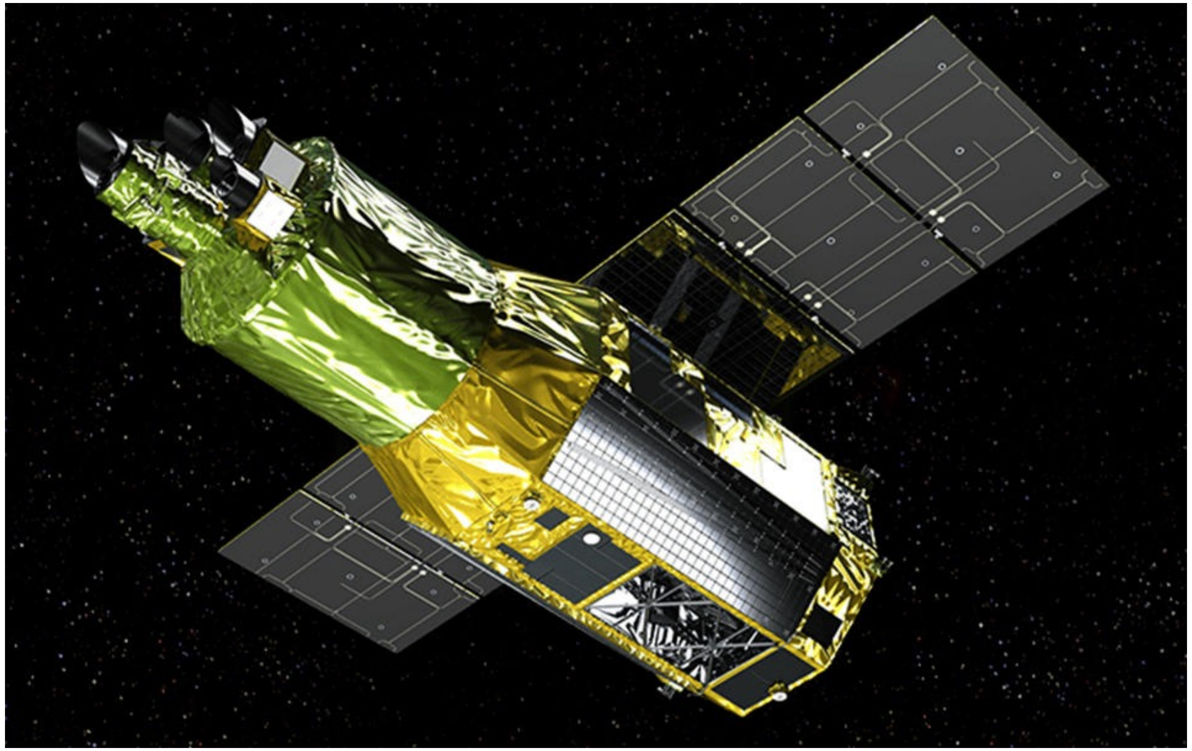
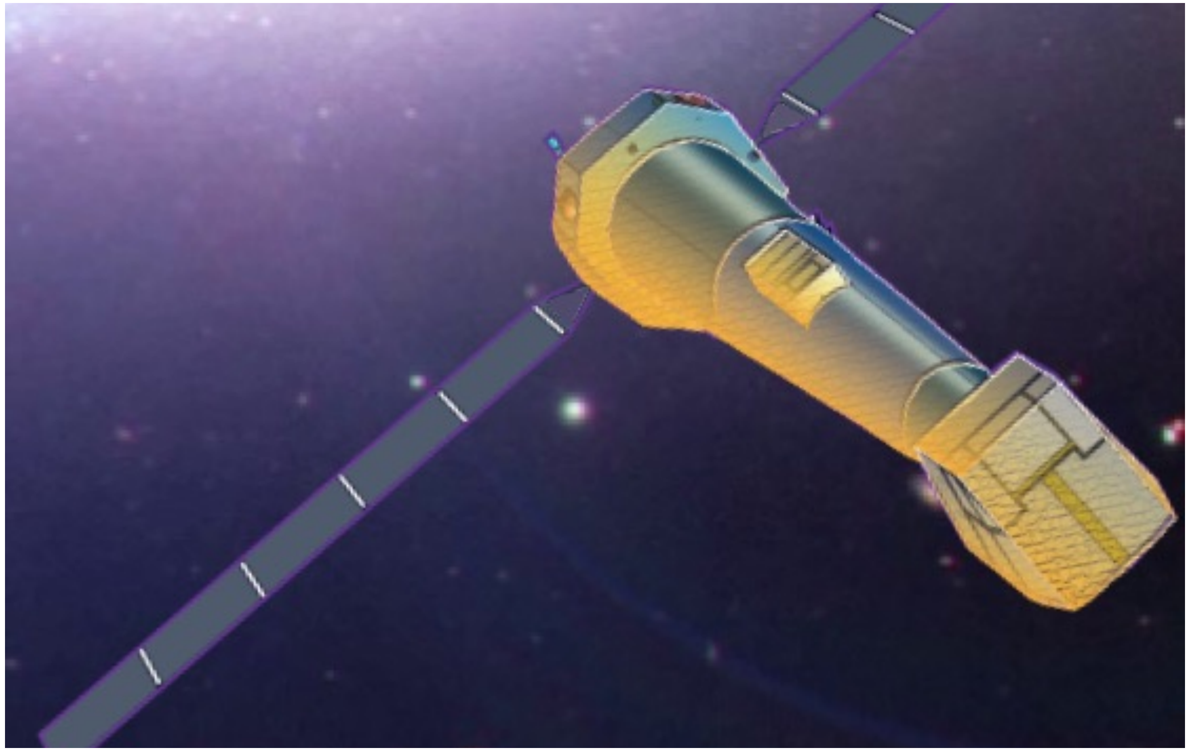
 

WHAT'S PAST IS PROLOGUE*: FROM XRISM TO NEWATHENA

MATTEO GUAINAZZI, NEWATHENA/XRISM ESA PROJECT SCIENTIST

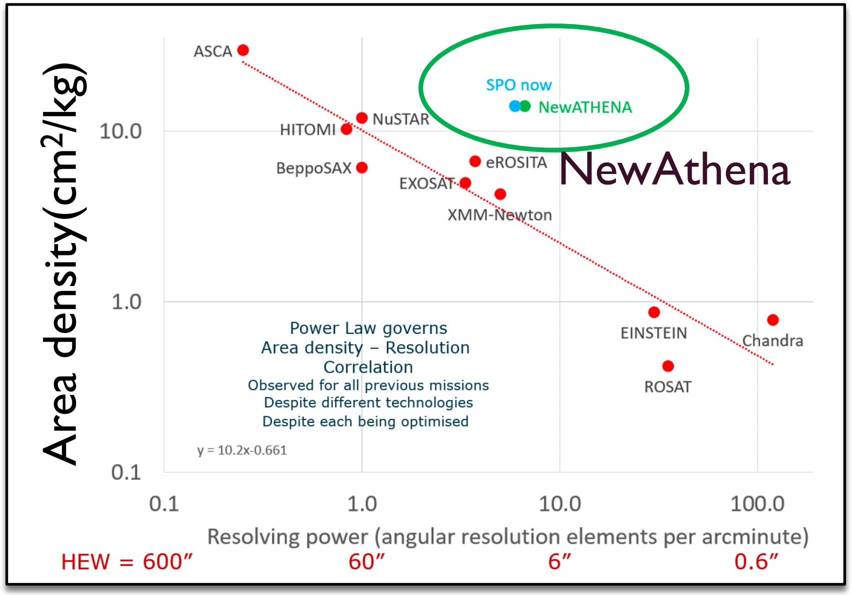
*Shakespeare, "The Tempest"

「見所の
あれや野分の
後の菊。」

松尾 芭蕉, 1644-1694

NEWATHENA FUNDAMENTALS

The largest space-qualified X-ray mirror for astronomy

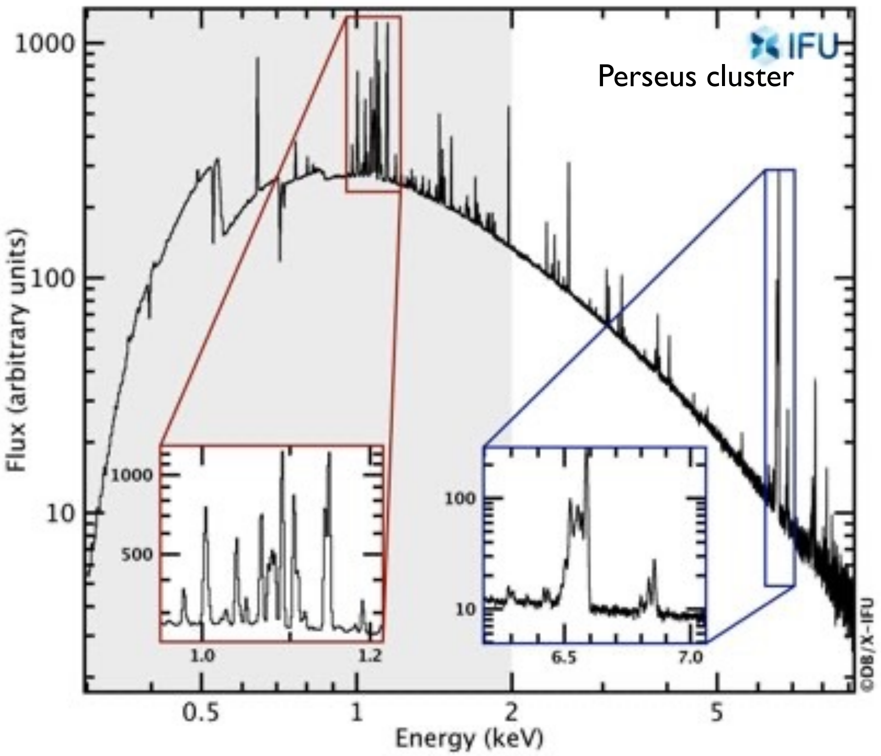


Resolving power

X-ray telescope based on **Silicon Pore Optics (SPO)** technology (ESA), 9" HEW, 1.0 m^2 area @1 keV

Bavdaz et al. 2023. SPIE, 1267902-1

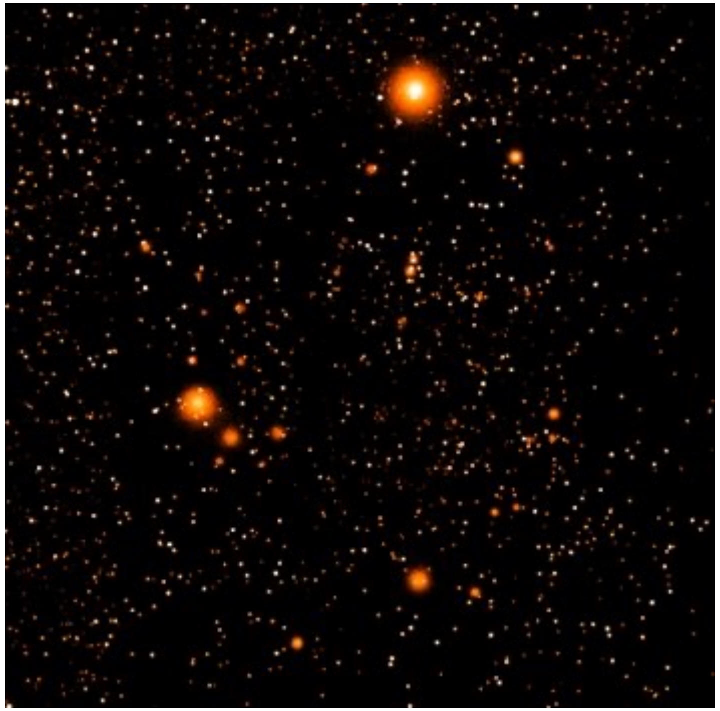
Unprecedented spectroscopic capabilities



X-Ray Integral Field Unit (**X-IFU**) (CNES/IRAP-led), ≤4 eV energy resolution, >1500 pixels, ~5" side (4' effective diameter FoV)

Barret et al., 2024, ExA, 55, 373

The fastest sky X-ray survey machine

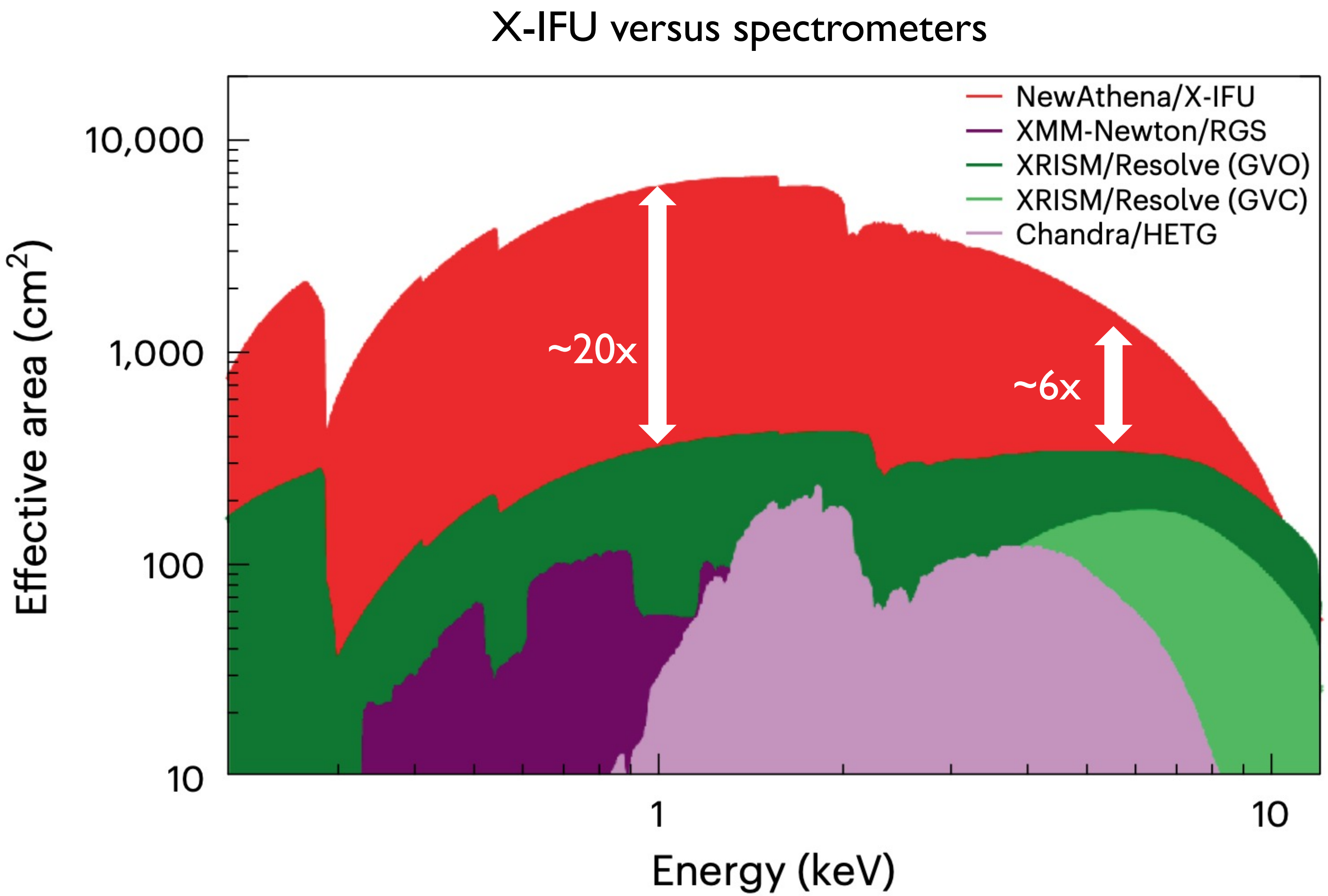


Wide Field Instrument (**WFI**) (MPE-led), DEPFET, <170 eV resolution @7 keV, 40'x40' FoV

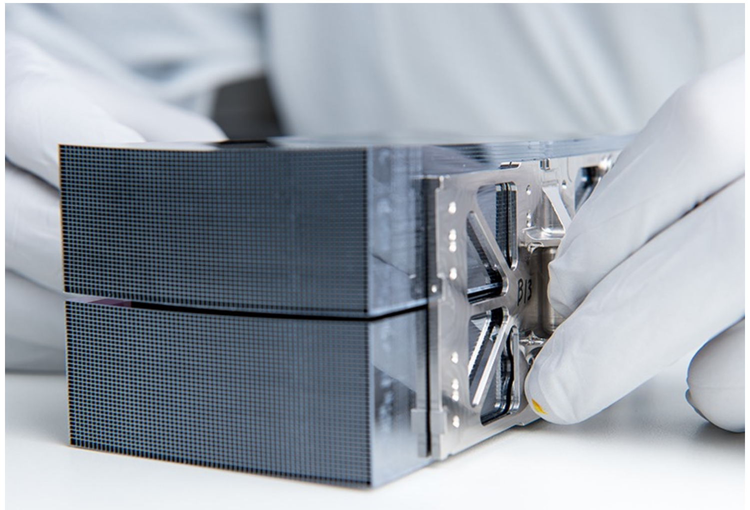
Credit: A. Rau (MPE)

NEWATHENA IS A *LARGE MIRROR* X-RAY OBSERVATORY

Cruise et al., Nature Astronomy, 2025

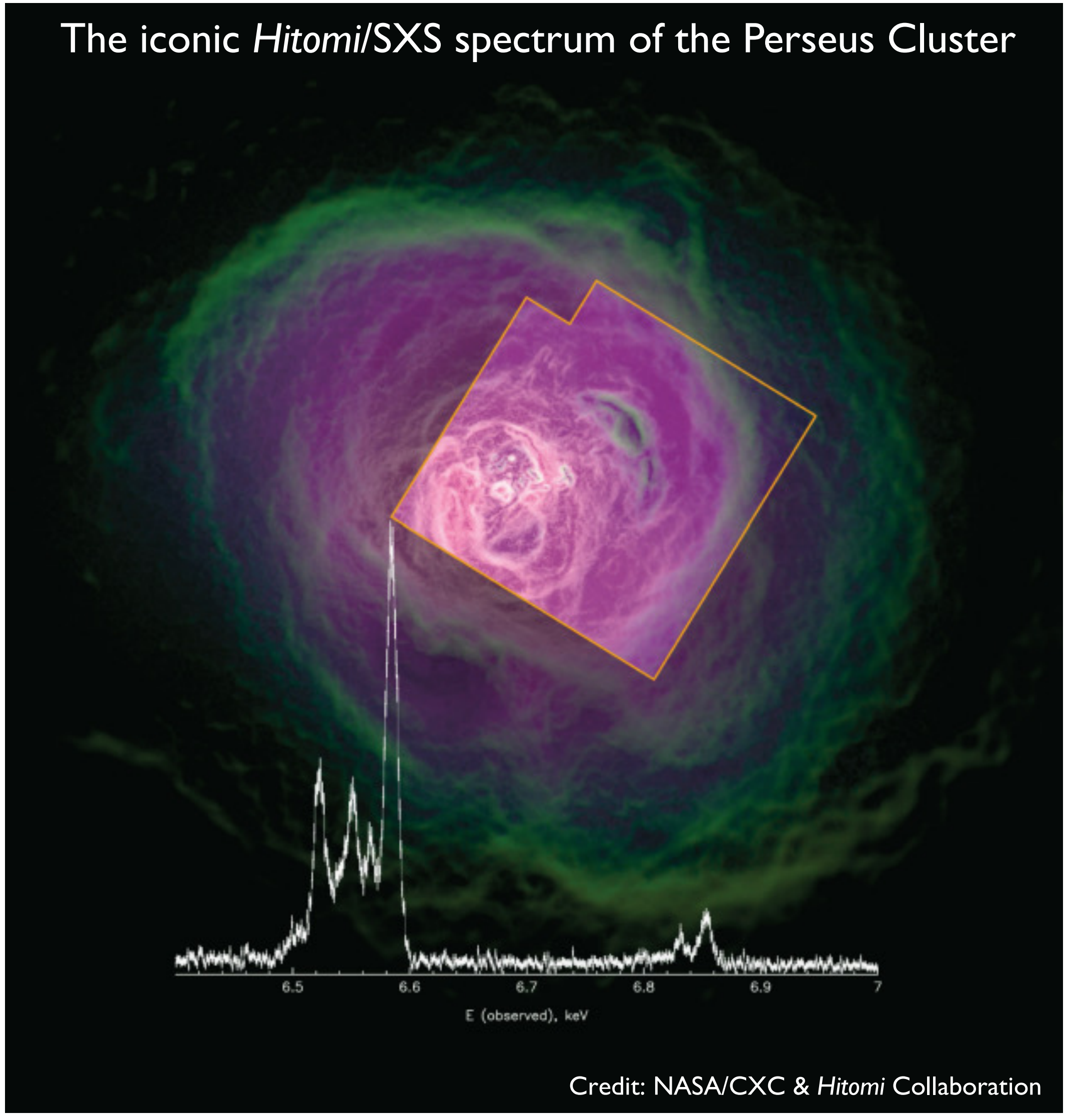


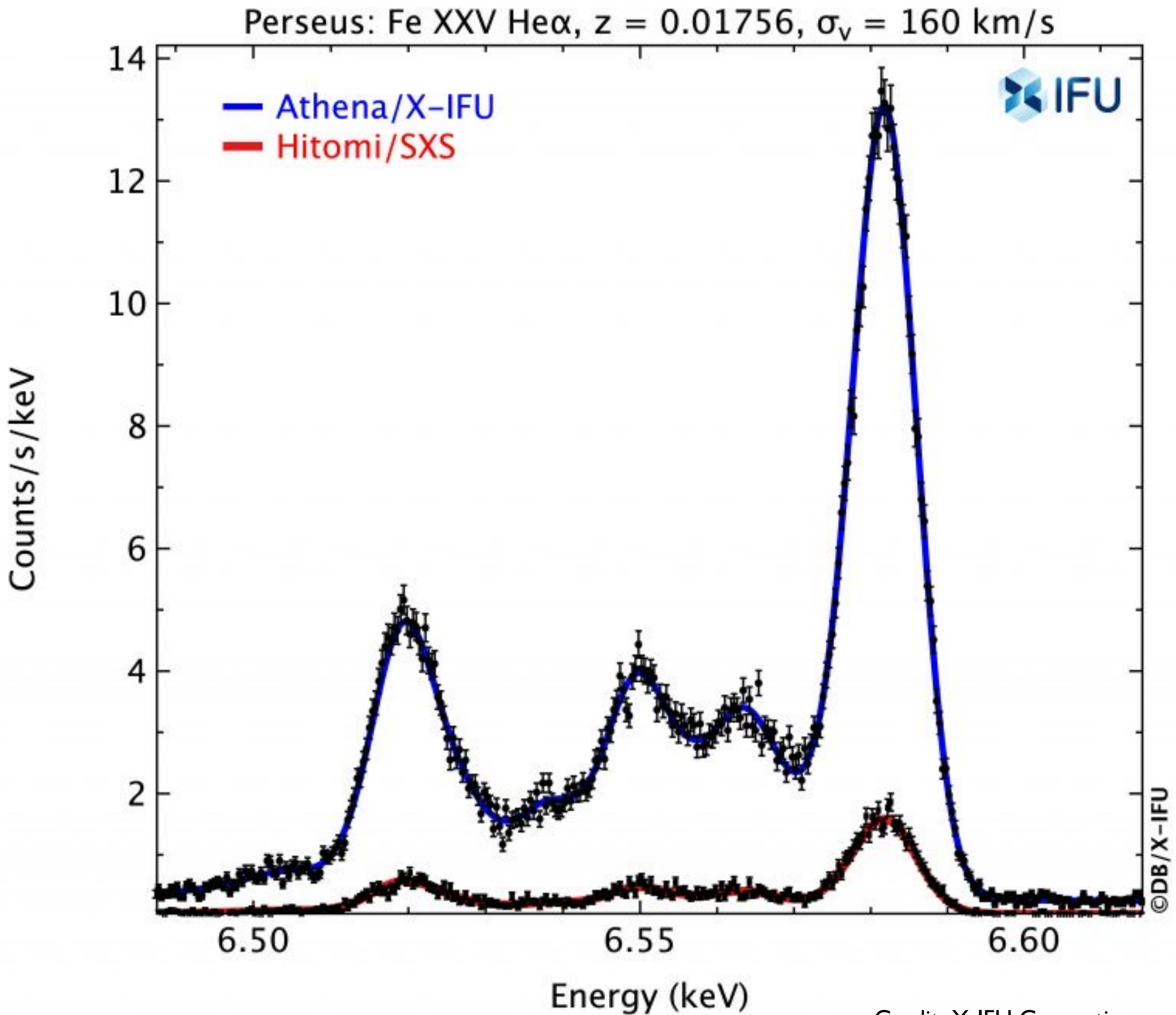
- The NewAthena mirror is a ~2 m wide structure, ~2 t mass
- It is based on ~500 “mirror modules”, stacks of commercially-available Silicon plates
- **~1 m^2 effective area** @1 keV, **9” HEW** angular resolution



A NewAthena mirror module; Credit: cosine

PAST AND FUTURE OF X-RAY SPECTROSCOPY



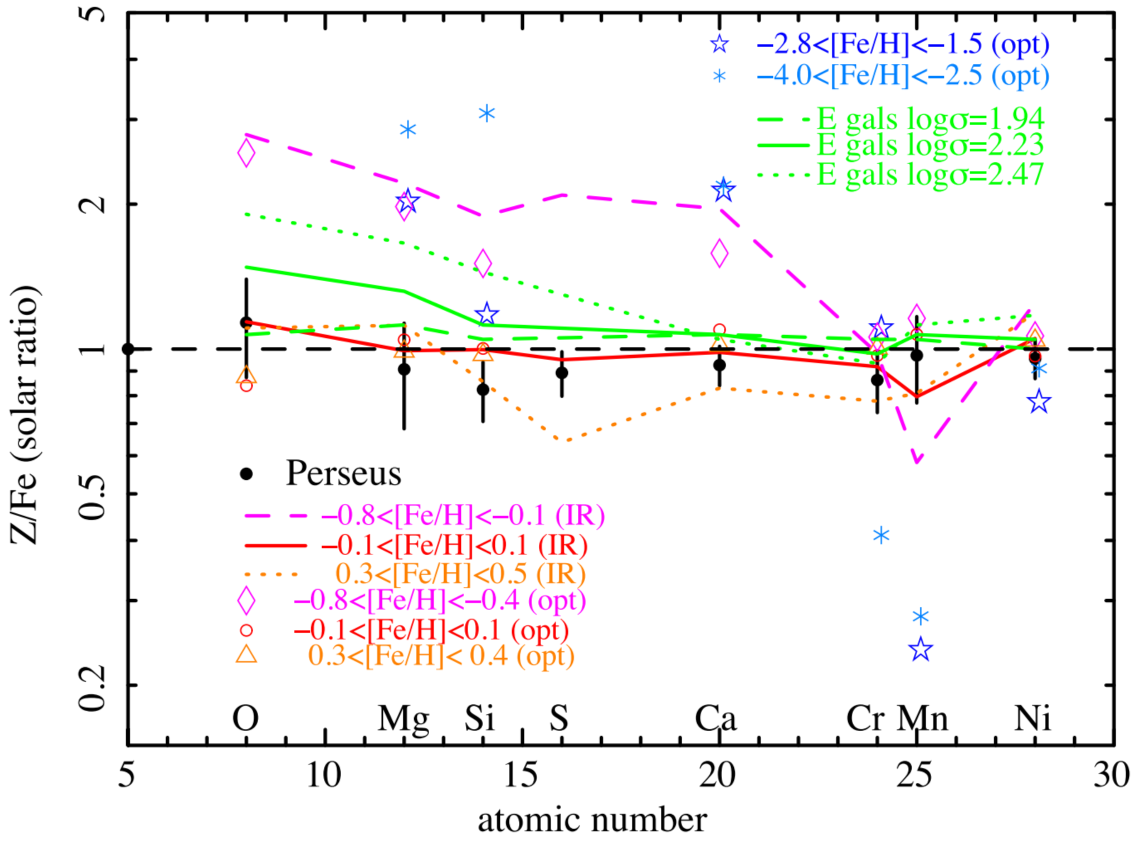


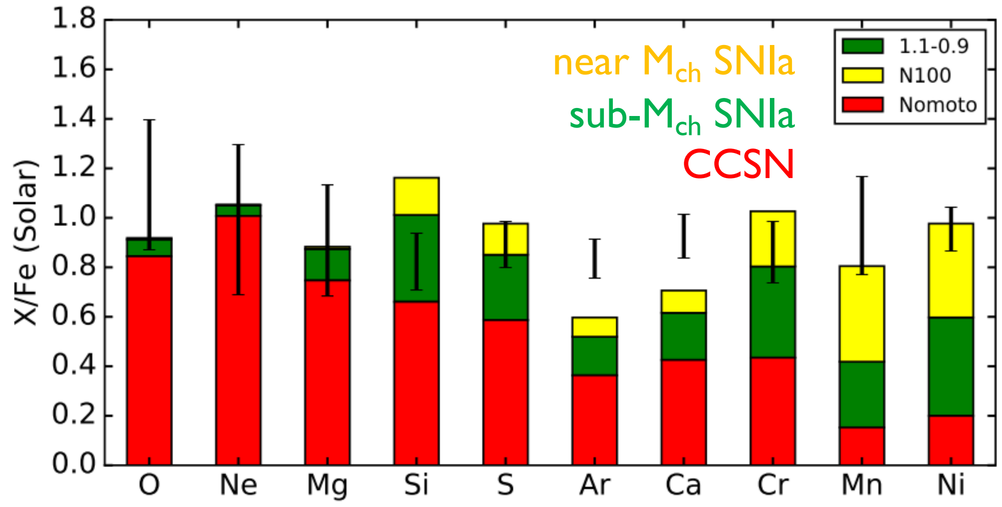
Credit: X-IFU Consortium

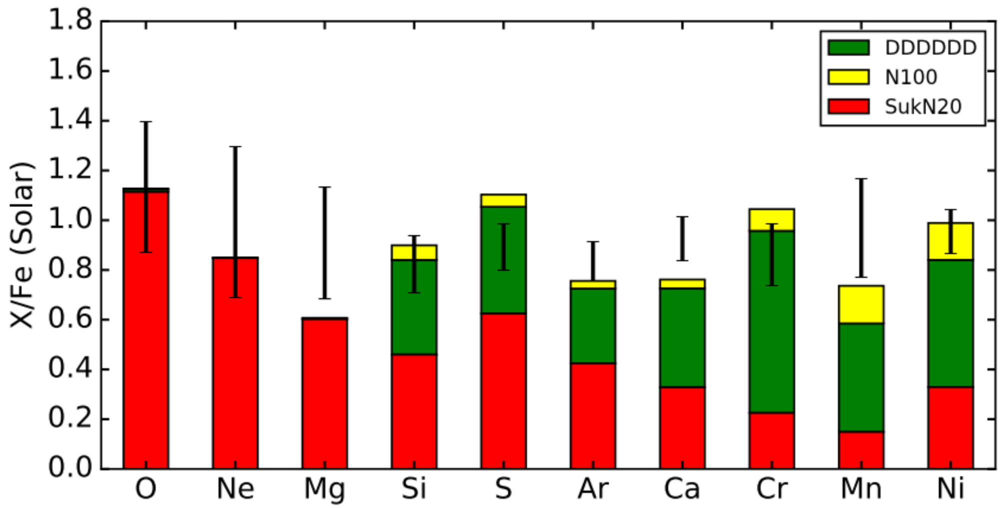
HITOMI AND XRISM LIFT THE VEIL ON METAL PRODUCTION

Simionescu et al., 2019, MNRAS, 483, 1701

Comparison of Perseus (z=0.017) metallicity (Hitomi) with the Milky Way (IR/opt) and early-type galaxies (SDSS)

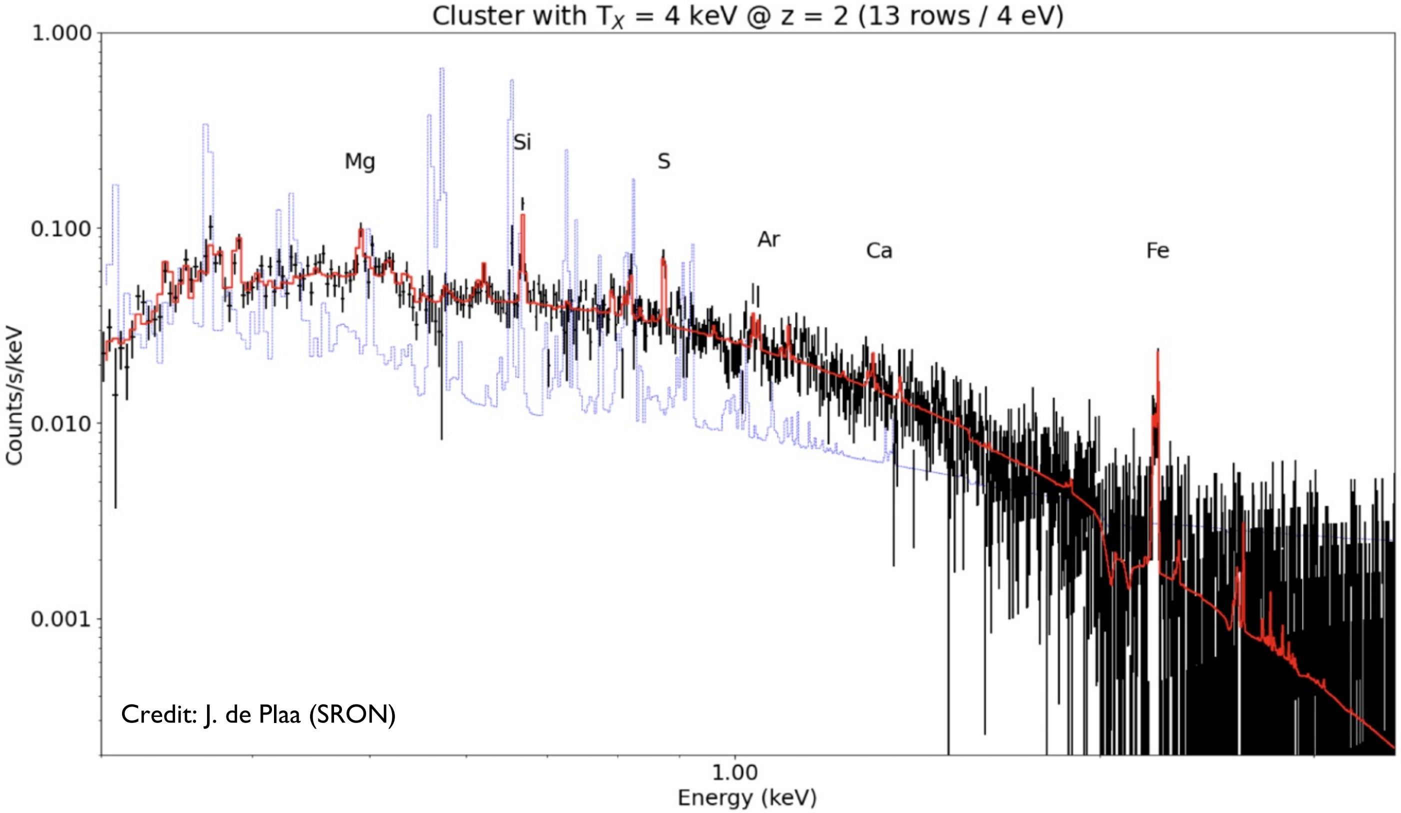






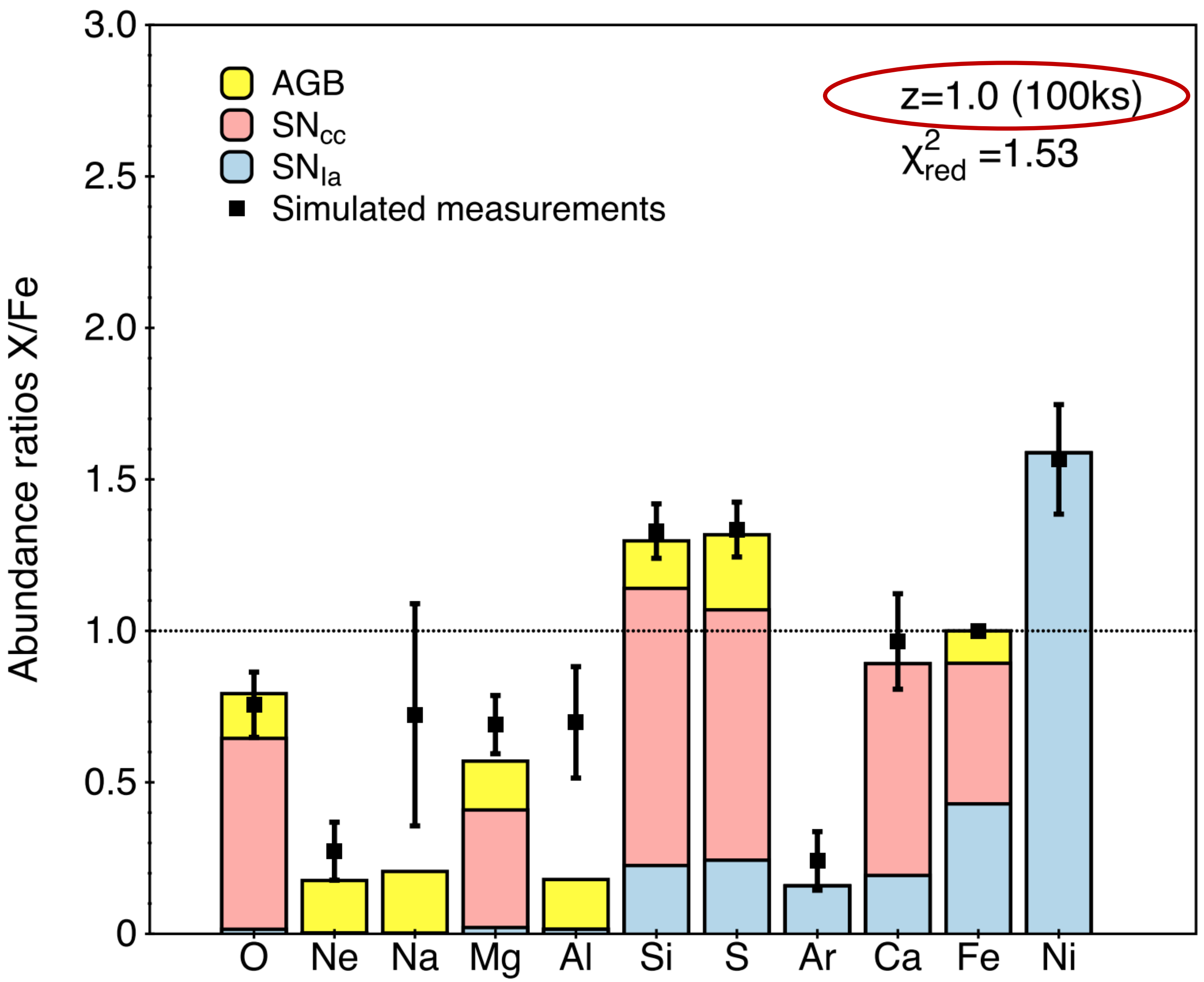
NEWATHENA EXTENDS TO Z~2

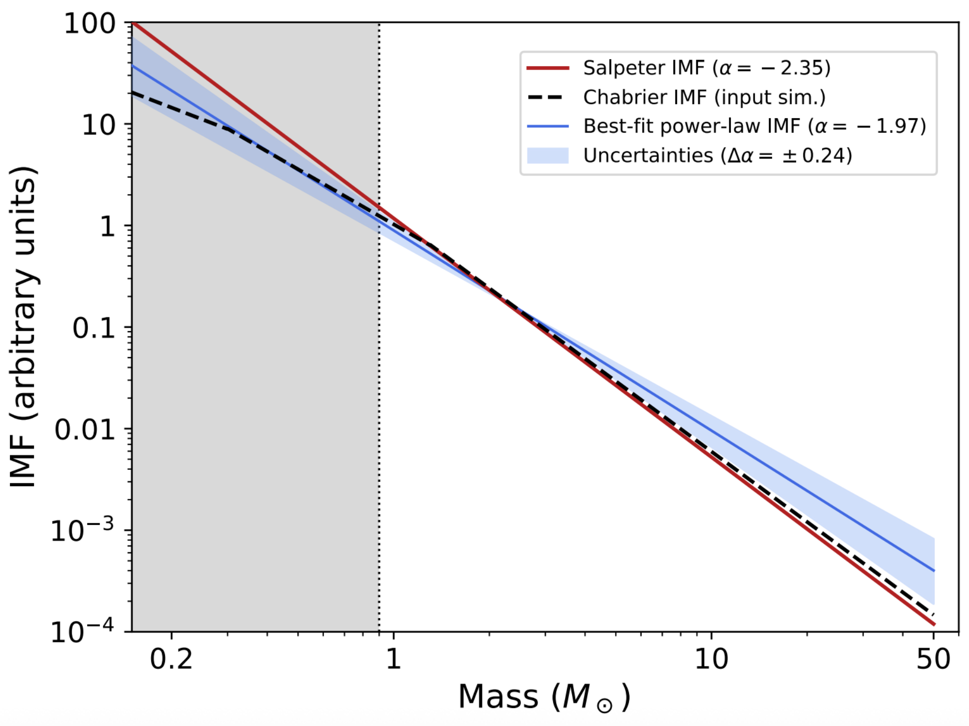
X-IFU simulation of a z=2 Perseus-like galaxy cluster with Z=0.3



- Goal: tracing the evolution of baryion physical properties from the epoch of structure formation (z~2)
- One of the key science objectives of NewAthena
- X-IFU can measure ICM metal content from Mg to Ni up to z~2
- Statistical (systematic) errors on Z_{Mg} ~15% (<~10%)

ABUNDANCE PATTERNS CONSTRAIN THE EARLY HISTORY OF SN





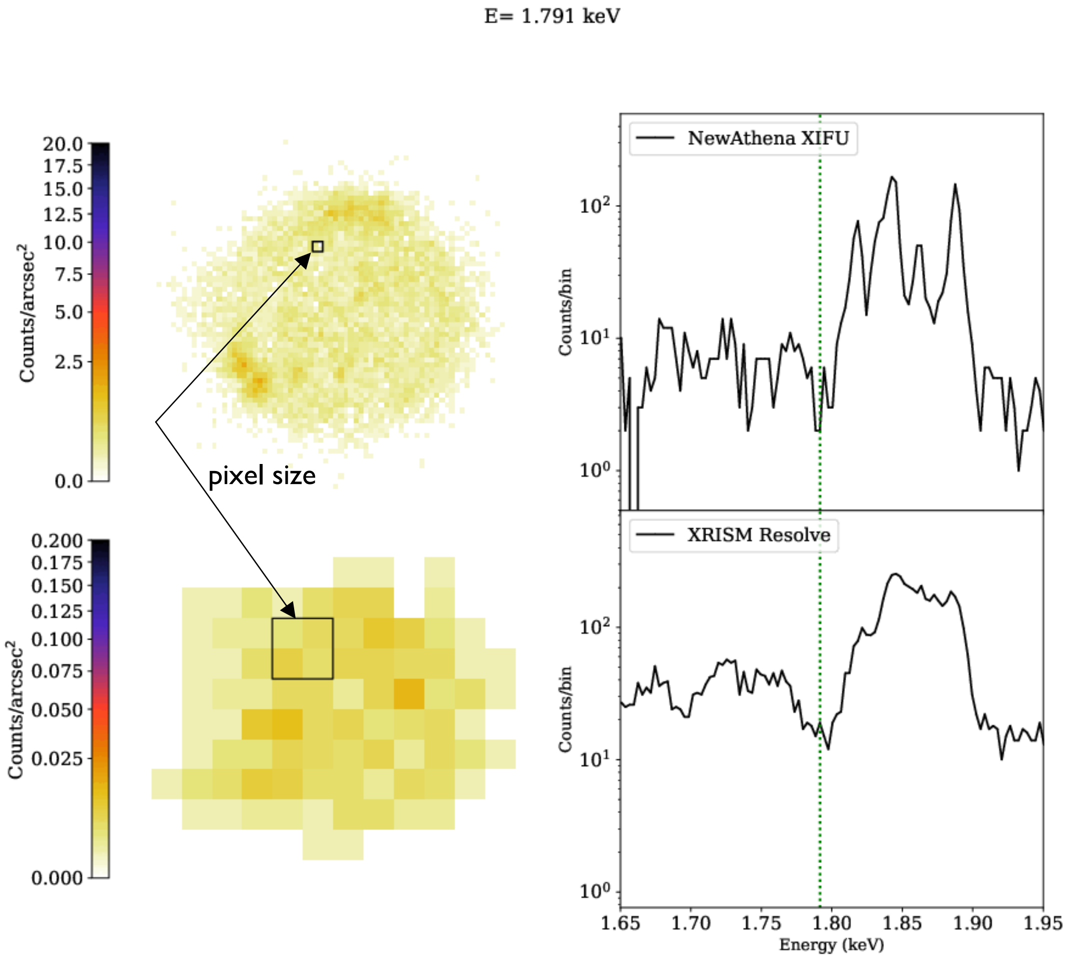
Independent constraints on the Initial Mass Function potentially possible

Mernier et al., 2020, A&A, 642, 90

INTEGRAL FIELD UNIT CAPABILITIES IN X-RAYS

Credit: F. Acero (CEA) & C. Kirsch (FAU)

Cassiopea A (X-ray bright SNR)



NewAthena X-IFU
ΔE≤4 eV
~1500 pixels, 5” side
Launch ~2037

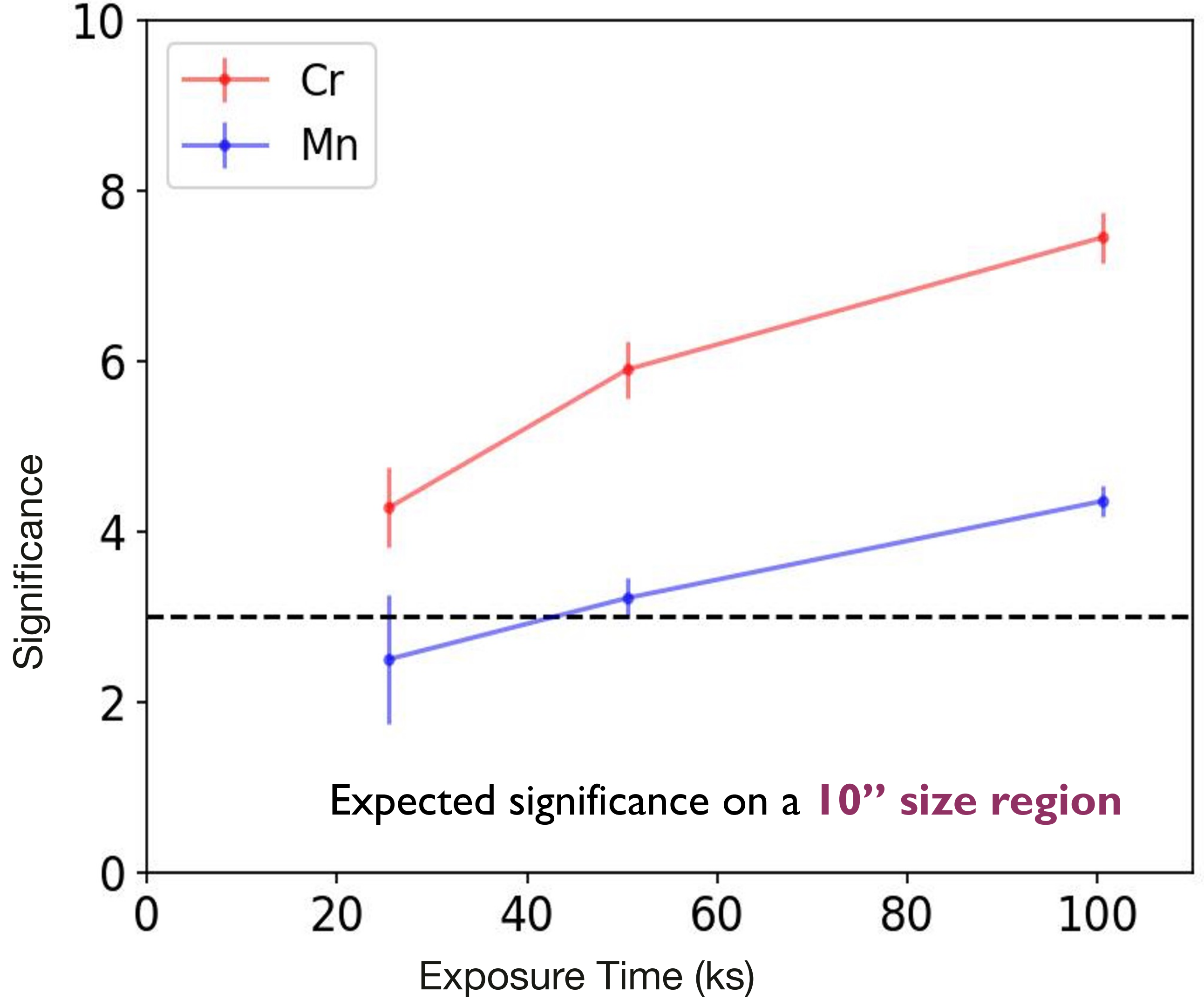
XRISM *Resolve*
ΔE≤5 eV*
35 pixels, 30” side
Operational (2023-)

*7 eV (requirement) shown

EXAMPLE: DETERMINATION OF RARE ELEMENTS IN SNR

Embargoed by Nature

X-IFU simulations of CasA



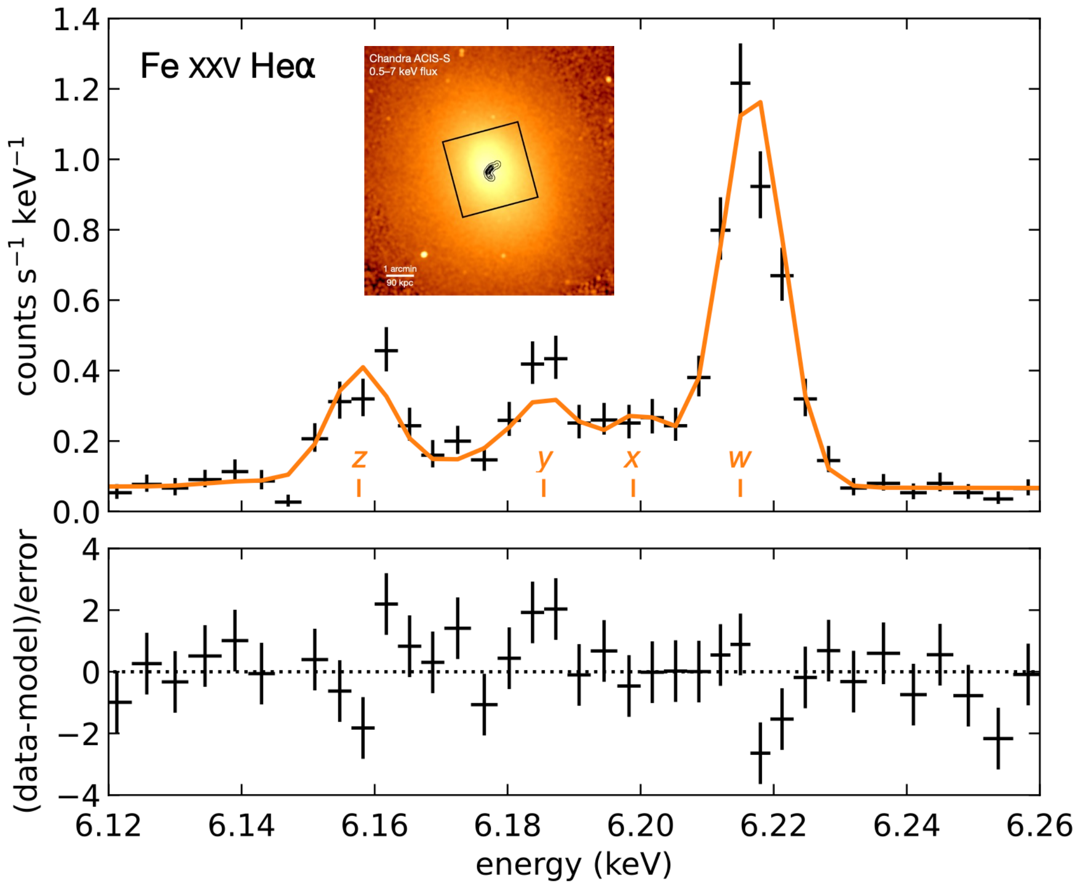
Credit: F. Acero (CEA) & C. Kirsch (FAU)

XRISM UNVEILS A "QUIET" ICM

XRISM Collaboration, 2025, ApJ, 982, L5

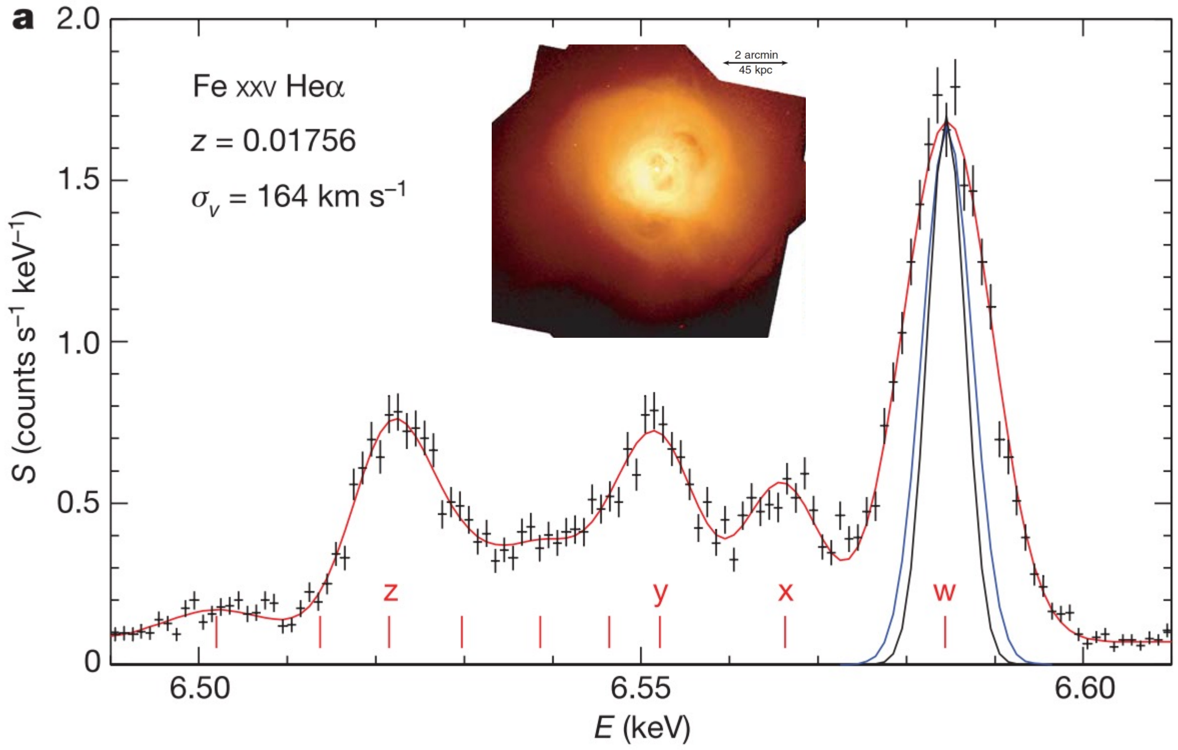
Hitomi Collaboration, 2016, Nature, 535, 117

Abell 2029: a "relaxed" cluster



Non-Thermal/Thermal pressure ~2%

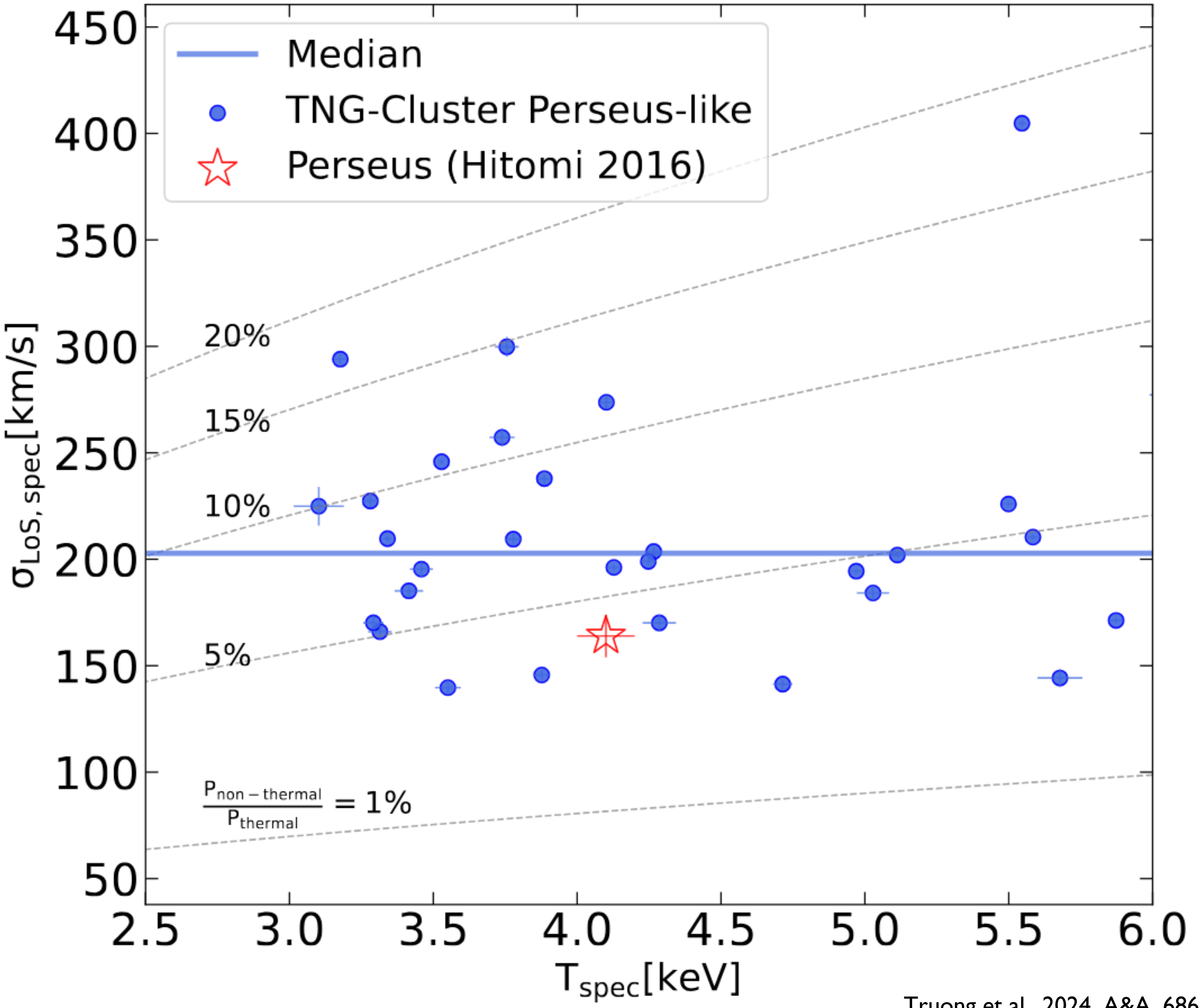
Perseus: a cluster with strong AGN feedback



Non-Thermal/Thermal pressure ~4%

PREDICTIONS OF COSMOLOGICAL SIMULATIONS

- XRISM has found many more examples of low-turbulent ICM (Centaurus, Hydra …) even in presence of large bulk motions (Coma …)
- How do these results compare with cosmological simulations?
- Here, a few tens of Perseus-like clusters extracted from the TNG suite
- Typically, NT pressure ≤10%
- Still unclear whether this level of turbulence can avoid the "radiation cooling catastrophe"

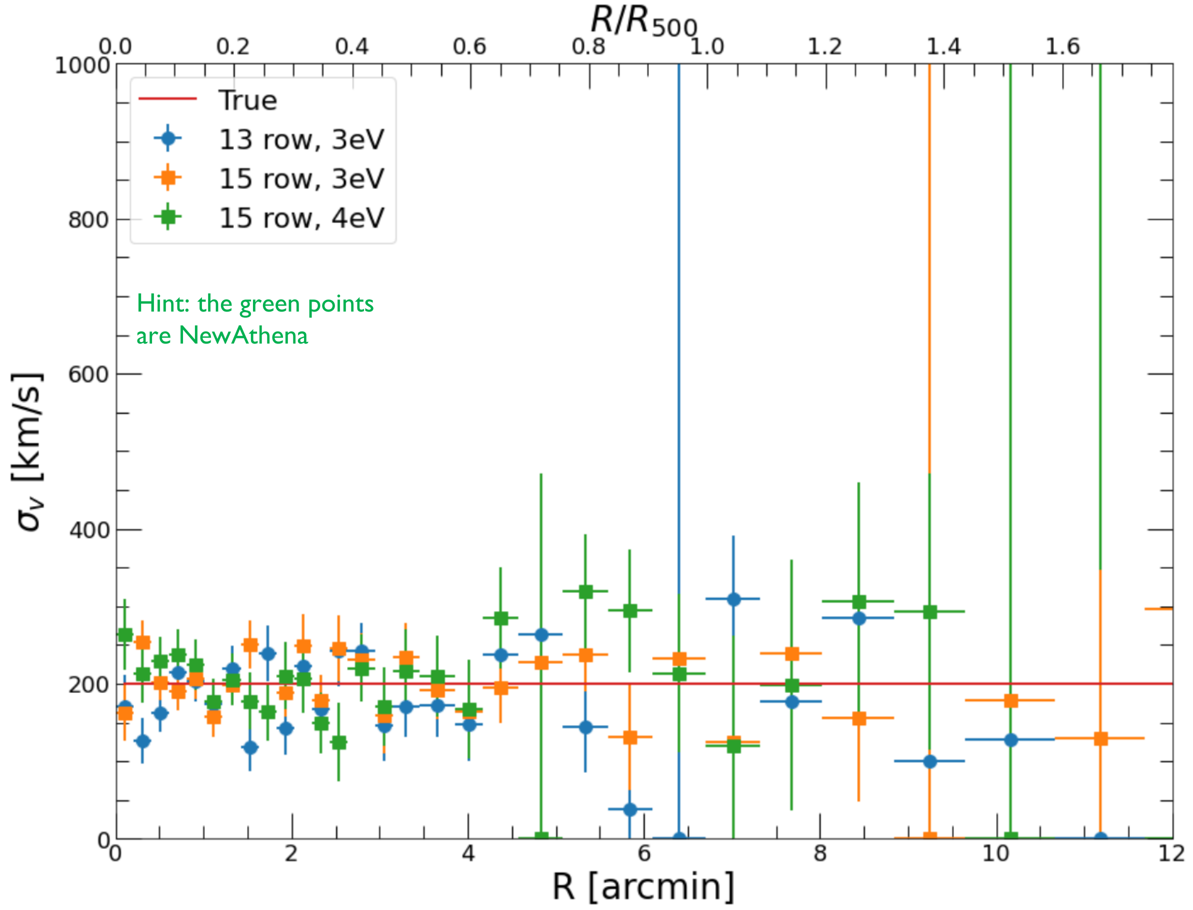


Truong et al., 2024, A&A, 686, 200

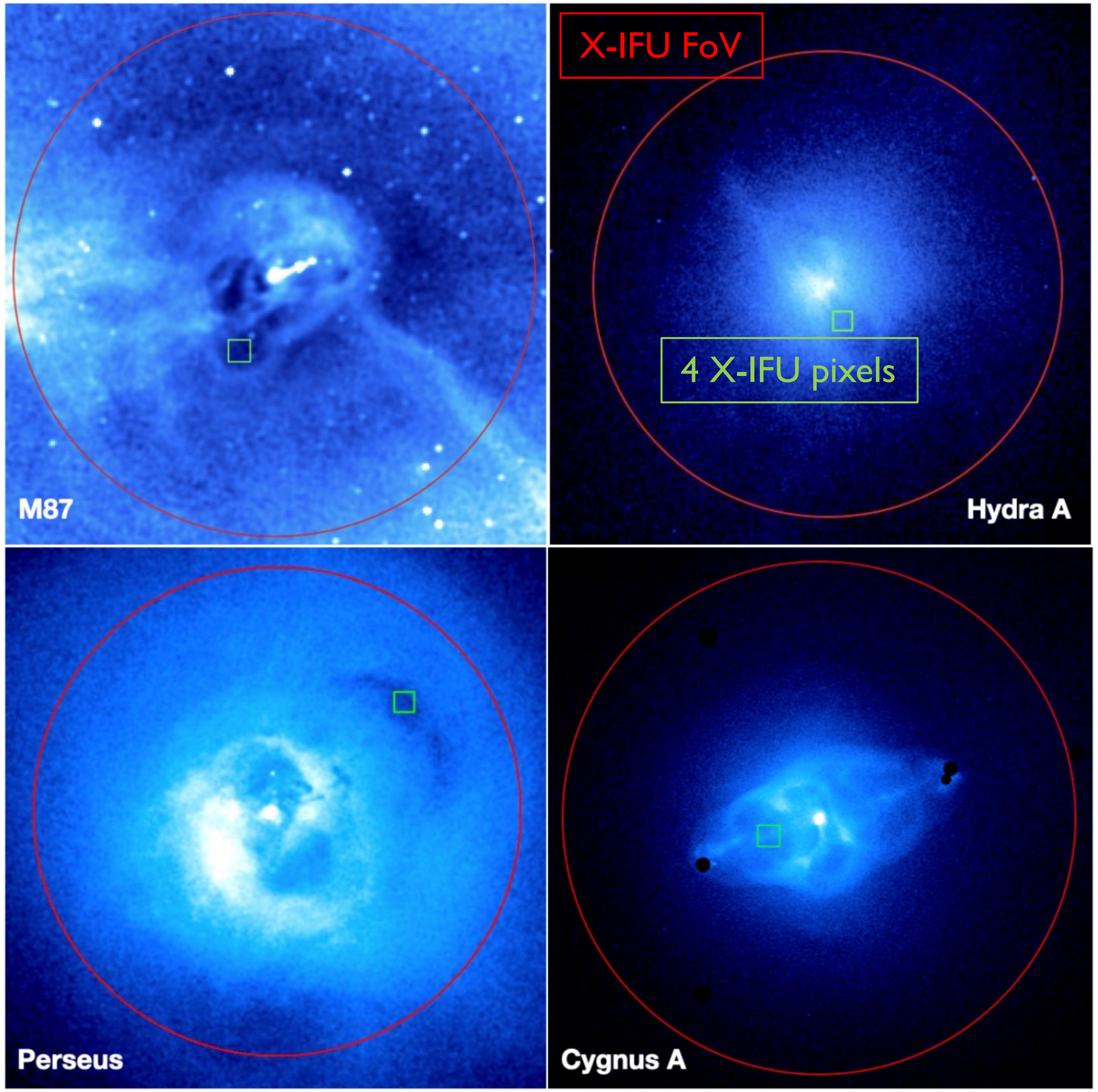
ENERGY DISSIPATION IN GALAXY CLUSTERS WITH NEWATHENA

Spectroscopy of radio-mode AGN feedback on its spatial scale →

Extend the measurements to R_{500} and beyond ↓



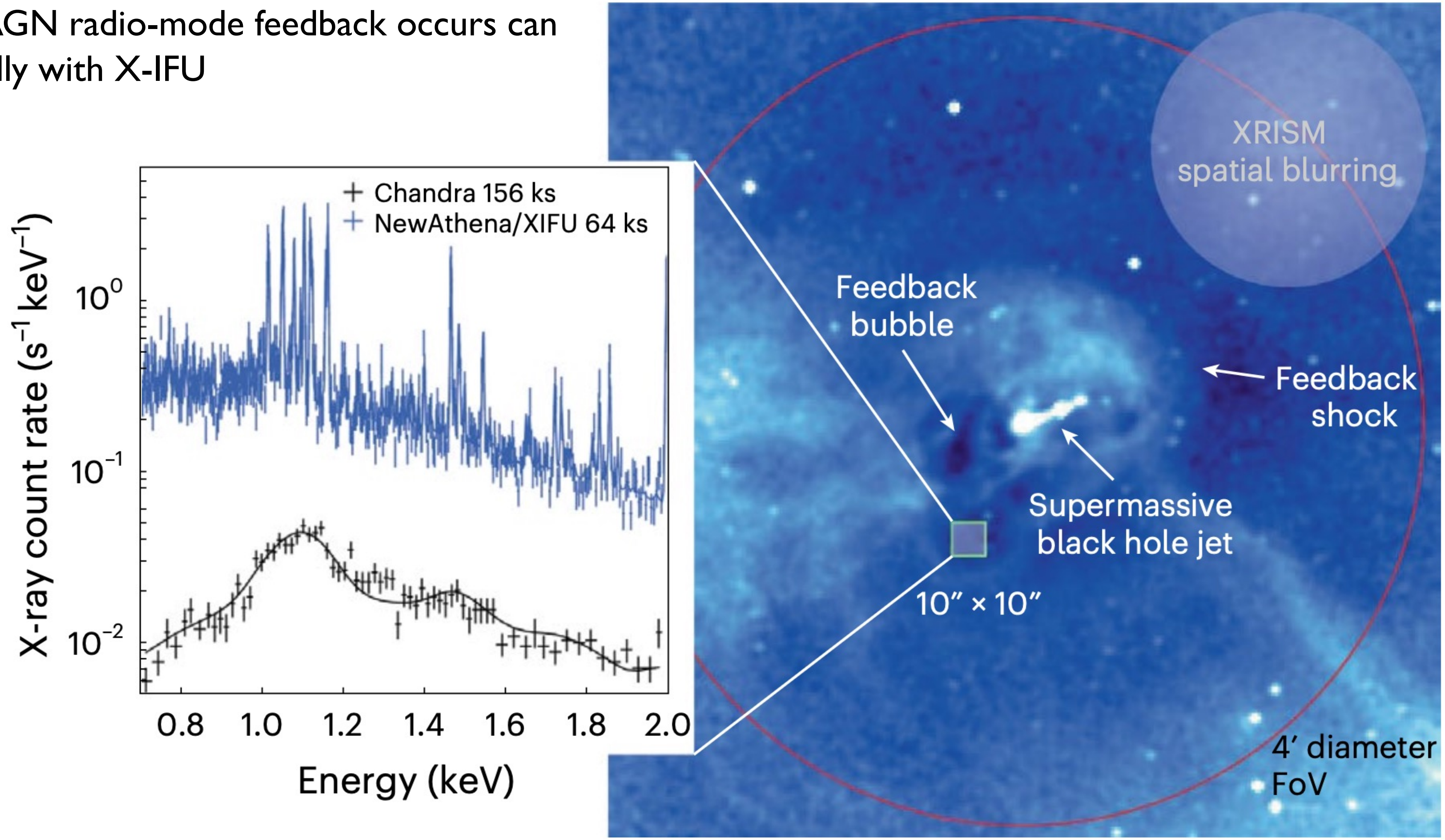
Credit: D. Eckert (Un. of Geneva)



Credit: A. Simionescu (SRON)

AGN FEEDBACK WITH NEWATHENA

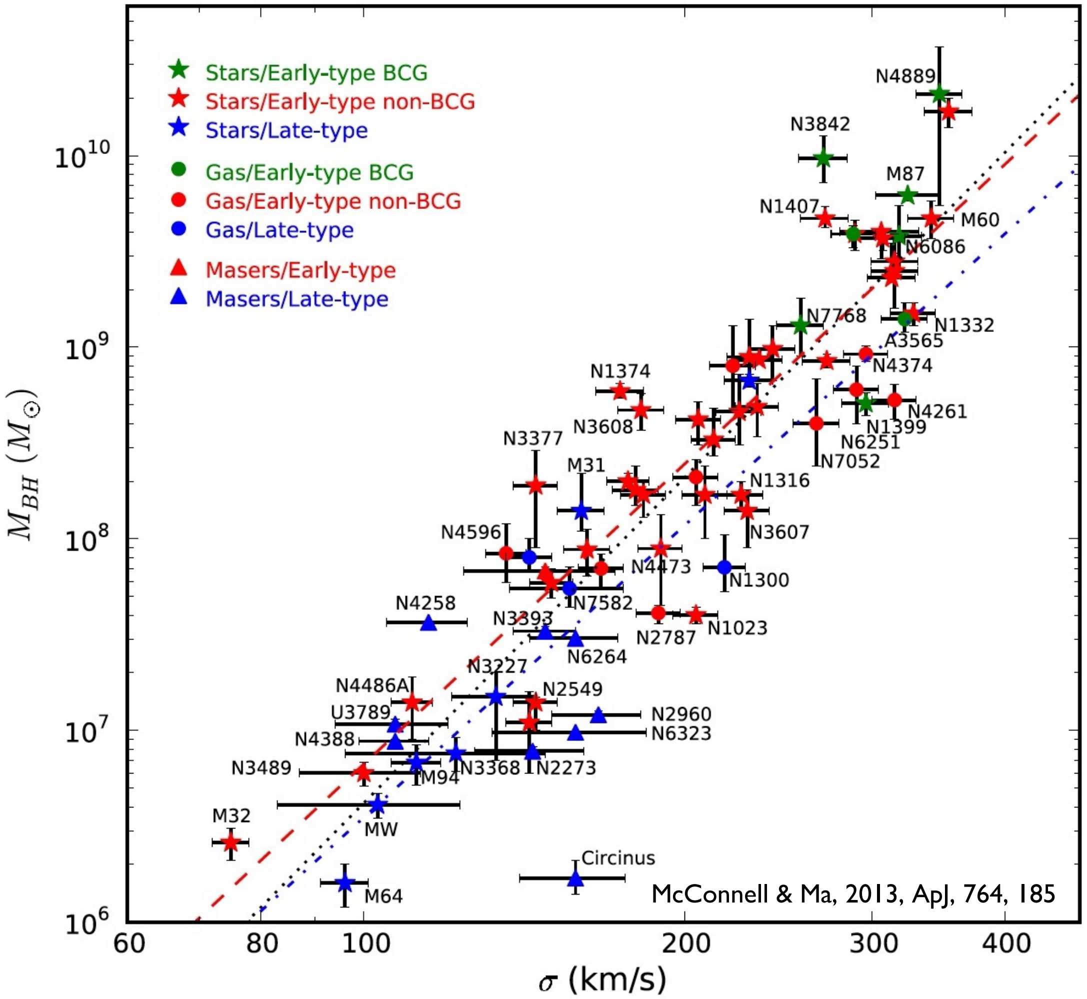
Individual regions where AGN radio-mode feedback occurs can be studied spectroscopically with X-IFU



Cruise et al., Nature Astronomy, 2025

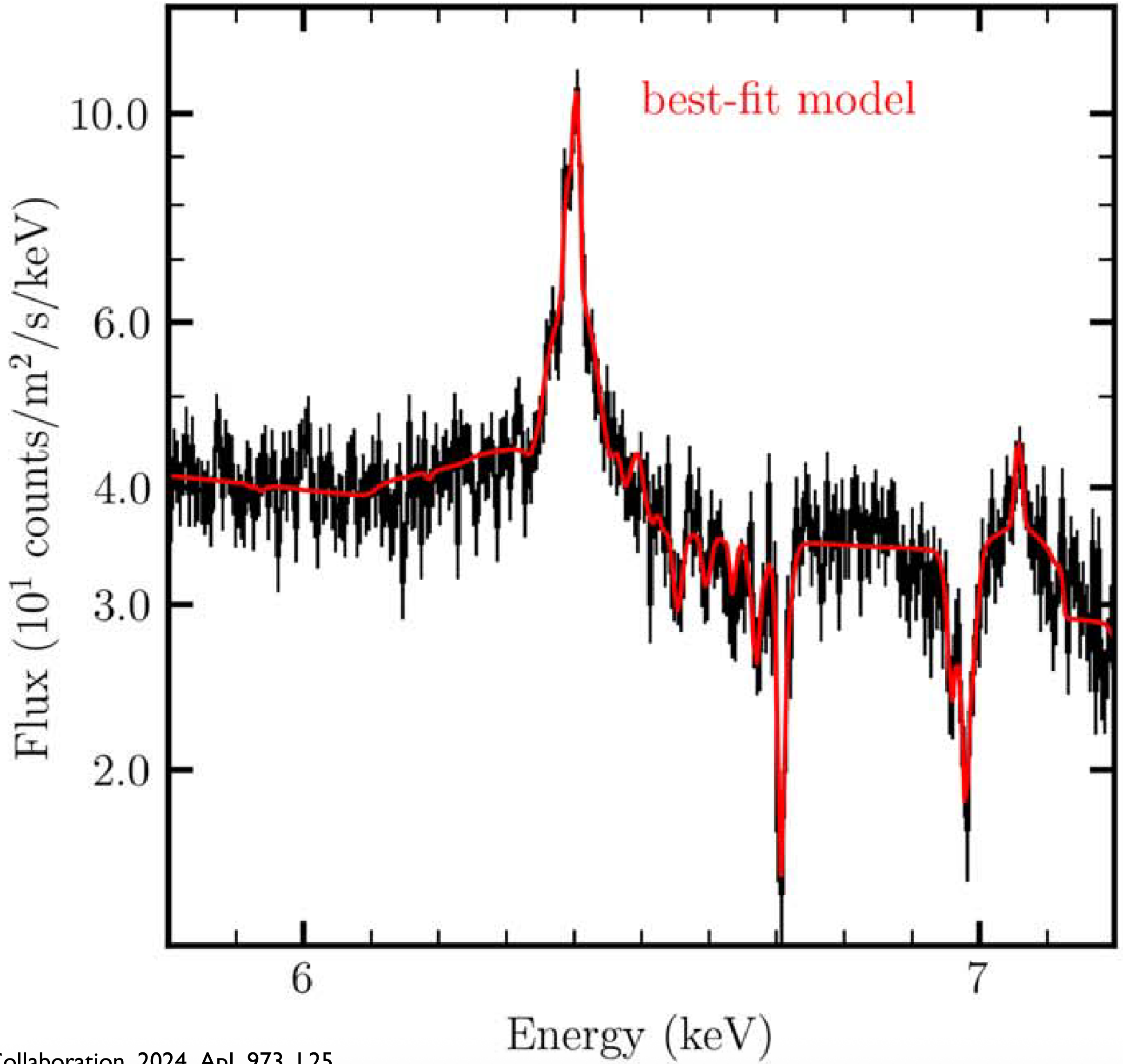
AGN “FEEDBACK”

Observational relations between **black hole mass** (y) and quantities related to the **host galaxy size/mass** (x)



Hypothesis: powerful winds ejected close to the BH heat/sweep the interstellar medium and regulate star formation

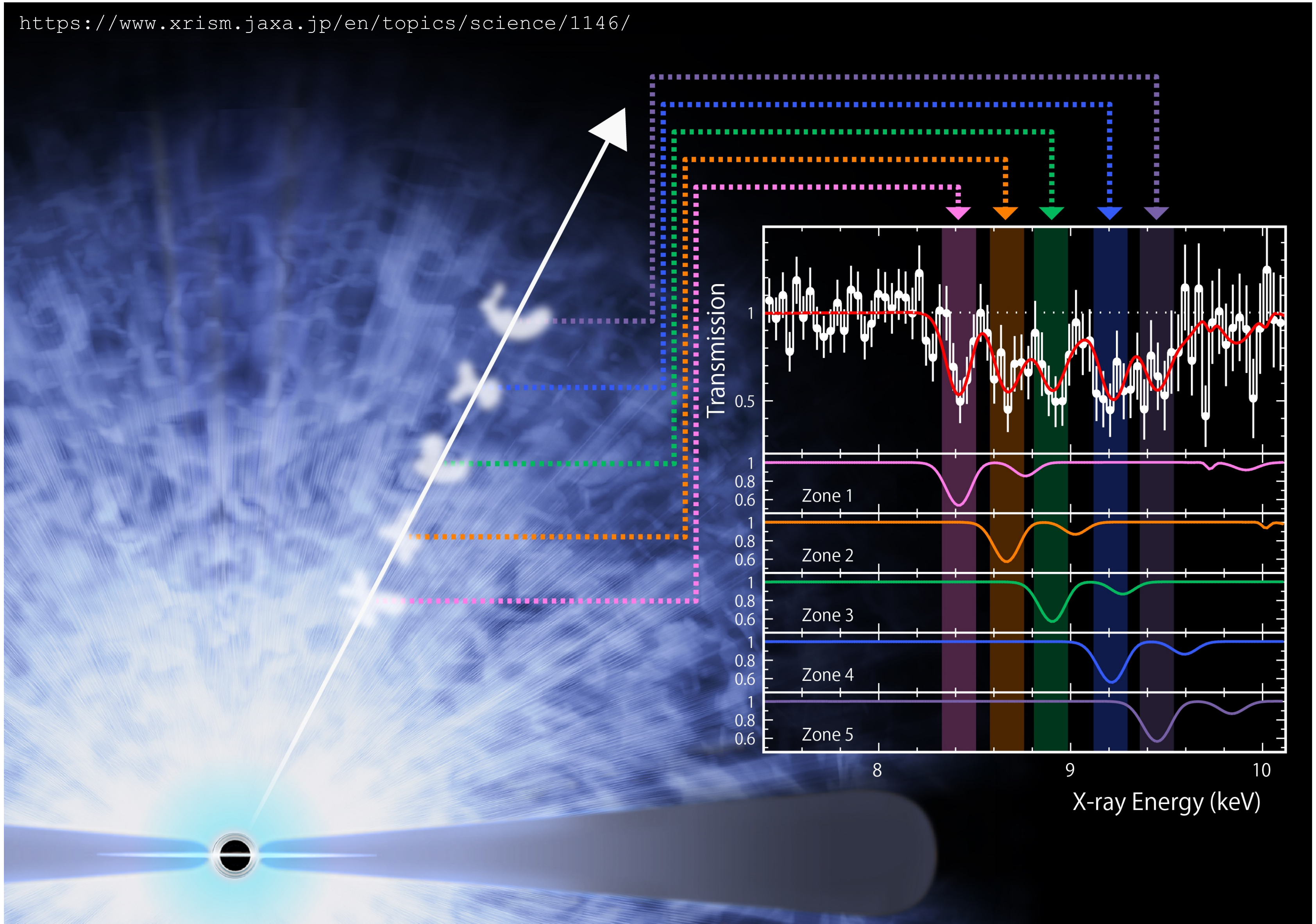
EVIDENCE OF OUTFLOWING GAS IN XRISM AGN SPECTRA



XRISM Collaboration, 2024, ApJ, 973, L25

- Evidence of outflowing gas in AGN is 40-year old
- Spectrometers on *Chandra* and XMM-Newton have enabled enormous progress
- Measured in ~75% of active galaxies in the local Universe [Laha et al., 2014, MNRAS, 441, 2613]
- Cover a wide range of ionization parameters, column density, dynamical components
- Only with XRISM (coupled with RGS as long as the *Resolve* Gate Valve is closed) we can measure the Absoprtion Measure Distribution [$dlog(N_H)/dlog(\xi)$]
- The most feedback-relevant outflows have the highest velocities, because the kinetic energy flow scales as v^3

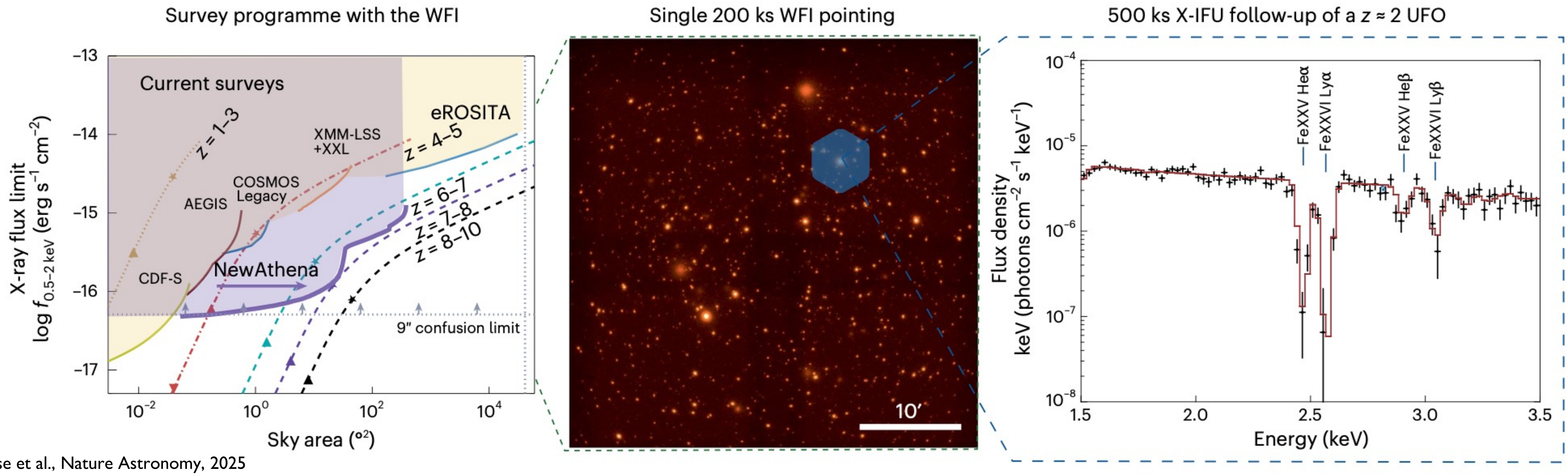
HAS XRISM DISCOVERED THE ULTIMATE FEEDBACK MESSENGER?



- 2nd published XRISM Collaboration Nature paper: **PDS456**
- One of the most powerful quasars in the local Universe
- XRISM discovers of a system of relativistic (z~0.2-0.3 c) "Ultra-Fast Outflows"
- Millions of clumps within ~600 gravitational radii
- Wind kinetic power exceeds the Eddington luminosity
- UFO mass outflow comparable to molecular outflows (~1 kpc)

NEWATHENA WILL BRING THESE STUDY TO A MASSIVE SCALE

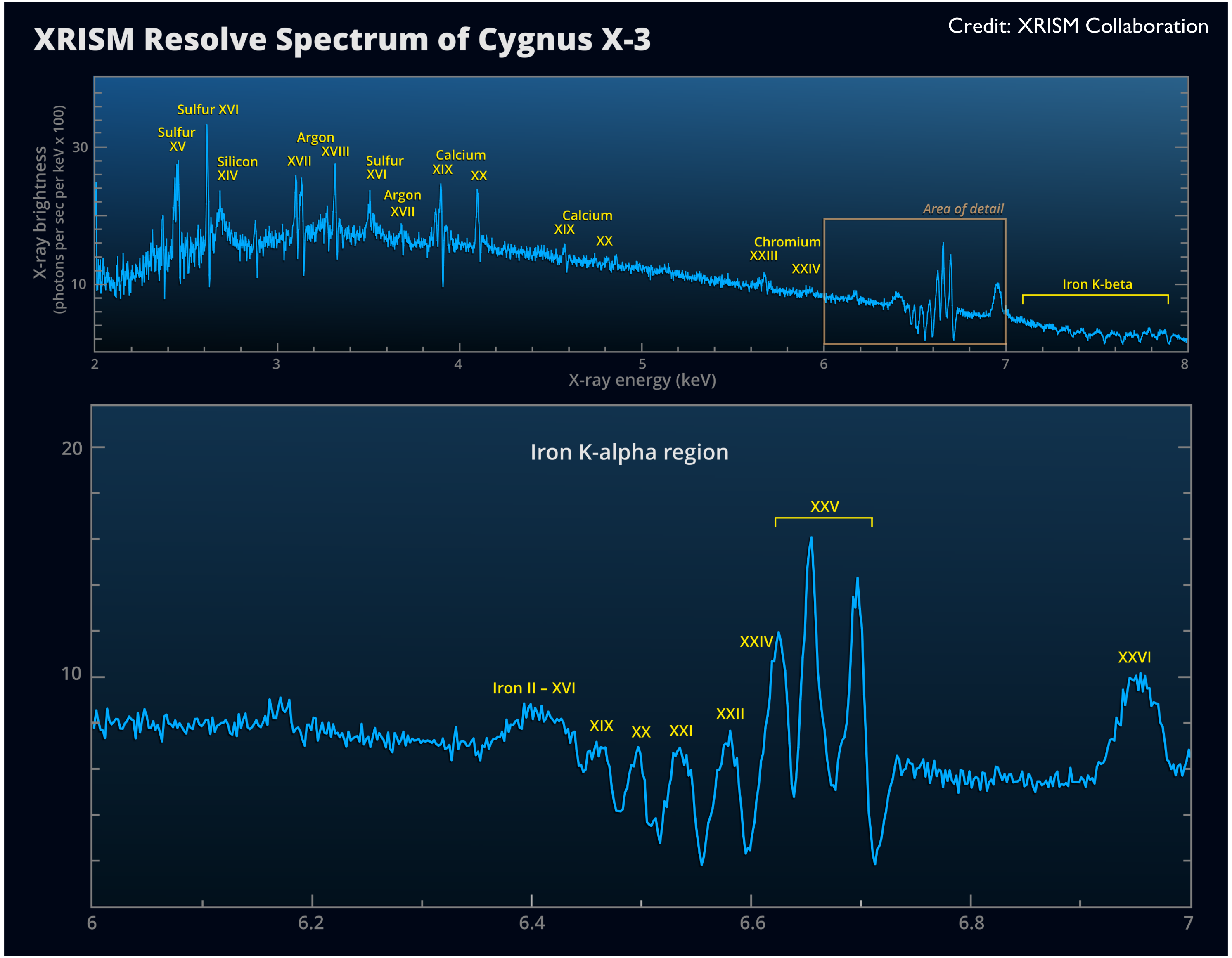
The WFI survey (~400,000 AGN) will enable to find many **AGN with strong UFOs at z~2-3**



Cruise et al., Nature Astronomy, 2025

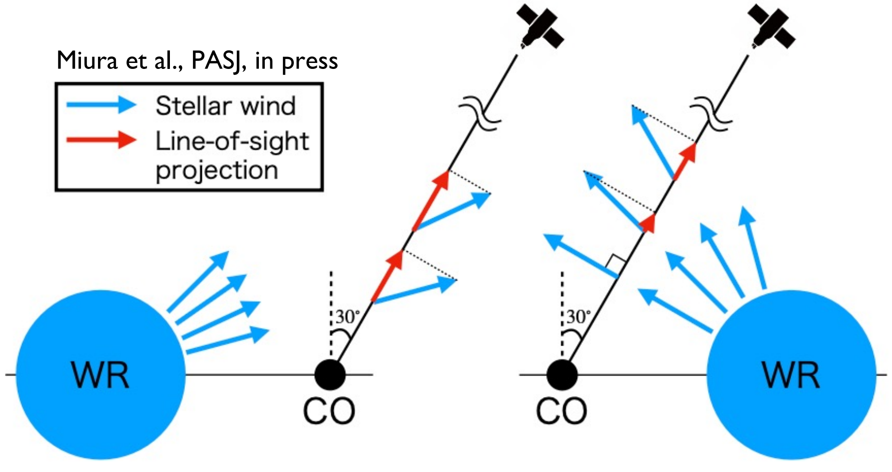
z~2-3 is the "Cosmic Noon", where the **density of accreting black holes** and the **star formation rate** peak

OUTFLOWS IN X-RAY BINARIES LOOK MUCH RICHER …



- X-ray binary: Wolf-Rayet star and an unknown compact object
- Absorption lines produced in a region commensurate to the binary orbit (stellar wind?)
- Emission lines from a region fixed with respect to the orbiting compact object

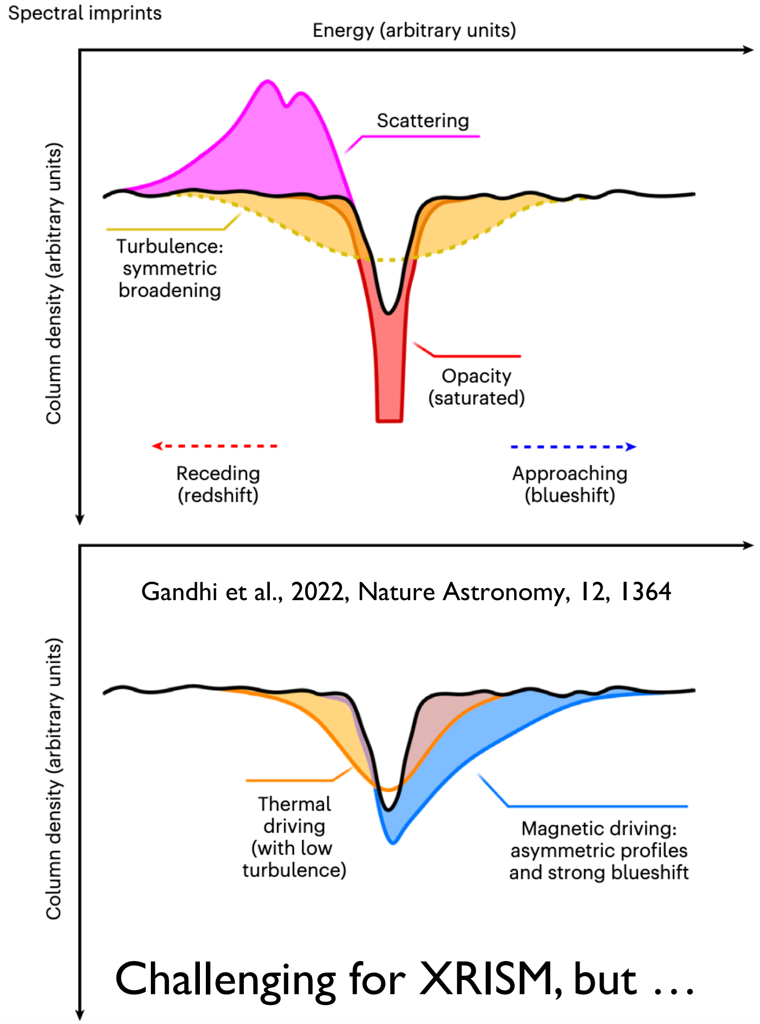
Miura et al., PASJ, in press



(a) inferior conjunction ($\varphi = 0.5$) (b) superior conjunction ($\varphi = 0.0$)

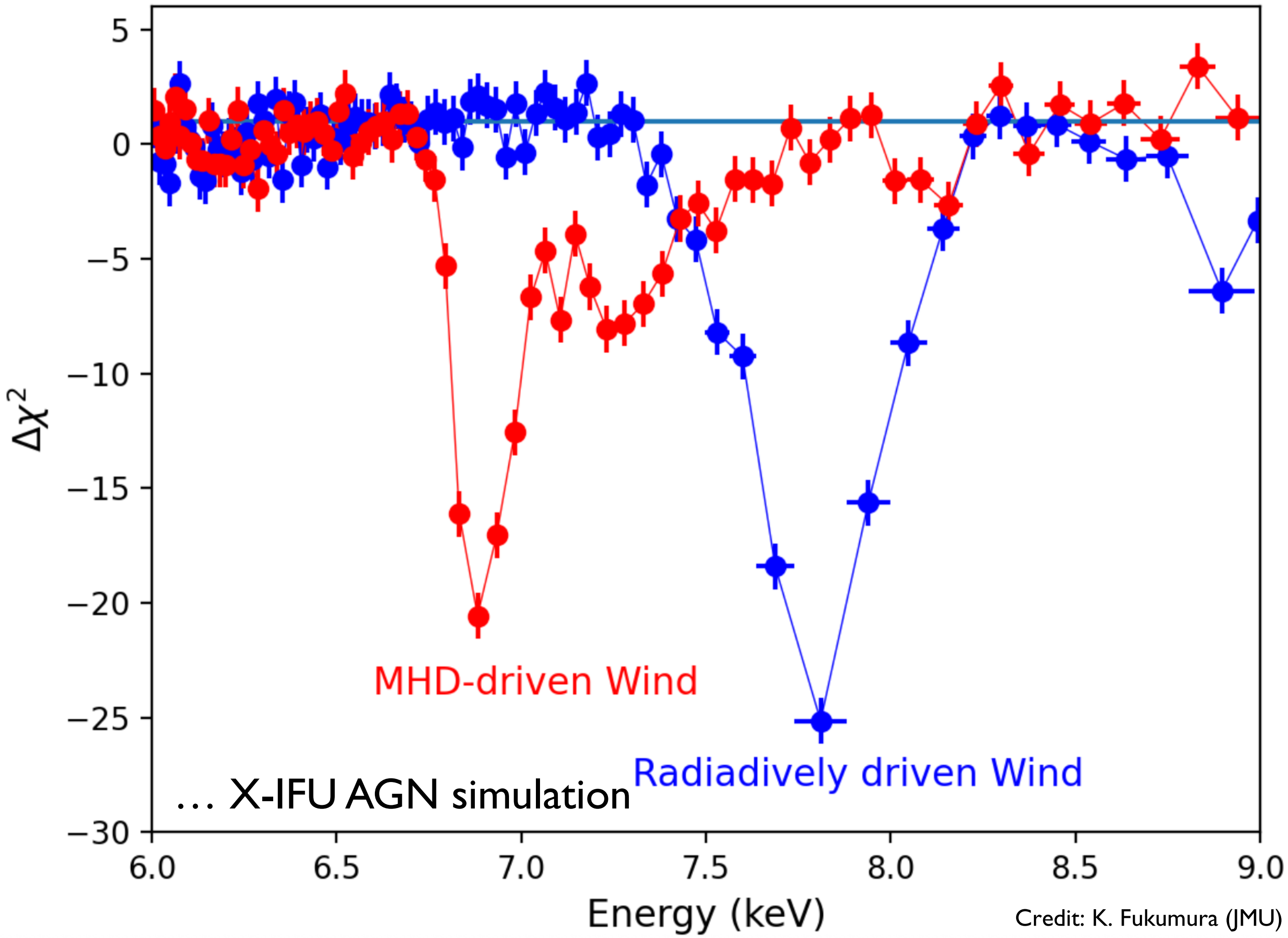
UNVEILING THE LAUNCHING MECHANISM VIA LINE PROFILE

For winds ejected by accretion disks, line profiles can pinpoint the launching and accellaration mechanism



Gandhi et al., 2022, Nature Astronomy, 12, 1364

Challenging for XRISM, but …

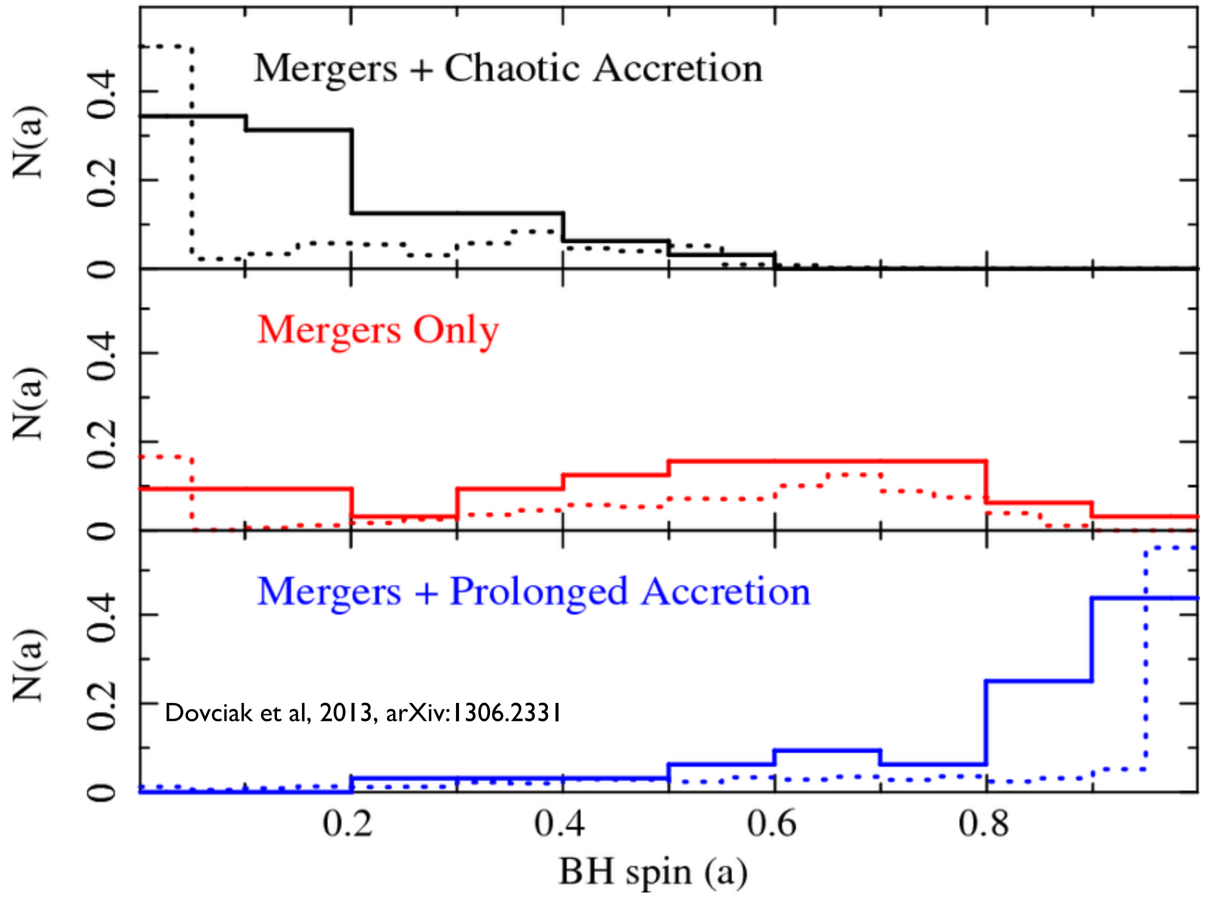


… X-IFU AGN simulation

Credit: K. Fukumura (JMU)

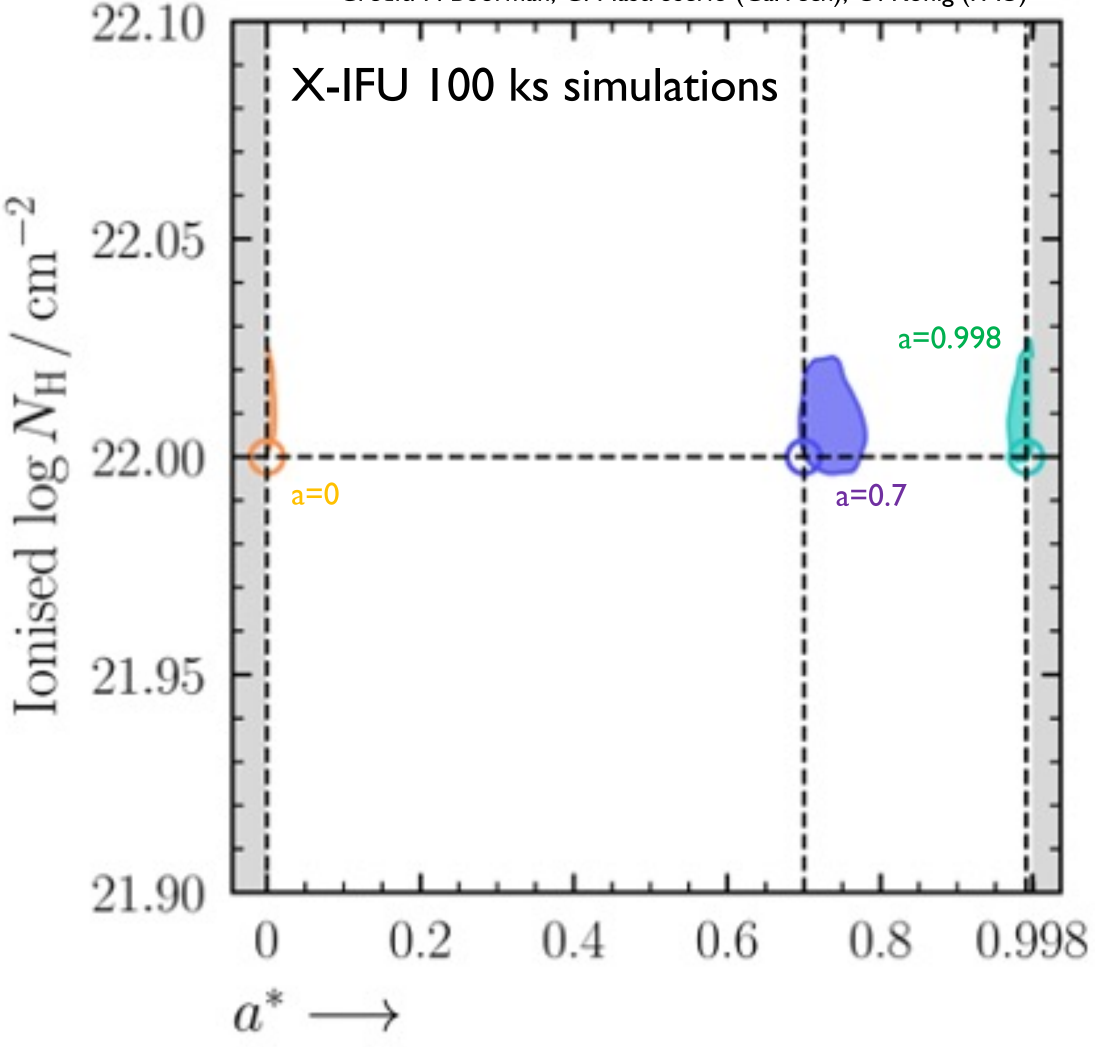
THE DECADE-LONG QUEST FOR THE BLACK HOLE SPIN

Black hole spin distribution probe the host galaxy evolution



Dovciak et al, 2013, arXiv:1306.2331

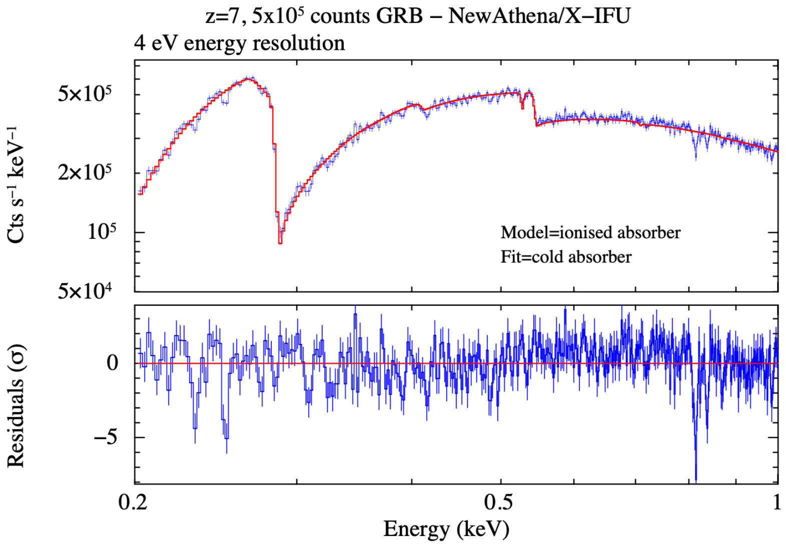
Credit: P. Boorman, G. Mastroserio (CalTech), O. König (FAU)



Sneak preview: this is a challenging measurement even for XRISM

NEWATHENA IS A WIDE-RANGE X-RAY *OBSERVATORY*

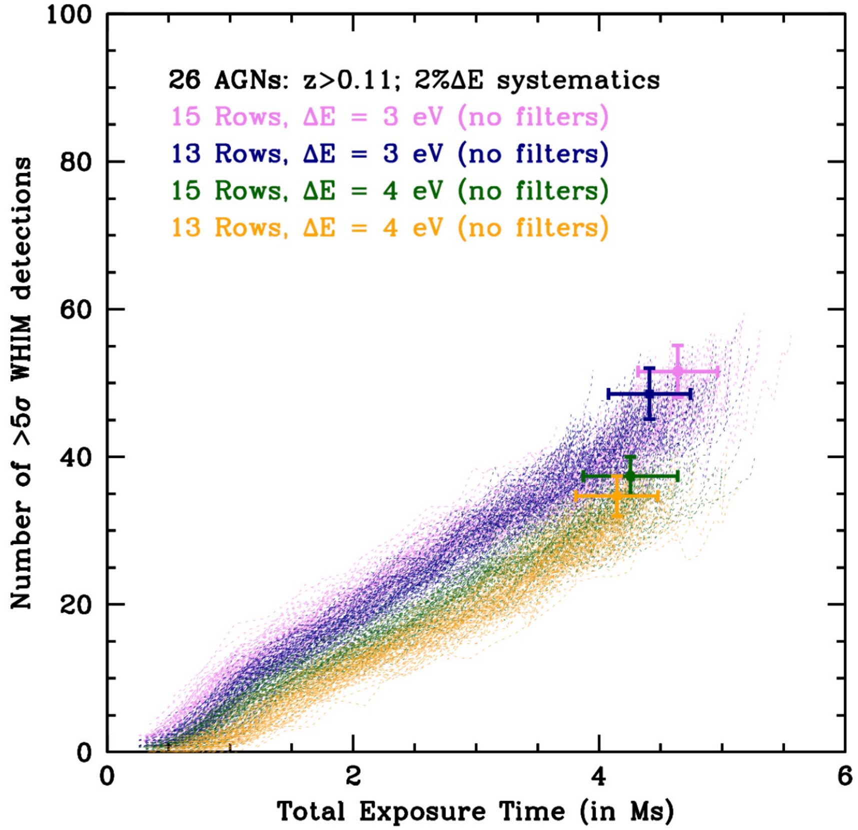
Credit: A.L. Thakur, L.Piro (IAPS), M. Guainazzi (ESA)



Probe ISM via high-z (~7) GRB

… and much more

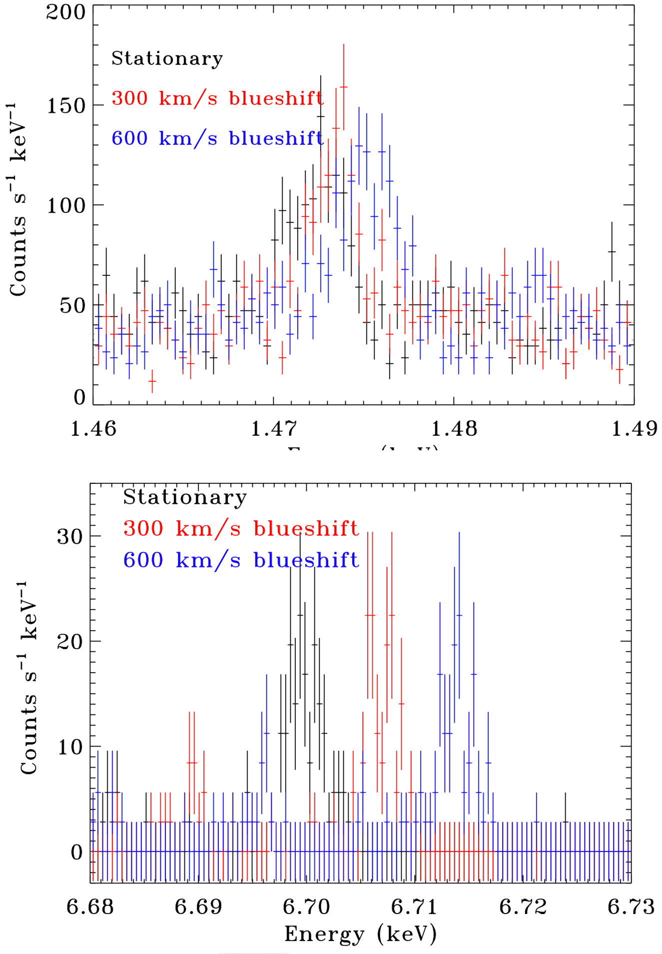
Credit: F. Nicastro (OAR)



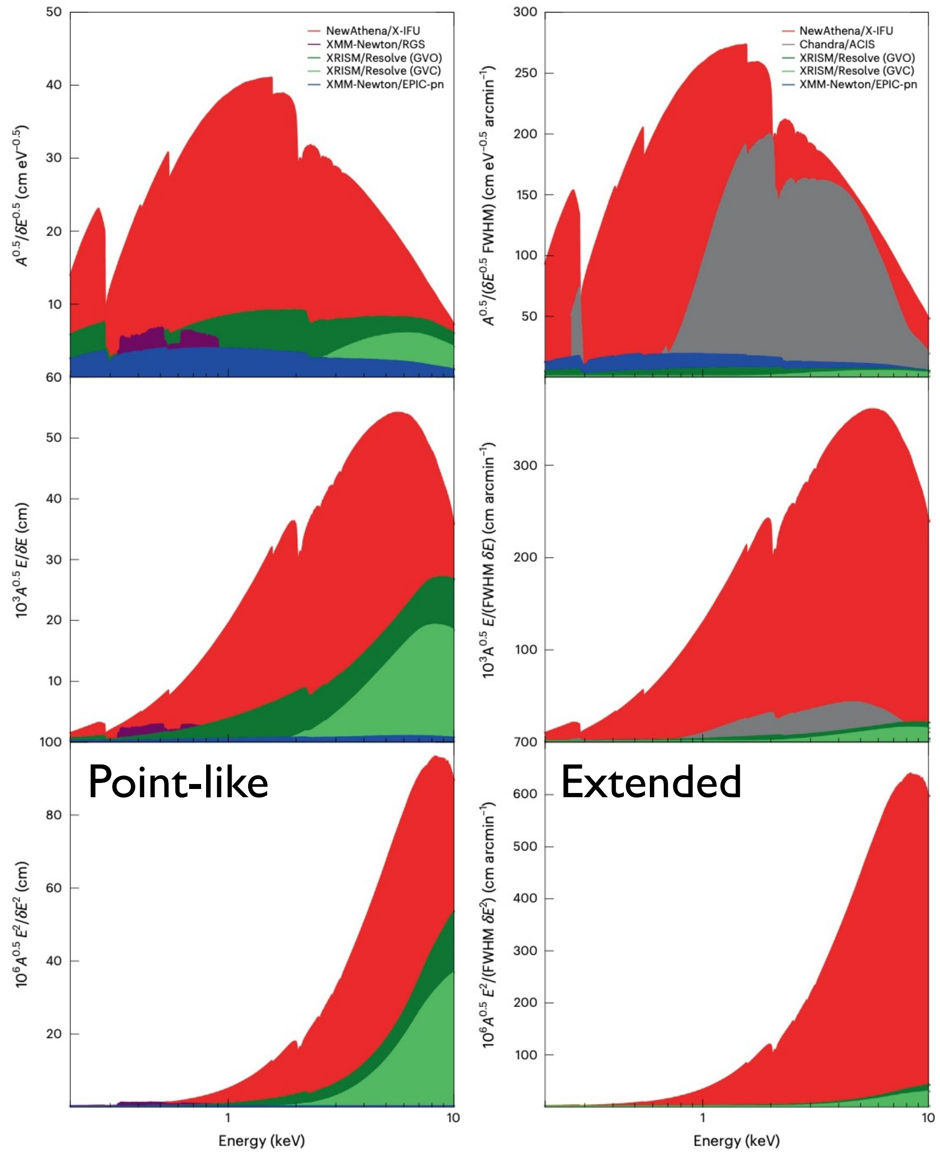
WHIM

Credit: R. Osten (STSci)

Stellar flares and habitability



SPECTROSCOPY FIGURES-OF-MERIT



Detection of weak lines

Measurement of strong line bulk velocity

Measurement of strong line broadening

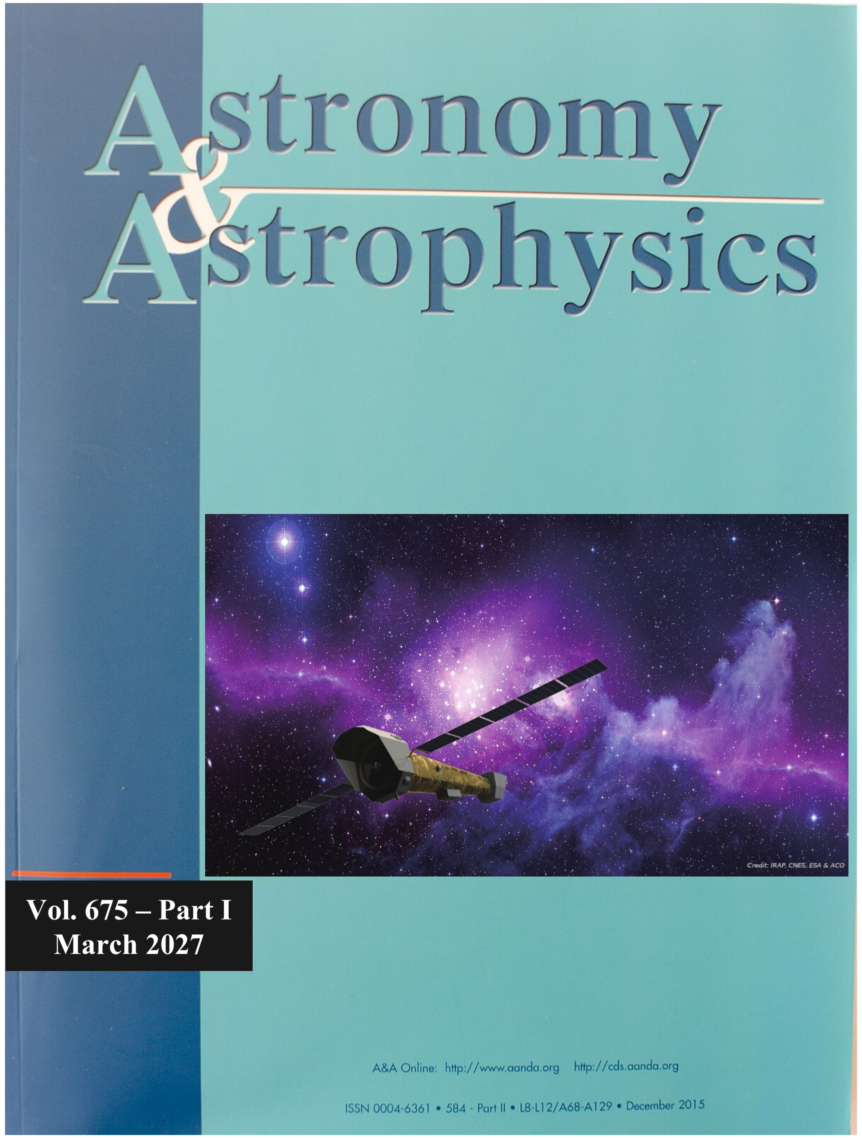
Athena
XRISM/Resolve
Chandra/ACIS
RGS
EPIC-pn

Cruise et al., Nature Astronomy, 2025

ASTRONOMY & ASTROPHYSICS SPECIAL ISSUE

Caveat: figure is my own rendering – do not quote!

- The Astronomy & Astrophysics Editorial Board has agreed to host a **Special Issue on NewAthena science**
- A call for abstracts will be issued in **July 2025**
- Papers from the Japanese science community more than welcome! **申し込んで、参加してください！**
- Papers shall be prepared/submitted in the **first/second half of 2026**
- The Special Isse will be published in support to the **Mission “Adoption”** (final decision on implementation) in **early 2027**
- NewAthena launch is foreseen in **2037**



CLOSURE

Parameter	Required value
X-IFU total effective area at 7 keV	0.087 m^2
X-IFU total effective area at 1 keV	0.60 m^2
X-IFU energy resolution at 7 keV	4 eV
X-IFU field of view (effective diameter)	4 arcmin
X-IFU pixel size on the sky	5 arcsec
X-IFU background (2–7 keV)	5×10^{-3} photons $cm^{-2} s^{-1} keV^{-1}$
WFI effective area at 1 keV	0.86 m^2
WFI field of view (side)	40 arcmin × 40 arcmin
WFI background (2–10 keV)	8×10^{-3} photons $cm^{-2} s^{-1} keV^{-1}$
Background knowledge accuracy	5%
Optics angular resolution on axis at 1 keV	9 arcsec
Field-of-view-averaged optics angular resolution at 1 keV	On axis + 1 arcsec
Point source (45° off-axis) X-ray stray light area ratio against on-axis area	1×10^{-3}
Field of regard	34%
Target of opportunity response time	12 h

Perspective

https://doi.org/10.1038/s41550-024-02416-3

The NewAthena mission concept in the context of the next decade of X-ray astronomy

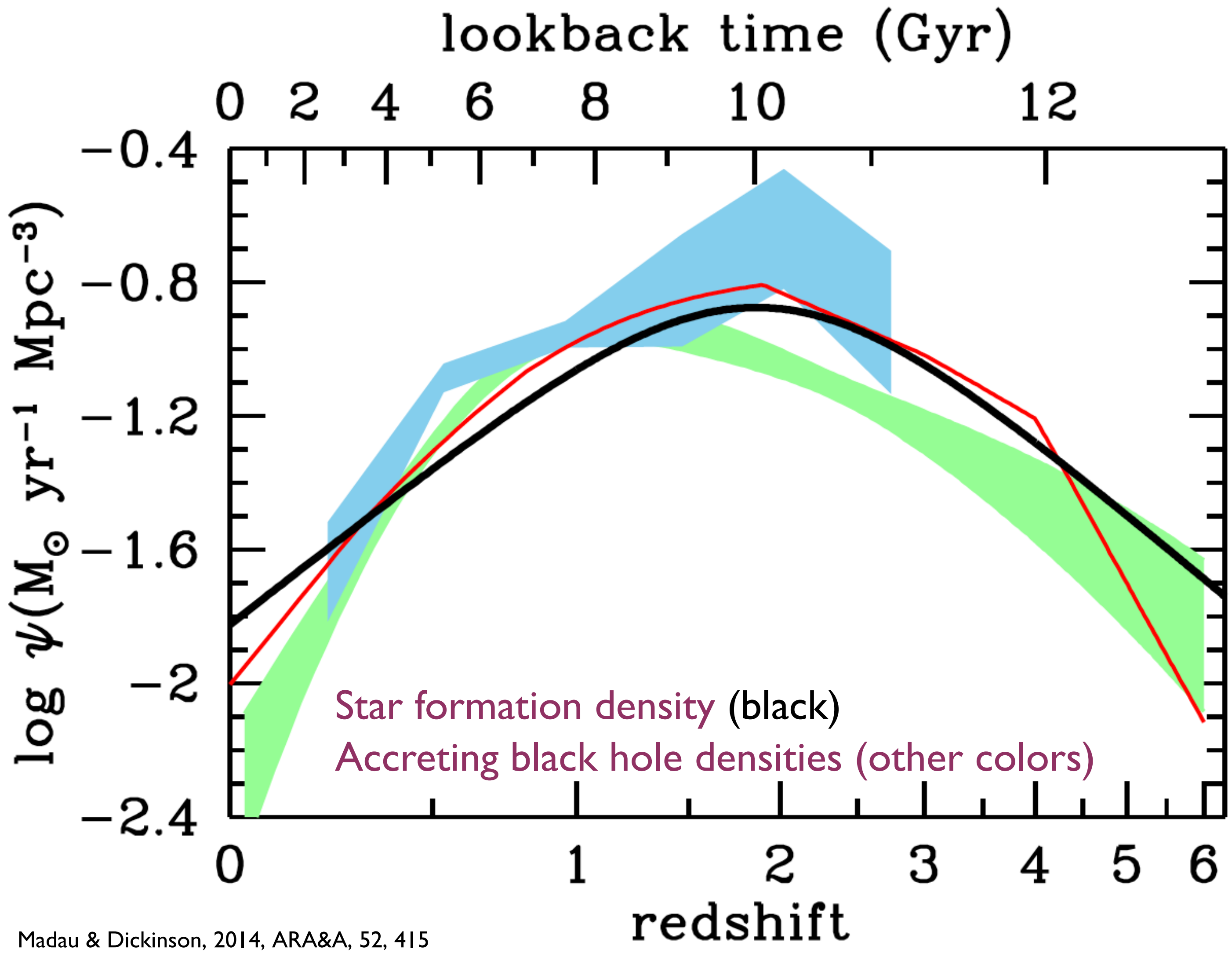
Mike Cruise[1], Matteo Guainazzi[2], James Aird[3], Francisco J. Carrera[4], Elisa Costantini[5], Lia Corrales[6], Thomas Dauser[7], Dominique Eckert[8], Fabio Gastaldello[9], Hironori Matsumoto[10], Rachel Osten[11,12], Pierre-Olivier Petrucci[13], Delphine Porquet[14], Gabriel W. Pratt[15], Nanda Rea[16,17], Thomas H. Reiprich[18], Aurora Simionescu[5], Daniele Spiga[19] & Eleonora Troja[20]

(now 8 photons cm^{-2} s^{-1} keV^{-1})

Contributions from the Japanese community to the NewAthena science are warmly welcome!

ADDITIONAL MATERIAL

THE "COSMIC NOON"



Madau & Dickinson, 2014, ARA&A, 52, 415

- Star formation rate and accreting black hole rate densities follow the same comsological trend
- The peak epoch is referred to as the "Cosmic Noon"
- *The BH rate is very uncertain for z≥3 (that's why we need NewAthena!)*
- Possible interpretation: AGN feedback
- Notwithstanding the exact interpretation, evidence for BH/host galaxy cosmological co-evolution