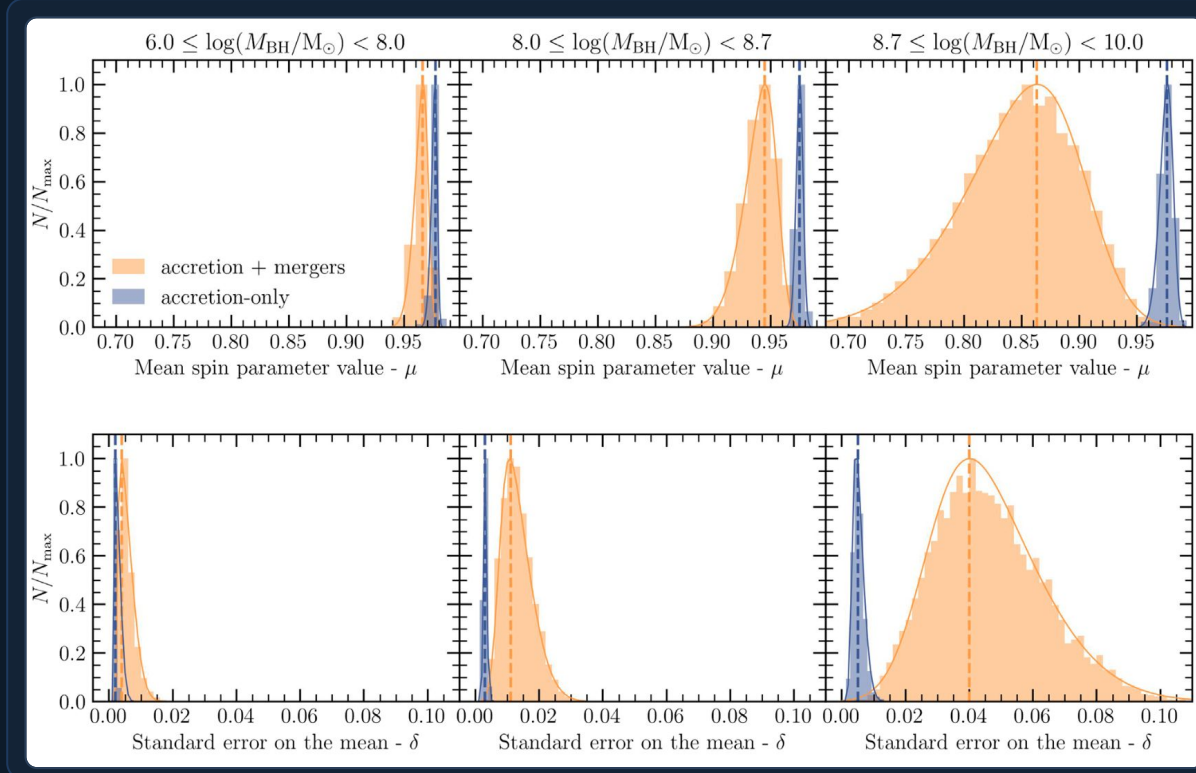
- 51 SMBH spin measurements to date — only 22 with well-defined uncertainties
- Below $\approx 3 \times 10^7 M_{\odot}$: 26 of 30 consistent with $a^* \geq 0.9$; slower rotators emerge at higher mass
- Many groups, heterogeneous models, mostly statistical errors — choices shift a^* by ~ 0.1
- Selection bias: spin boosts luminosity — the sample selects for what it measures
- Lesson from the stellar-mass band: homogeneous analysis, explicit quality criteria



SMBH mass–spin plane — Sisk-Reynés et al. (2026), Fig. 1; regenerated from the paper's public data (CC BY)

B2 — How ~100 spins discriminate growth channels

- Simulated spin surveys through Horizon-AGN growth scenarios (accretion-only vs. accretion+mergers)
- Expected means separate: e.g. $\log M \in [8.7, 10.0]$: $a^* = 0.976 \pm 0.005$ vs. 0.86 ± 0.04
- Strongest signal in the most massive bin: today's 51 (22 constrained) cannot separate them



Mean spin (μ) and its standard error (δ) per mass bin, 10^4 simulated 100-AGN campaigns: the scenarios separate at high mass — Piotrowska et al. (2024), Fig. 9

B3 — Why broad-band, not high-resolution soft alone

- Spin lives in broad structures: blurred Fe line, soft excess, Compton hump — resolution does not recover the hump
- >10 keV curvature breaks continuum–reflection–absorption degeneracies (reflection-fraction constraint)
- Joint soft+hard fit resolves what neither band does alone — shown in published simulation work
- High-resolution spectroscopy dissects narrow features (winds, obscurer) — complementary, not substitutable

B4 — Spin systematics and the quality-criteria answer

Sorted by what each one actually breaks

Bites continuum fitting	Bites reflection	Bites both
M, D, i priors	Continuum–reflection separability	$r_{\text{in}} = r_{\text{ISCO}}$ (truncation)
Colour correction f_{col}	Disk density	Returning radiation
Warm corona	Fe abundance, ionization gradient	Plunging-region emission
Zero-torque ISCO	Emissivity $\Rightarrow$ coronal geometry	Finite disk thickness
		Fit statistic blind to local minima

Plunge sits in both: neglecting it biases reflection spins high — most strongly at low input spin, the regime where the tension lives.

Instrumental — pile-up, passband, non-simultaneity — hits everything, and is the one class we already know how to eliminate.

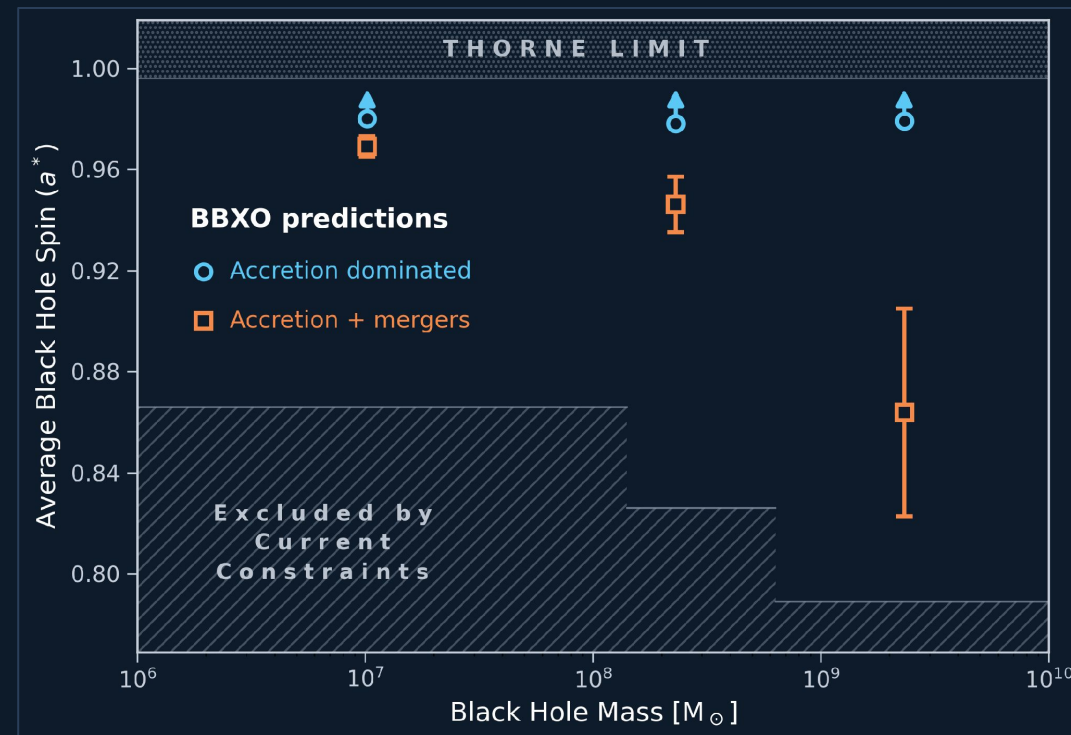
Plunge: Dong et al. (2023), arXiv:2312.09210 · Mummery et al. (2024), MNRAS, 531, 366 · Demiroglu et al. (in prep)

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From J. García's COSPAR 2026 review talk — systematics sorted by what they bite

B5 — Sample and feasibility, capability level

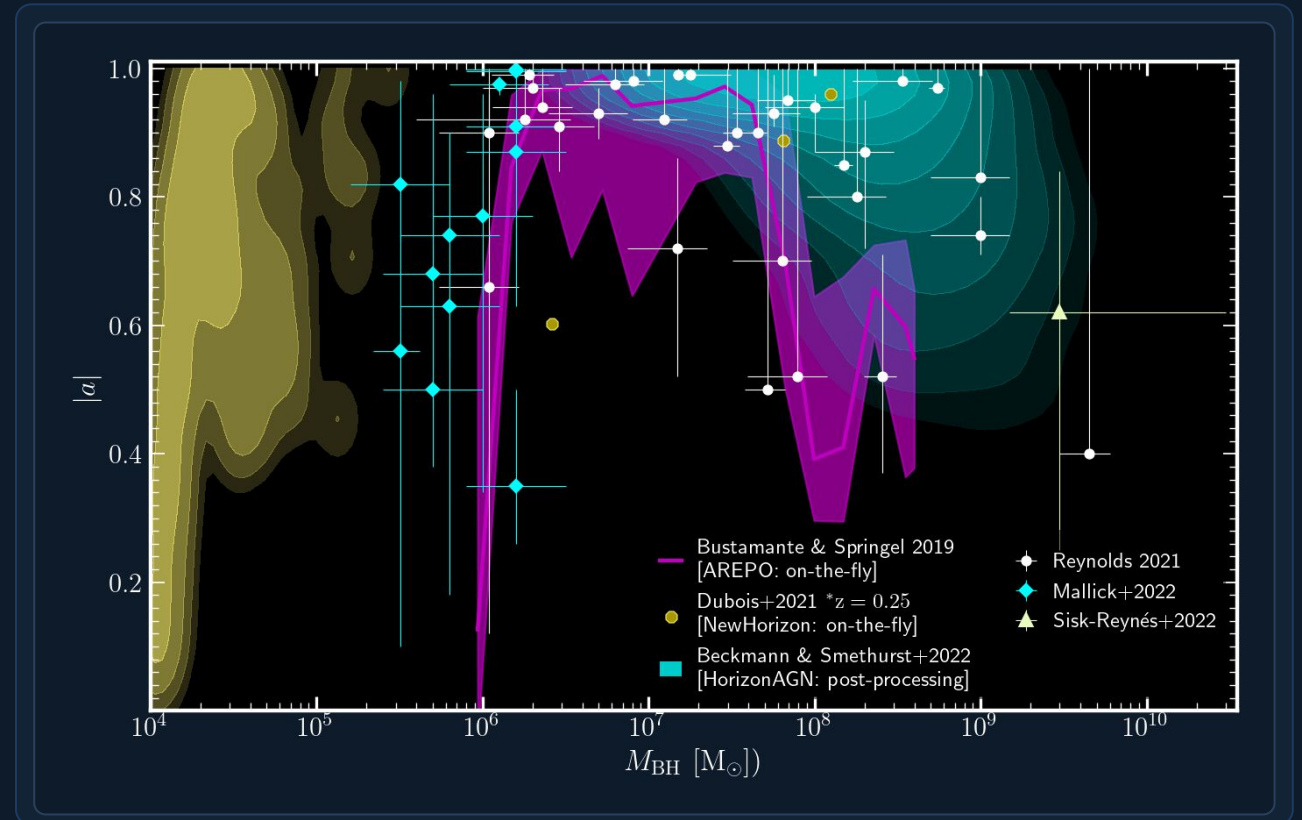
- Parent sample exists today: ~100 brightest hard-X-ray-selected unobscured AGN (Swift/BAT BASS)
- Published simulation: 150 ks broad-band $\rightarrow \sigma_a \leq 0.15$ ($a^* = 0.5$) at $F(2-10) = 6 \times 10^{-12} \text{ erg cm}^{-2} \text{ s}^{-1}$
- Total ~10 Ms for 100 AGN in one program — vs. ≥ 30 yr with coordinated separate soft+hard facilities
- Selection function defined before observing — the homogeneity requirement, by construction



Expected mean spins vs. region excluded by current constraints — simulations: Piotrowska et al. (2024); after García et al. (2024), Fig. 5B (heritage)

B6 — Spin constraints calibrate simulation subgrid models

- Simulations disagree on the spin–mass locus: AREPO on-the-fly, NewHorizon on-the-fly, Horizon-AGN post-processing
- Current constraints cannot arbitrate between subgrid prescriptions
- A homogeneous ~ 100 -AGN spin census calibrates the next generation of SMBH growth models



Simulated spin–mass predictions vs. measurements — Beckmann et al. (2024), Bustamante & Springel (2019), Dubois et al. (2021); figure courtesy J. Piotrowska

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