THE NEXT REVOLUTION IN HIGH ENERGY ASTROPHYSICS: **NEWATHENA**

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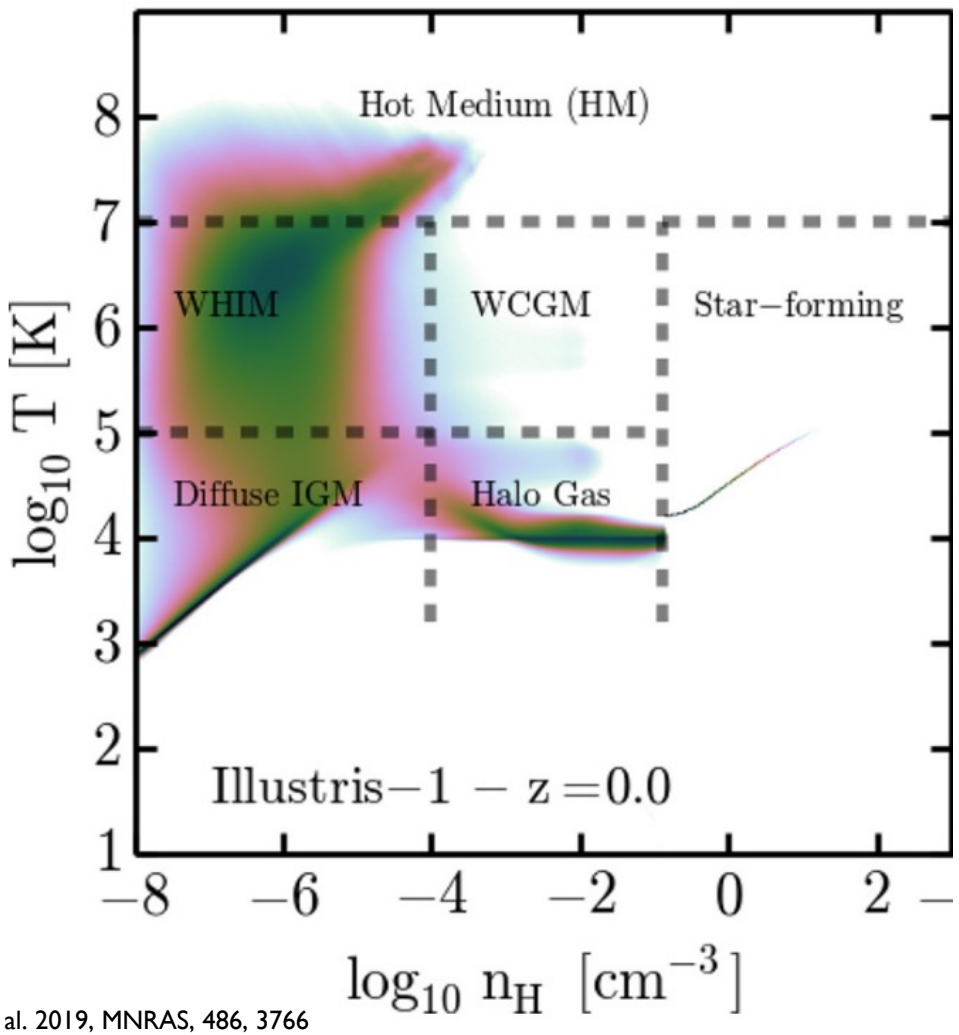
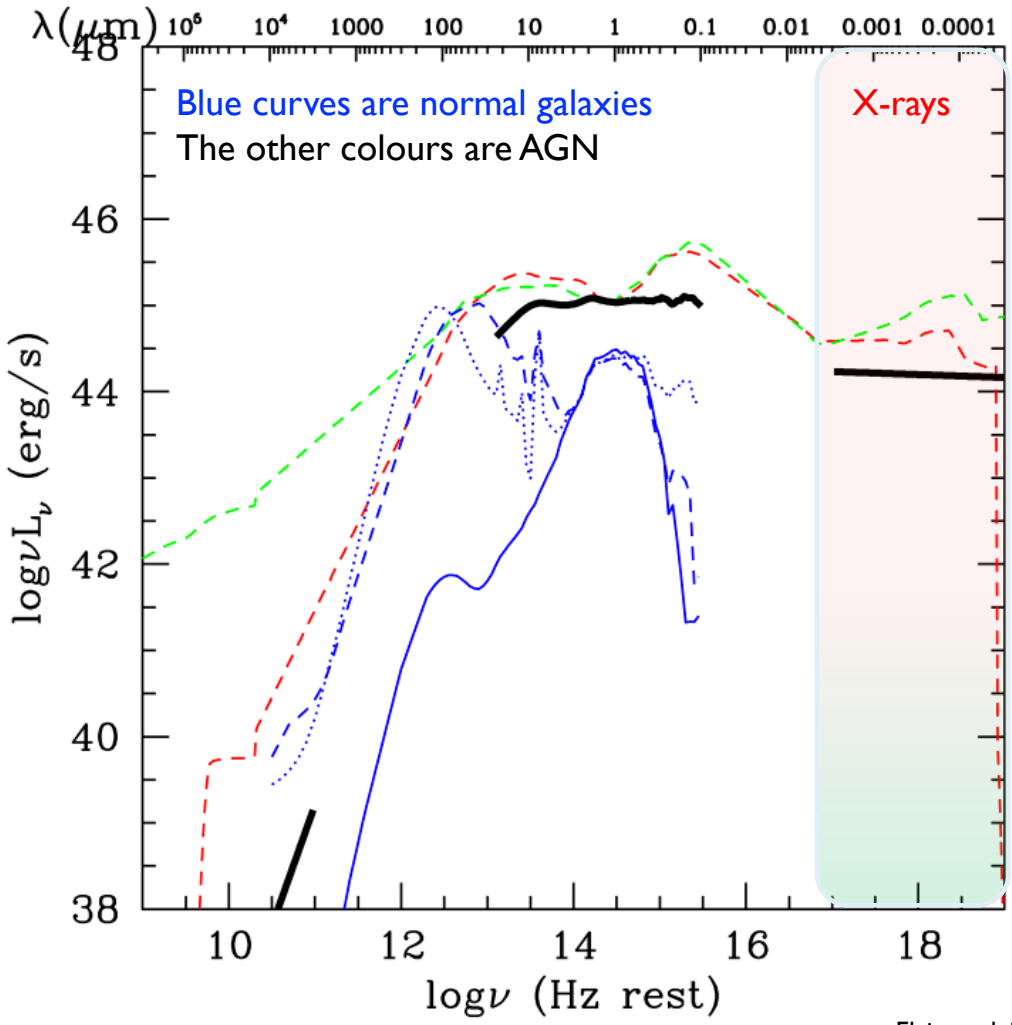
X-RAYS PLAY A SPECIAL ROLE TO UNDERSTAND SPECIAL COSMOS LOCII

Phase diagram of baryons in the Universe (z~0)



Martizzi et al. 2019, MNRAS, 486, 3766

Spectral Energy Distribution of typical AGN



Elvis et al. 2012, ApJ, 759, 6

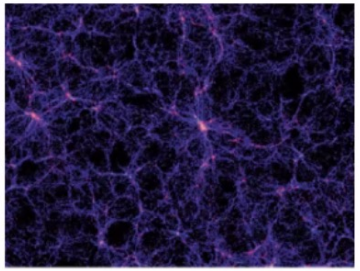
THESE SPECIAL PLACES IN THE UNIVERSE ARE CLOST TO ICE'S HEART

Maria de Maeztu award: Excellence Centre

Institute of Space Sciences

EXCELENCIA MARÍA DE MAEZTU

Research structured around three lines



What is our universe made of?

The fabric of the universe

Using multi-disciplinary cosmological probes and gravitational waves to understand what the universe is made of and how it evolves.

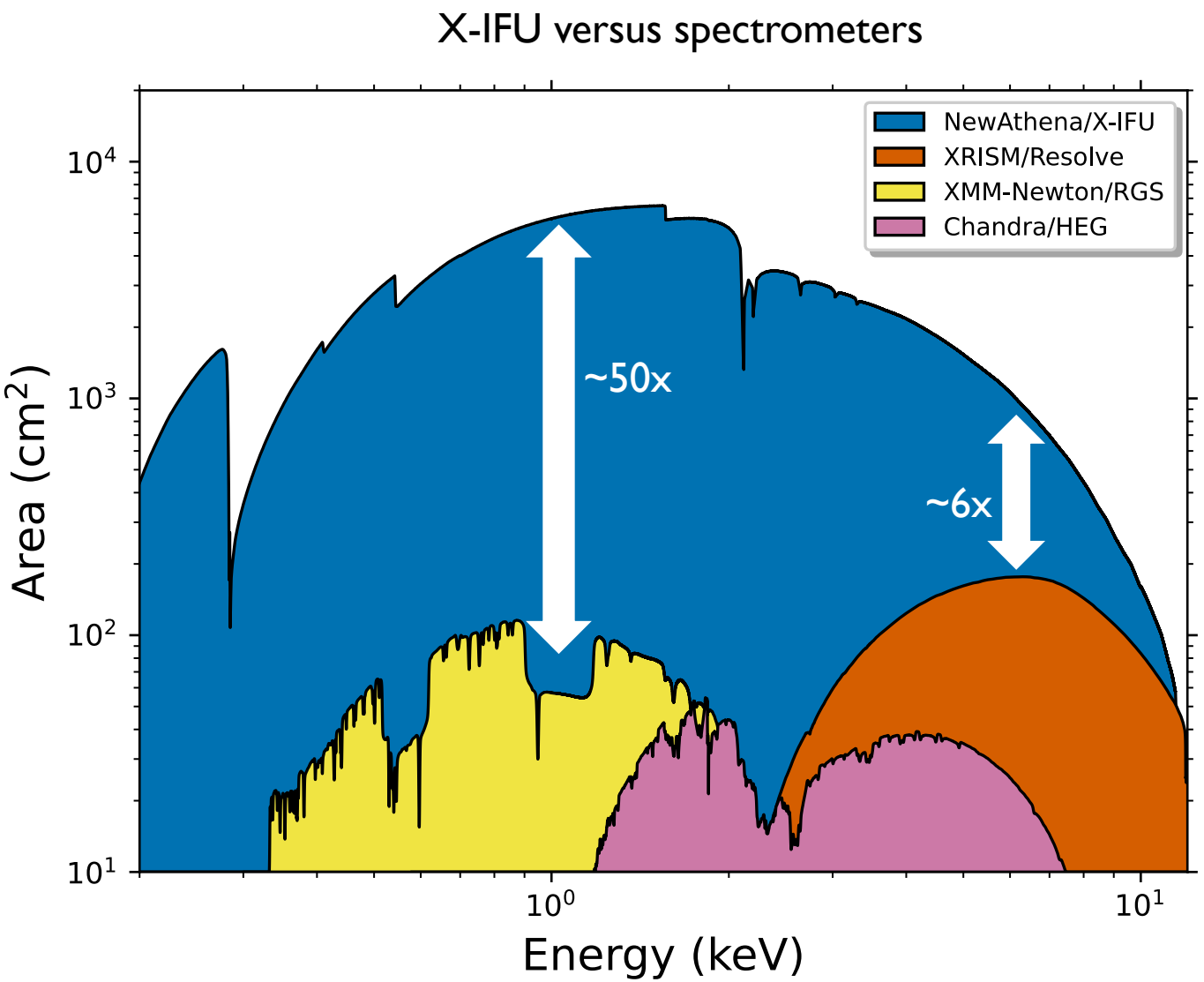
How matter and fields behave in extreme conditions

The extreme Universe

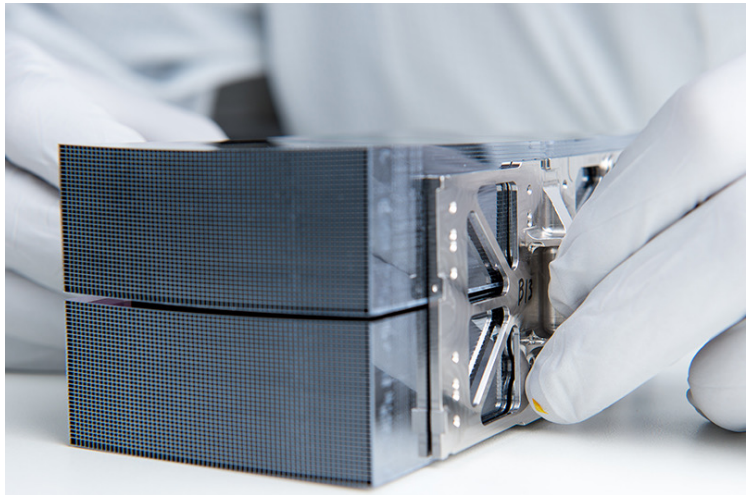
Understanding how matter and fields behave in extreme conditions of density and pressure, gravitational or electromagnetic forces.

NEWATHENA IS A *LARGE MIRROR* X-RAY OBSERVATORY

Adapted from Cruise et al., Nature Astronomy, 2025, 9, 36



- 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

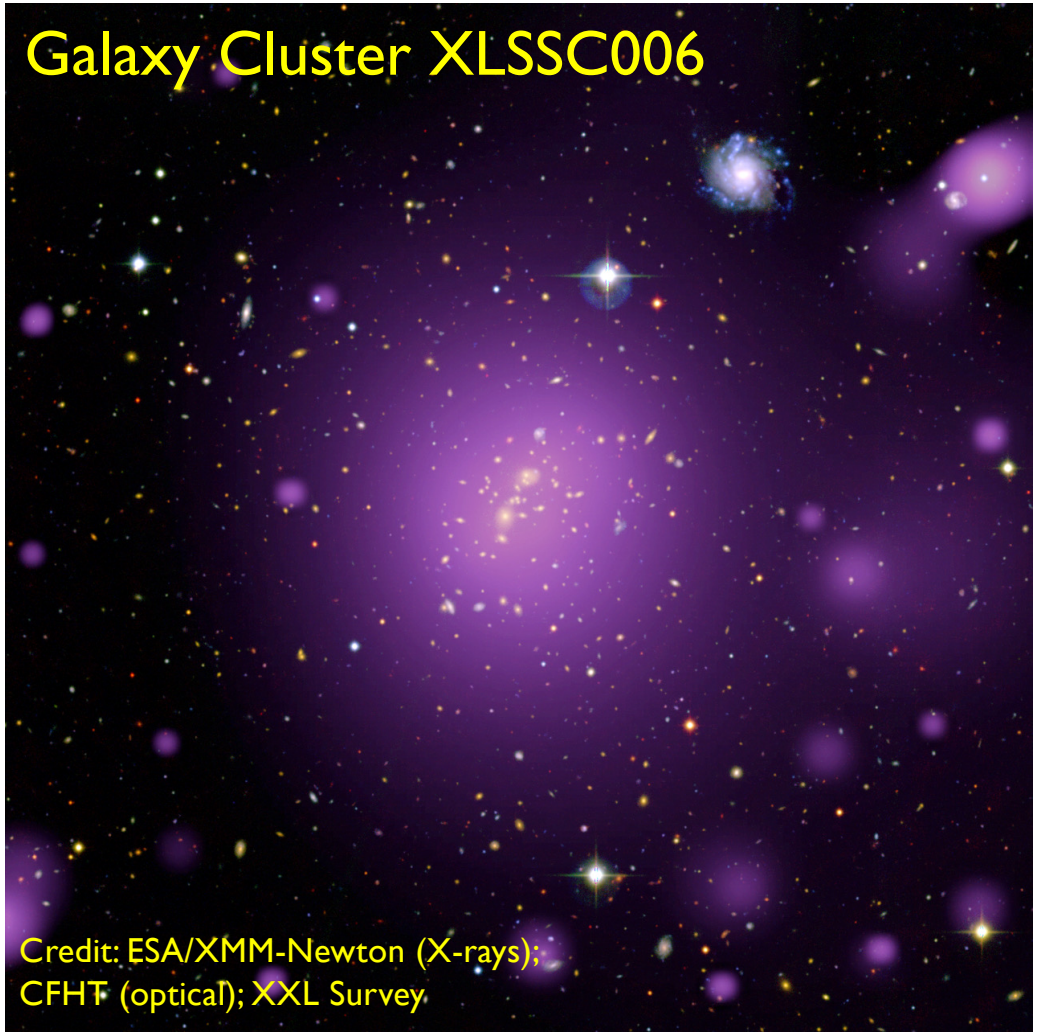


A NewAthena mirror module; credit: cosine

KEY SCIENTIFIC QUESTIONS TO BE ADDRESSED BY NEWATHENA

1. How do the largest cosmic structures form and evolve?
2. How is the Universe enriched with metals?
3. How do black holes grow and how do they impact galaxy evolution?
4. What physical conditions shape the black hole and neutron star environment?
5. What physical phenomena are associated with multi-messenger events?
6. How do high-energy phenomena shape stellar evolution and their environs?

GALAXY CLUSTERS

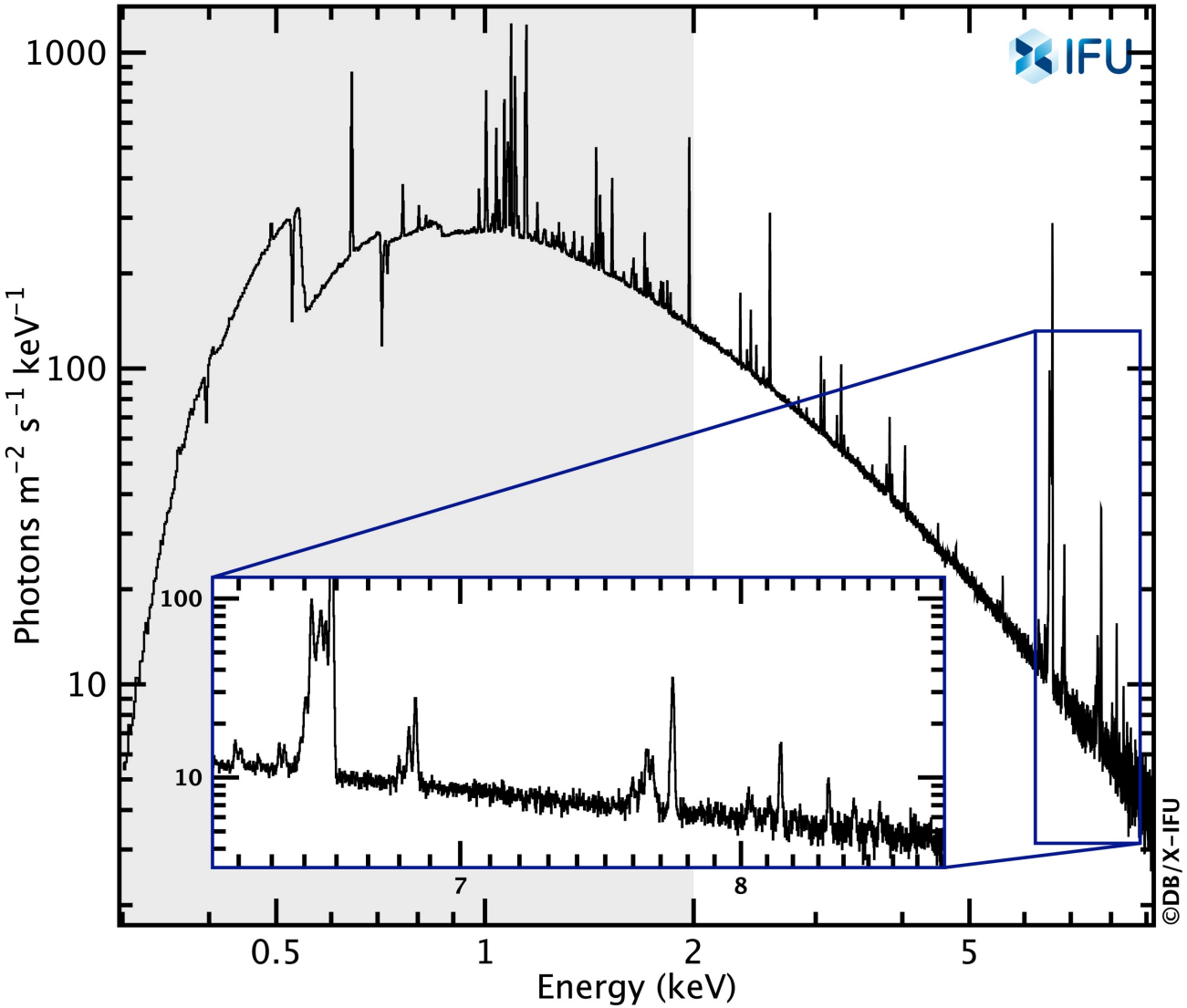


- Galaxy Clusters are the largest gravitationally-bound structures in the Universe
- Located at the "nodes" of the Cosmic Web
- Optical (white/yellow): galaxies
- X-rays (purple glow): $T \geq 10^6$ K gas
- Invisible: dark matter (85% of the total mass in the cluster)

WHAT IS NEWATHENA: X-IFU

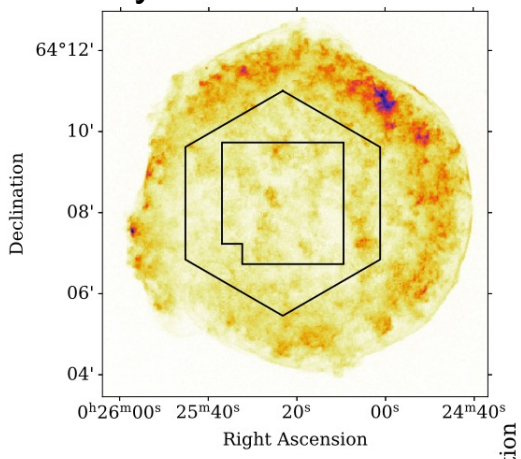
Credit: X-IFU Consortium

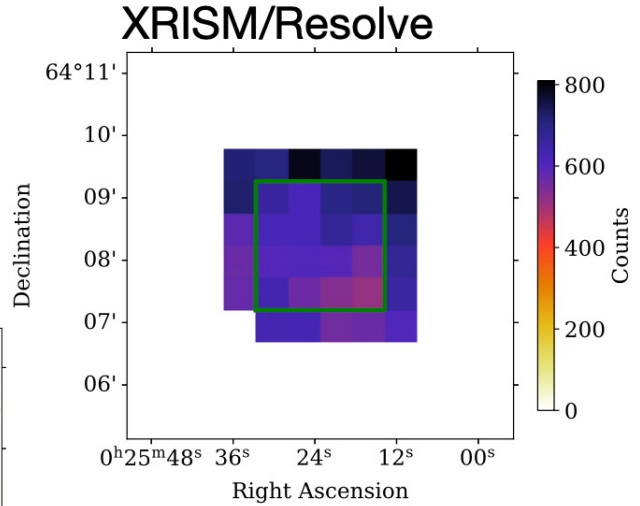
- **X-ray Integral Field Unit**: led by CNES/IRAP (PI: Didier Barret)
- Micro-calorimeter with almost energy independent energy resolution of 4 eV (@7 keV) → resolving power >1000
- ~1500 pixels (5" side) over a 4' diameter field-of-view (FoV)
- Very rapid readout (~50 μs)
- Simulation: X-IFU spectrum of the intra-cluster medium (ICM) from the center of the Perseus Cluster

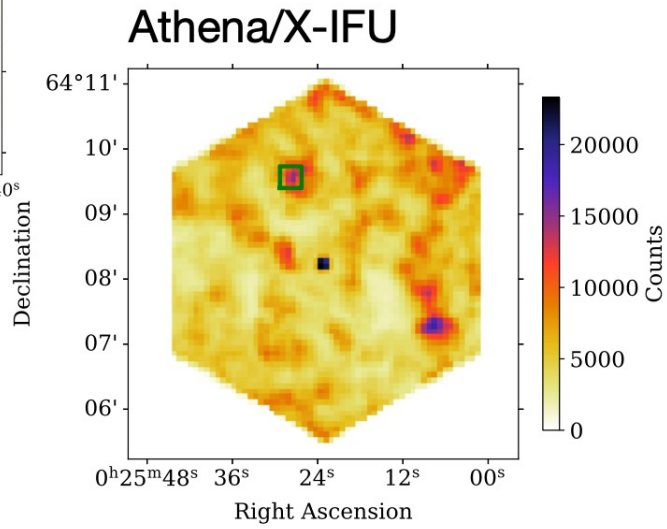


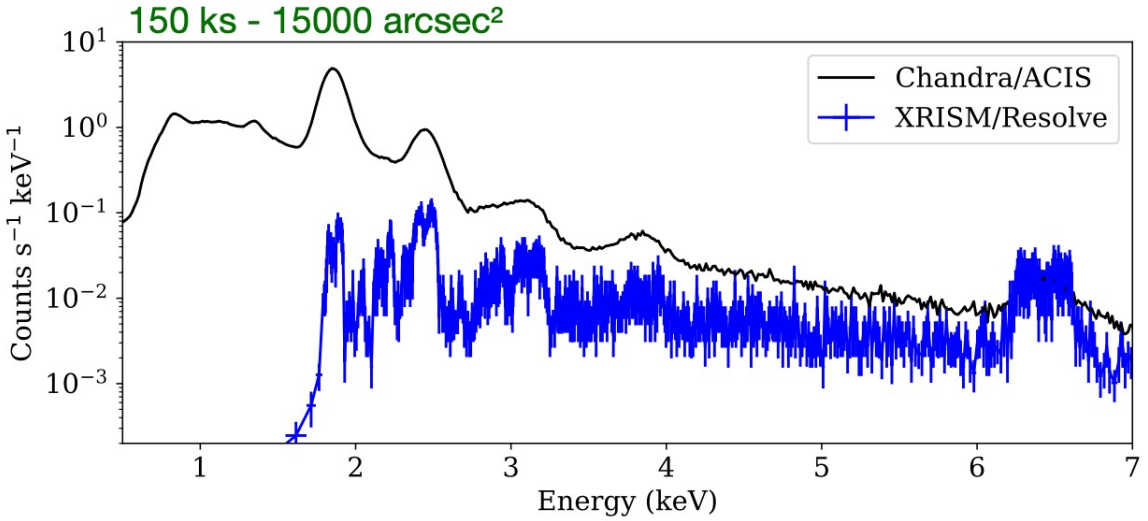
CRASH COURSE IN X-RAY OBSERVATIONAL ASTRONOMY

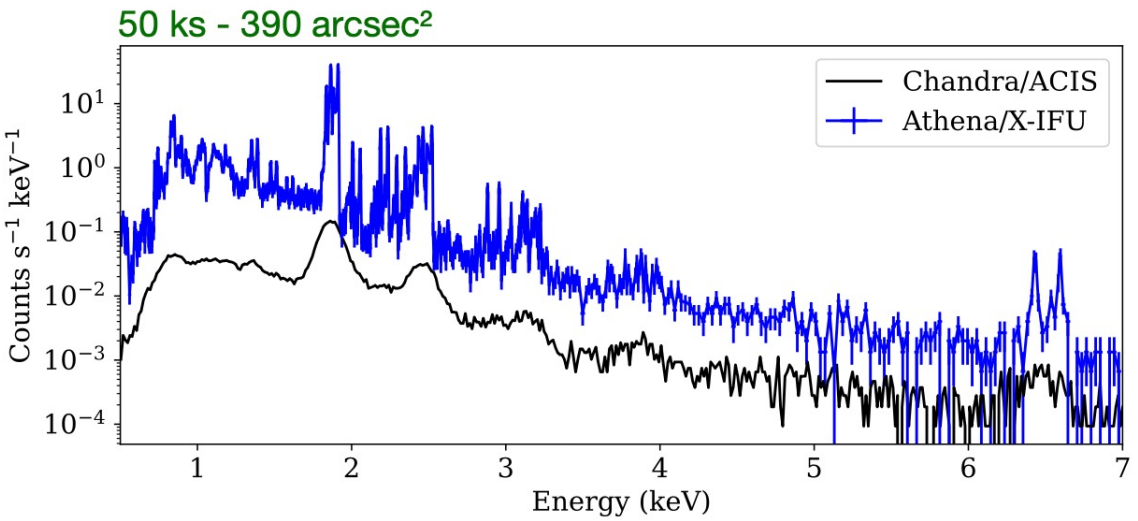
Godinaud et al., 2025, A&A, 693, 234





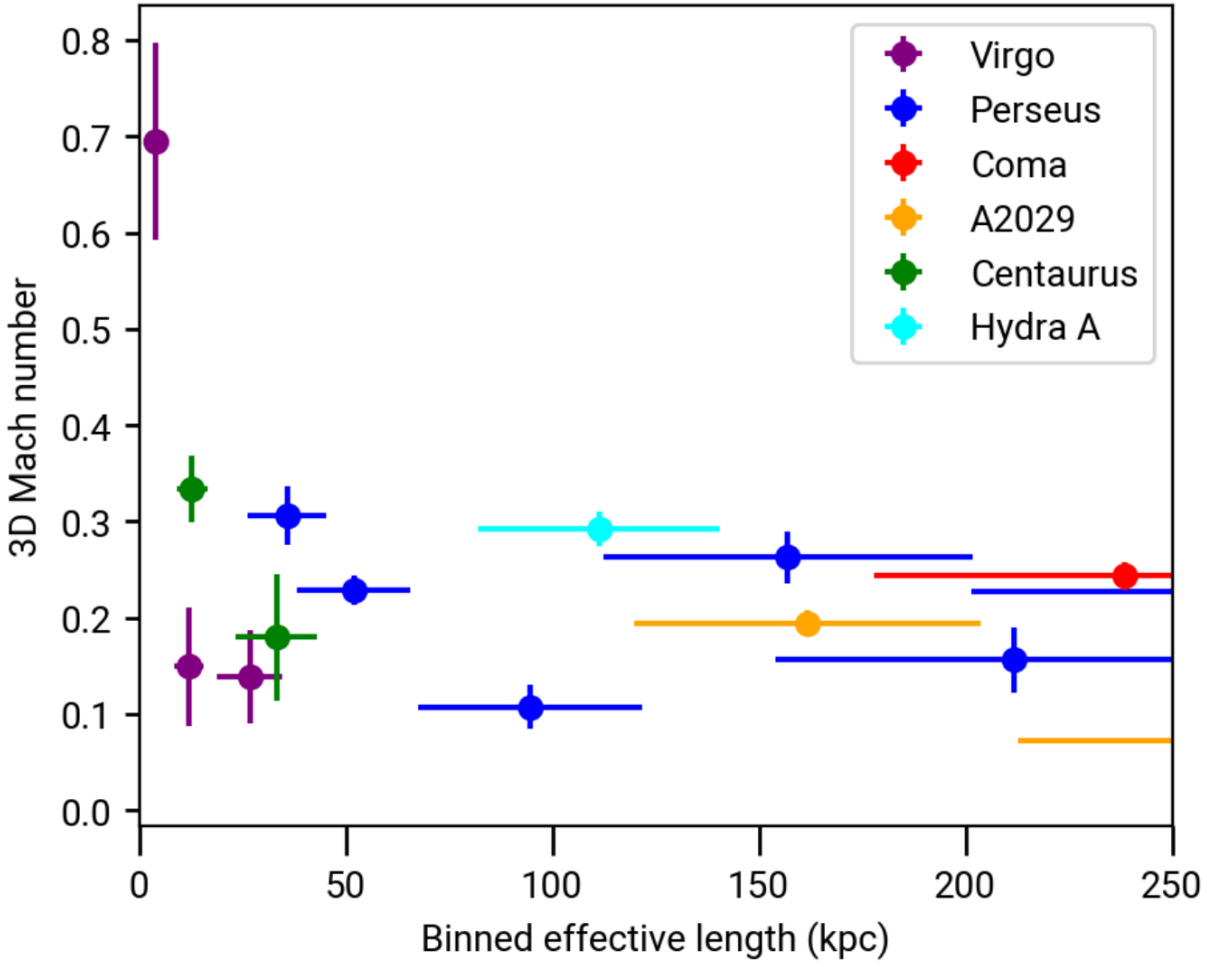






PREDICTIONS OF COSMOLOGICAL SIMULATIONS VS. XRISM

- XRISM has found many examples of low-turbulent ICM even in presence of large bulk motions
- Only **marginally consistent with the predictions of cosmological simulations**
- Different drivers on small (≤60 kpc; AGN) and large (>60 kpc; cosmology) scales in Perseus
- Spatial dilution effects to to the large *Resolve* pixels and optics Point Spread Function possible

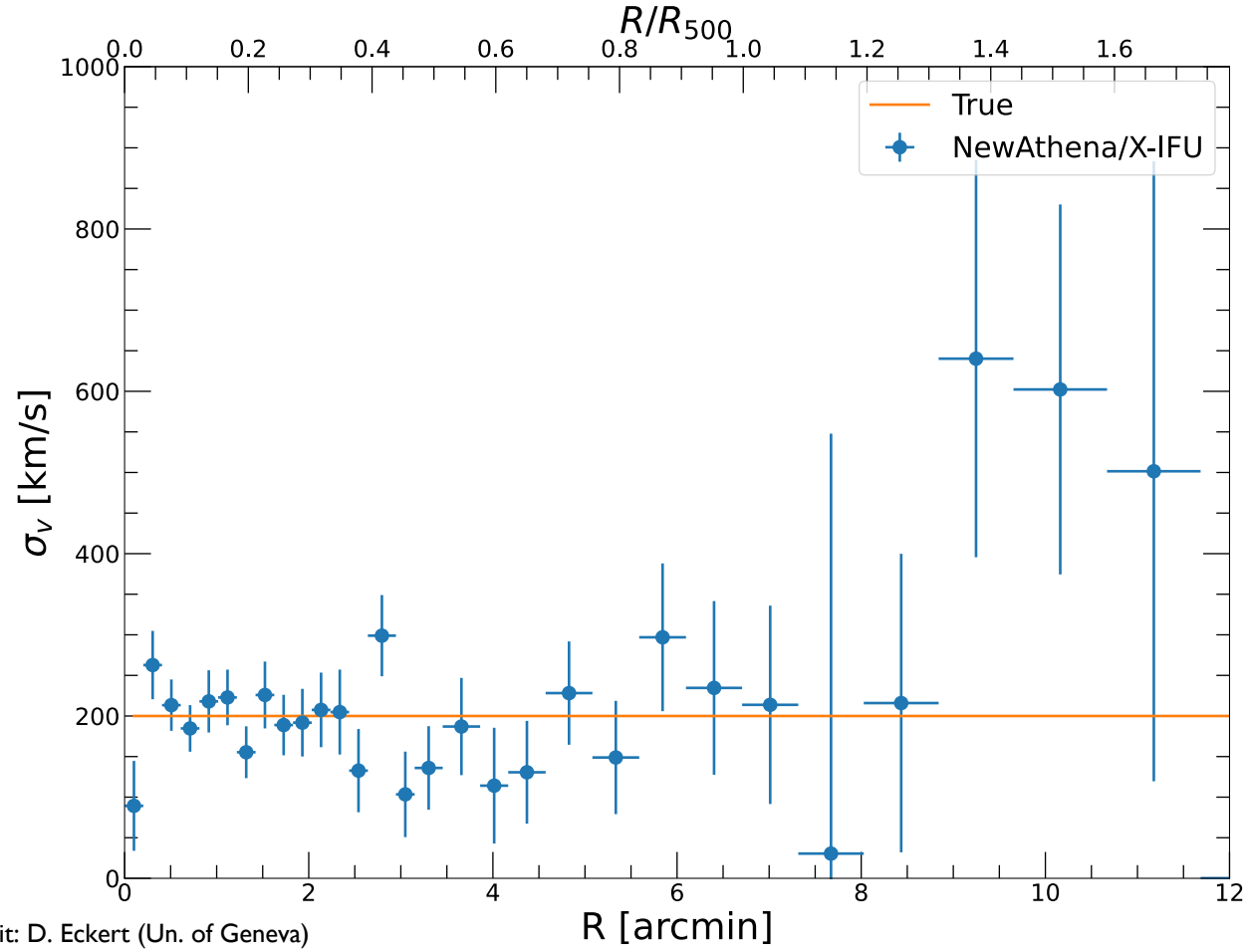


XRISM Collaboration, 2026, ApJ, 998, 210

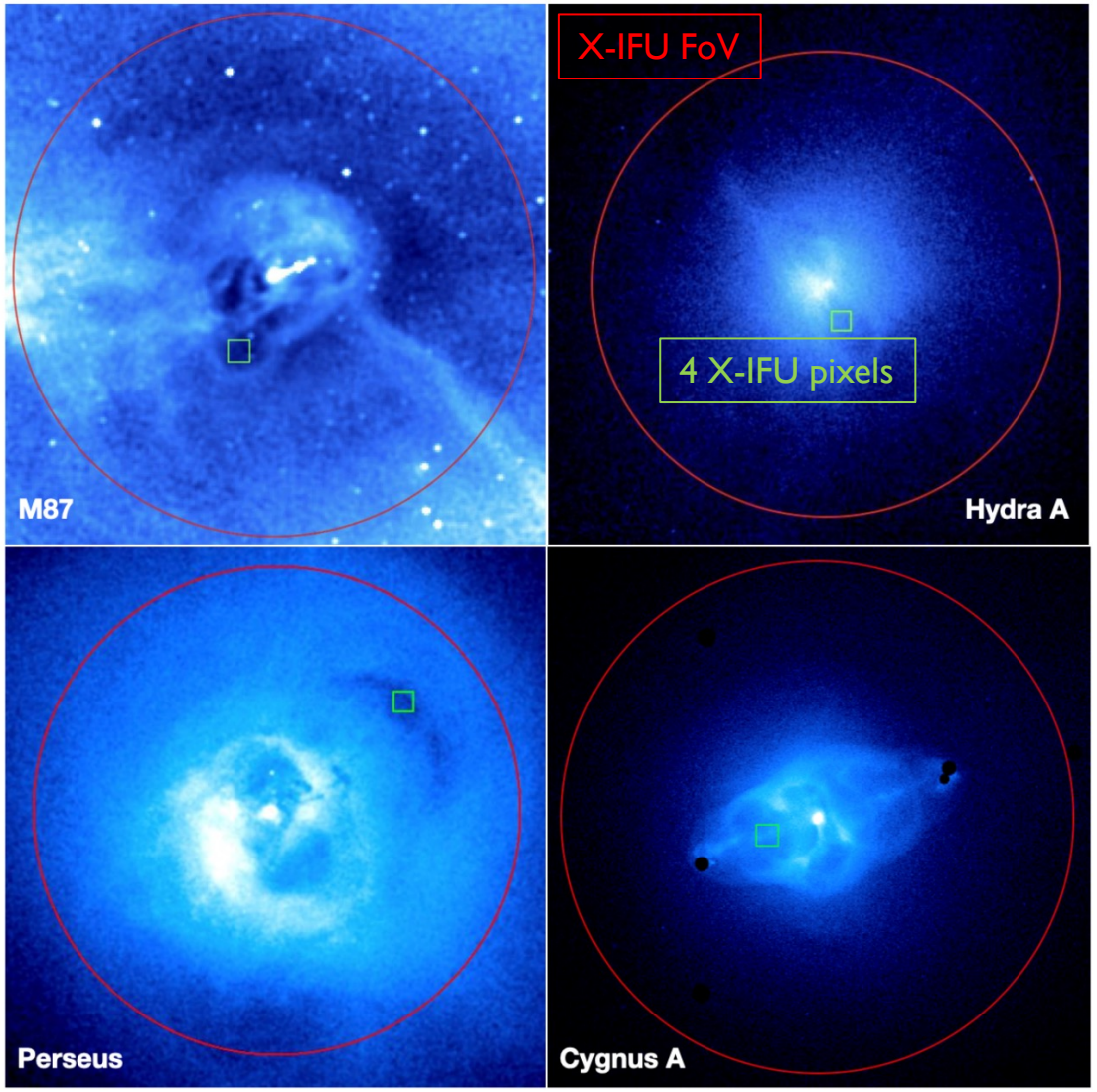
ENERGY DISSIPATION IN GALAXY CLUSTERS WITH NEWATHENA

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

Extend the measurements to R_{500} and beyond ↓

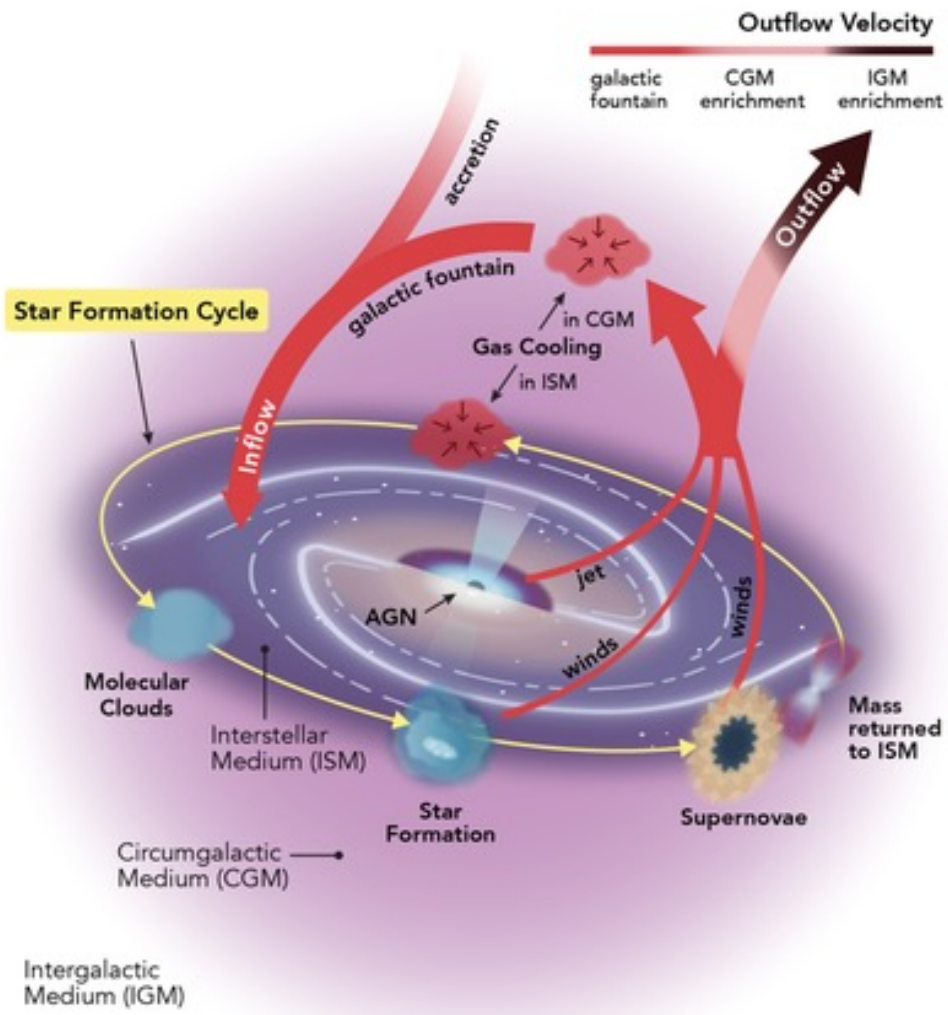


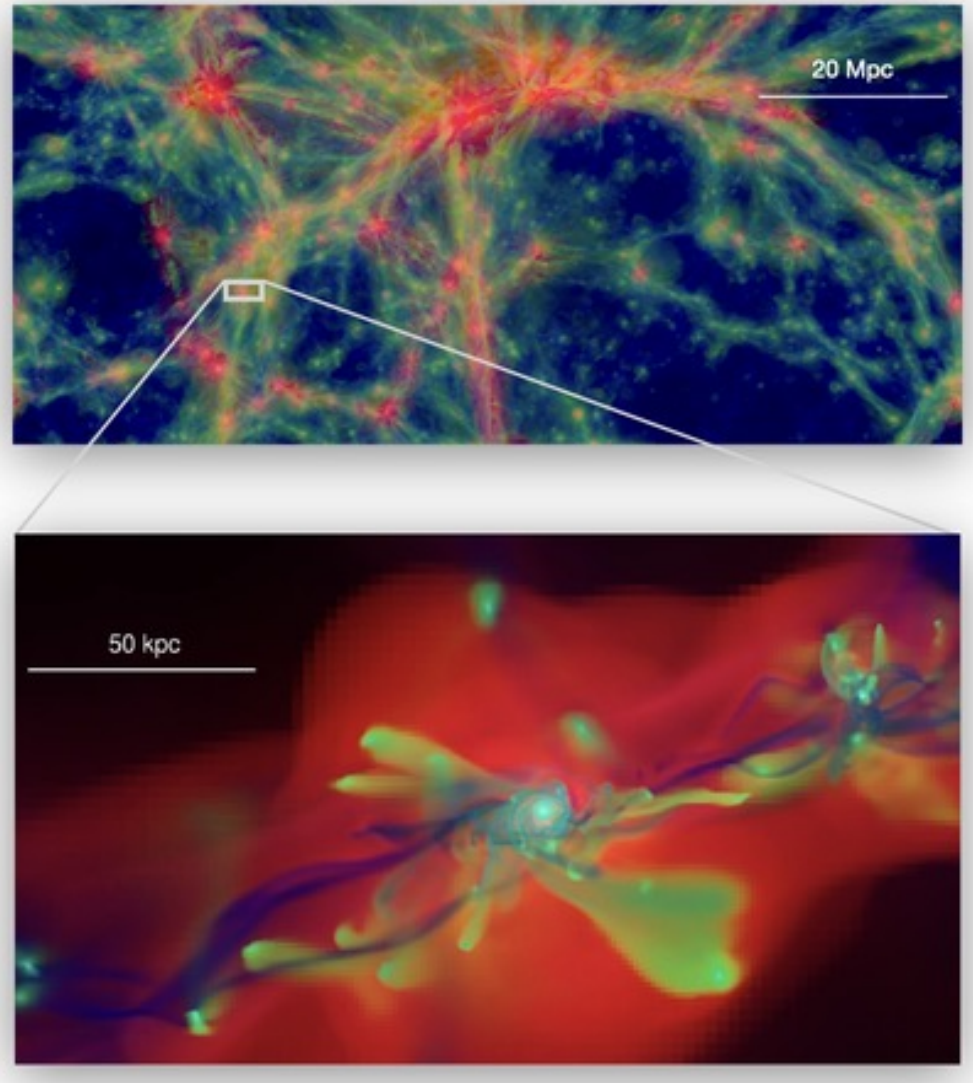
Credit: D. Eckert (Un. of Geneva)



Credit: A. Simionescu (SRON)

BARYON CYCLE IN THE UNIVERSE

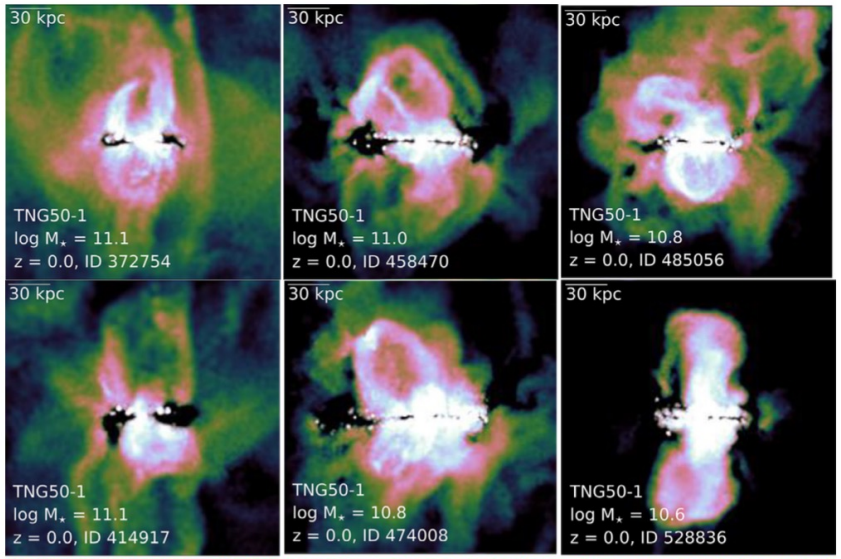




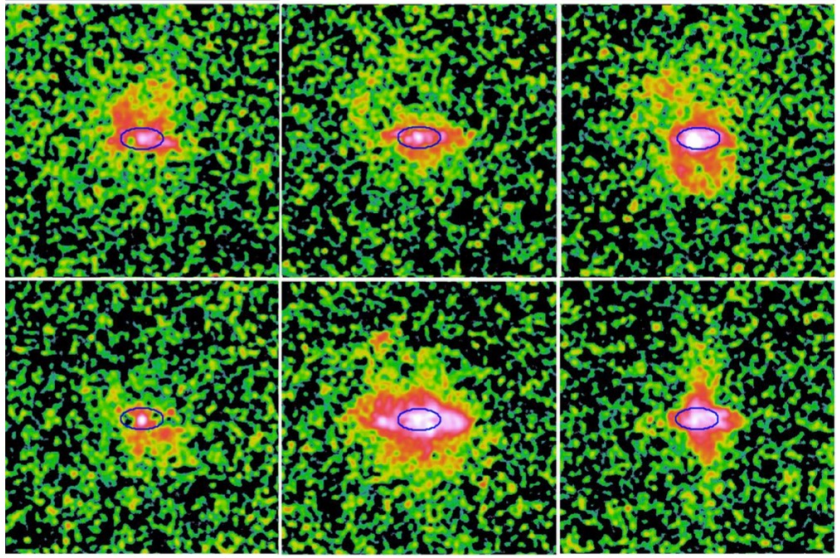
Saintonge, 2025, arXiv:2504.01410

MAPPING BARYONIC RESERVOIRS WITH NEWATHENA

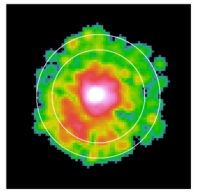
Soft X-ray images of TNG-50 galaxies hosting AGN bubbles



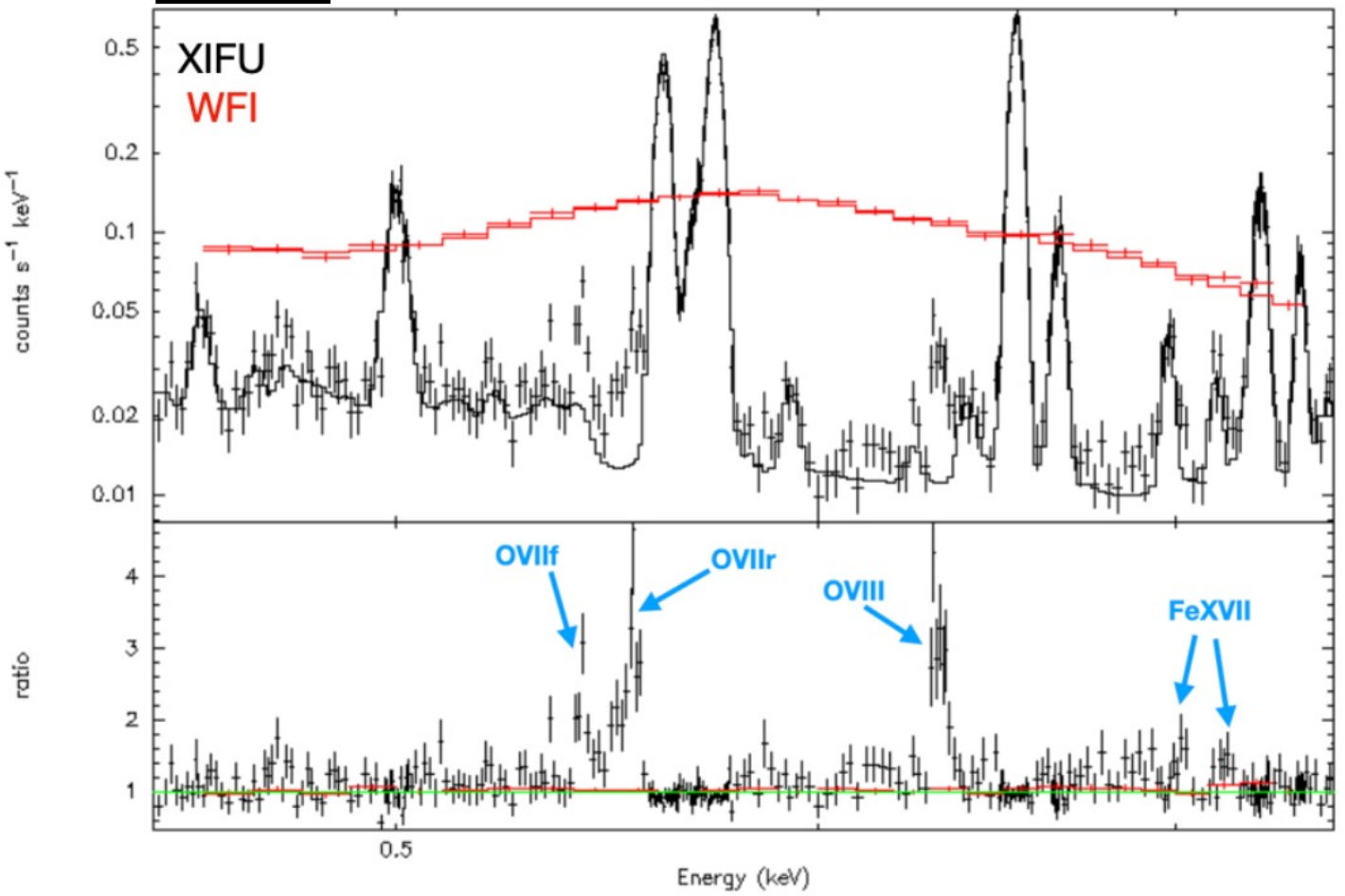
WFI 100 ks simulated images



Credit: N. Truong (GSFC)



Simulated X-IFU OVII image and soft X-ray spectrum of a TNG50 halo at z=0.035

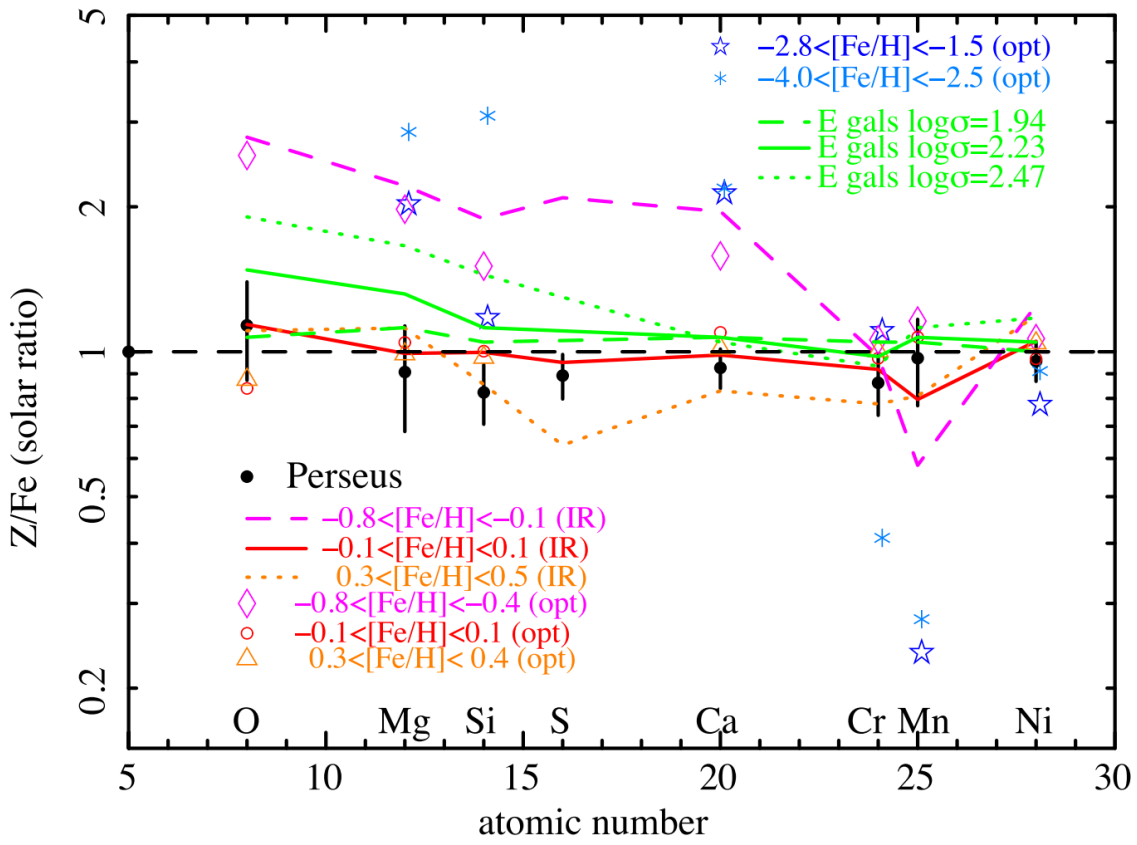


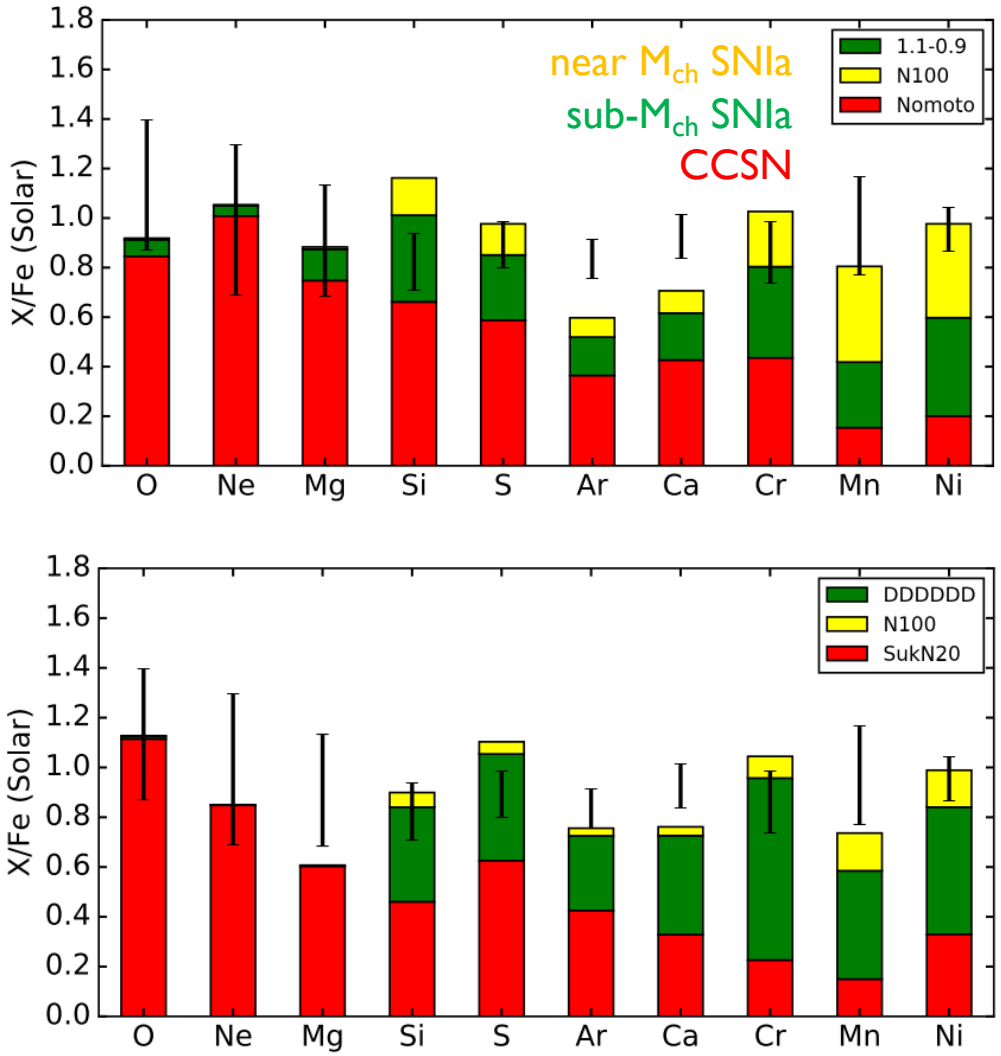
Credit: A. Simionescu (SRON)

HITOMI AND XRISM LIFTED THE VEIL ON METAL PRODUCTION

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

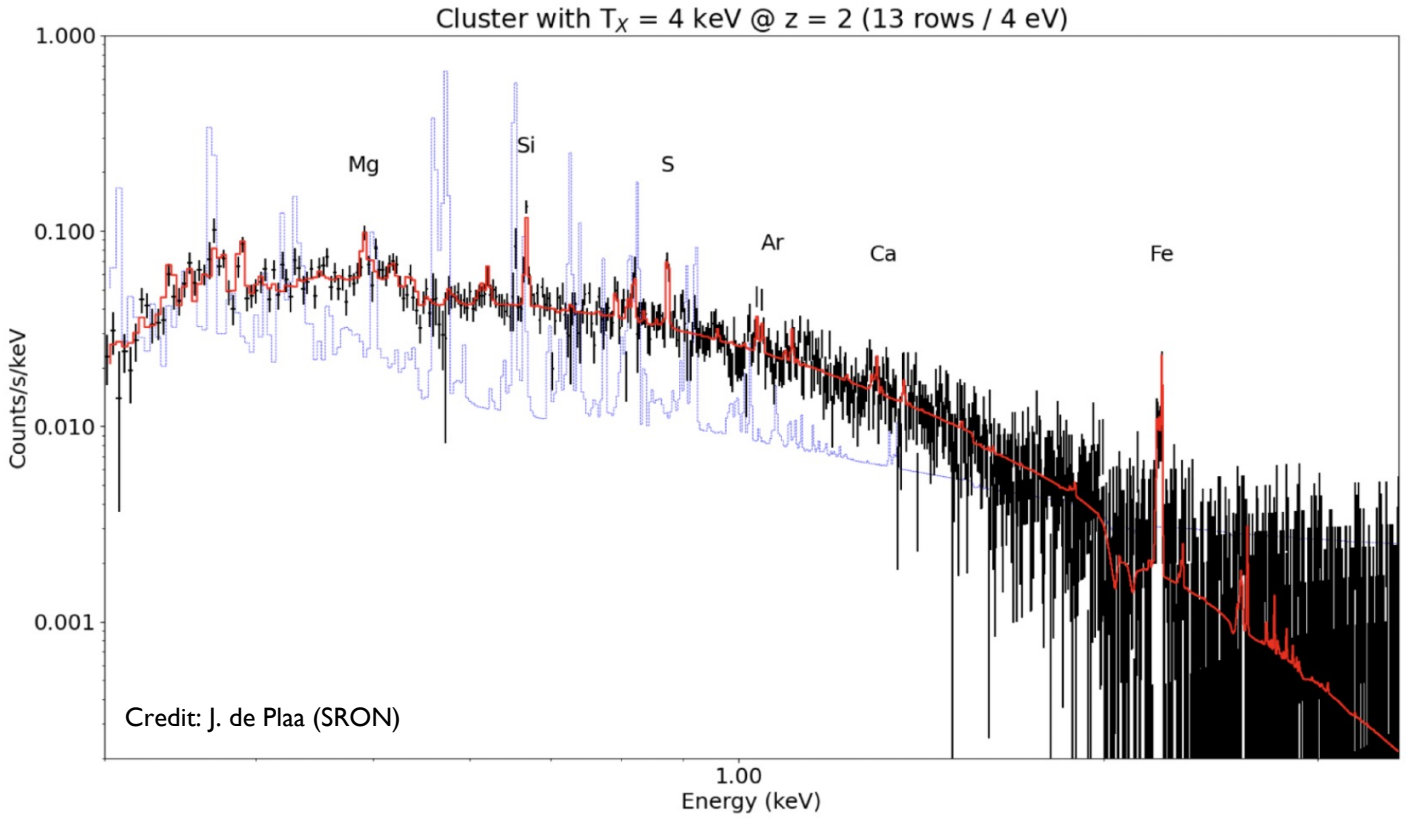
Comparison of Perseus (z=0.017) metallicity (Hitomi) with the Milky Way (IR/opt) and early-type galaxies (SDSS)





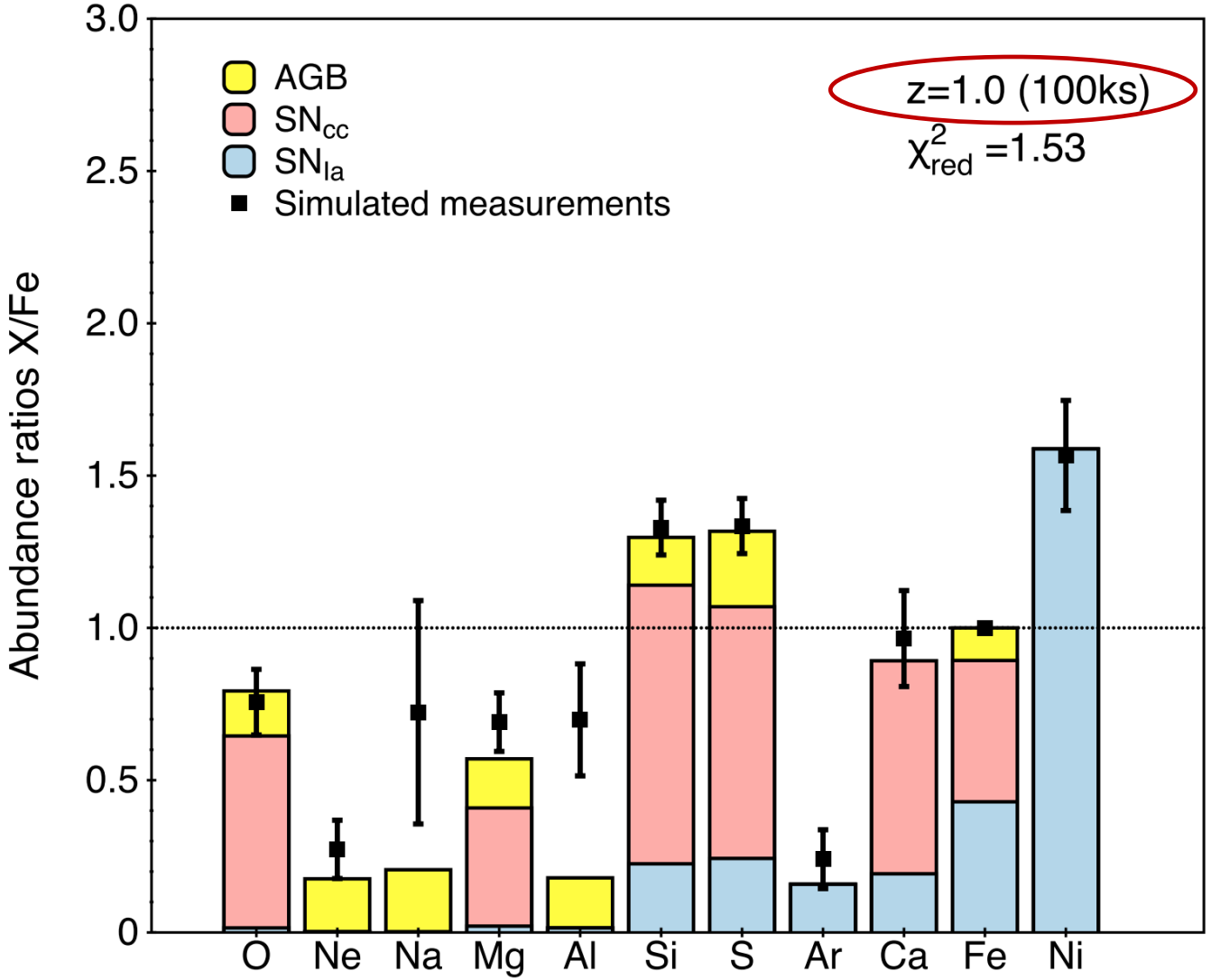
NEWATHENA EXTENDS TO Z~2

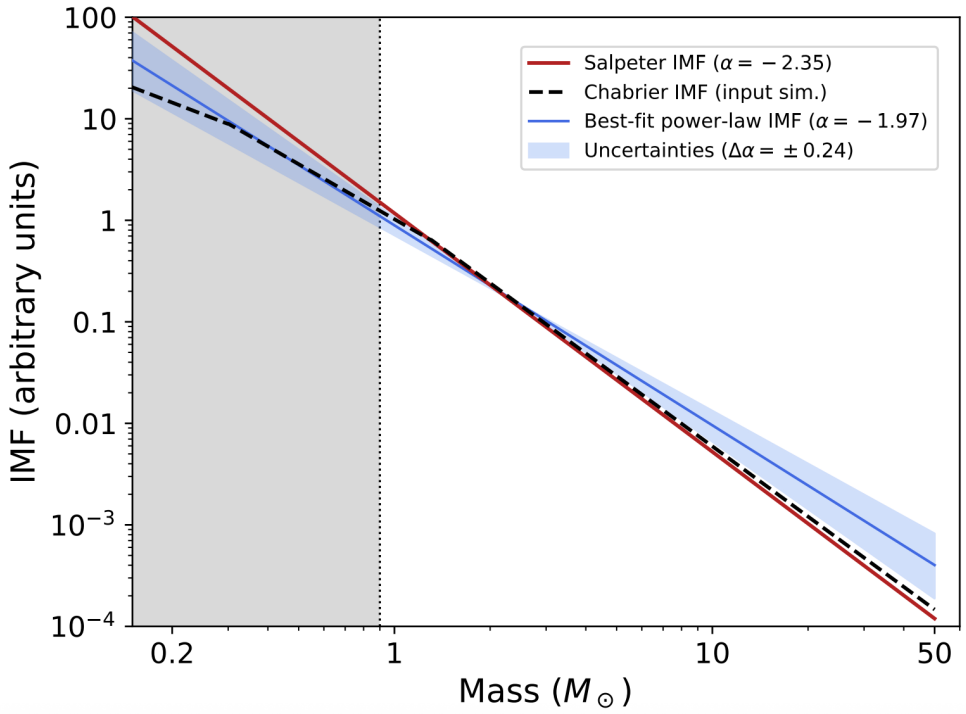
X-IFU simulation of a z=2 Perseus-like galaxy cluster with Z=0.3



- Tracing the evolution of baryion physical properties from the epoch of structure formation (z~2)
- 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





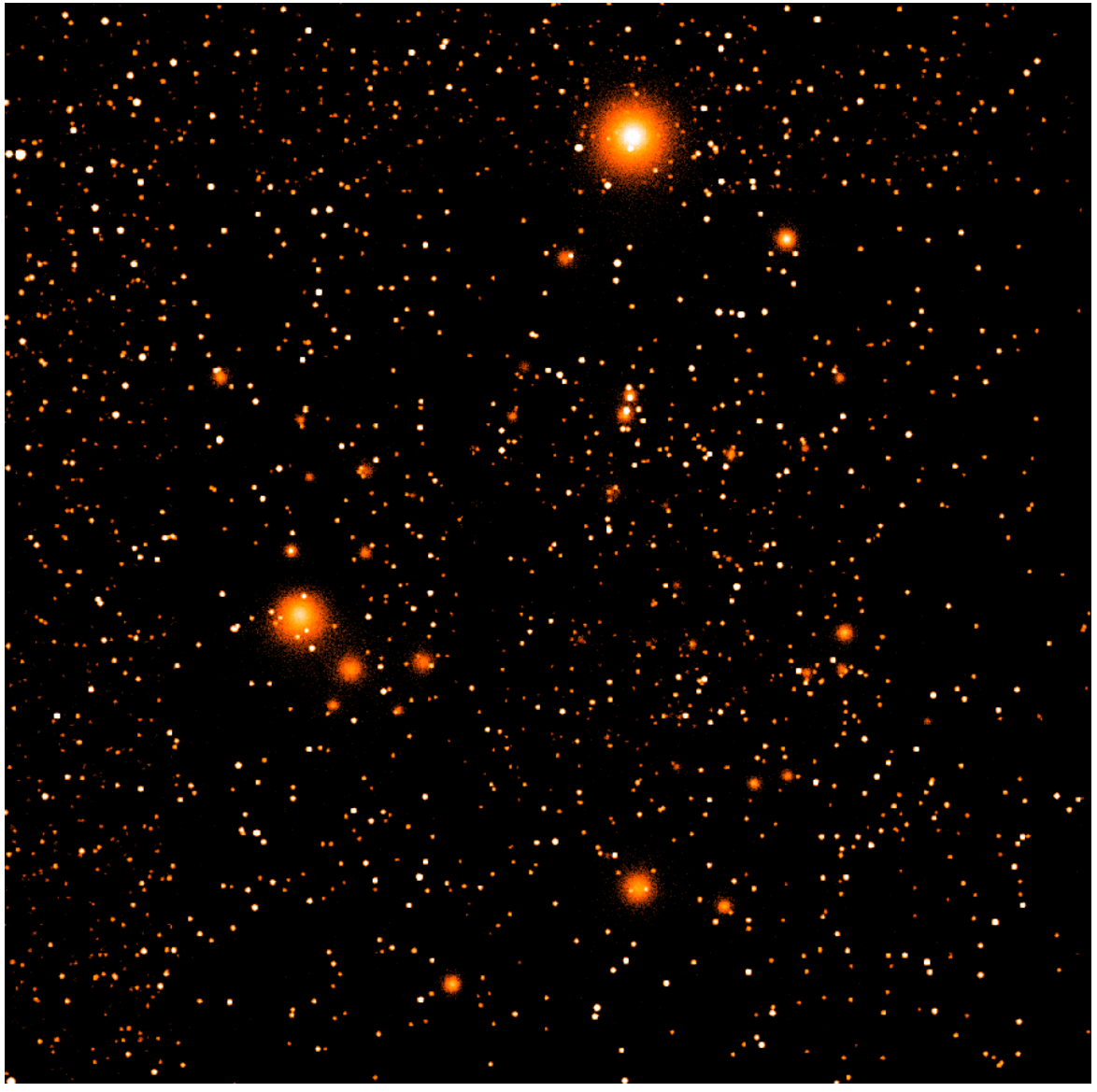
Independent constraints on the Initial Mass Function potentially possible

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

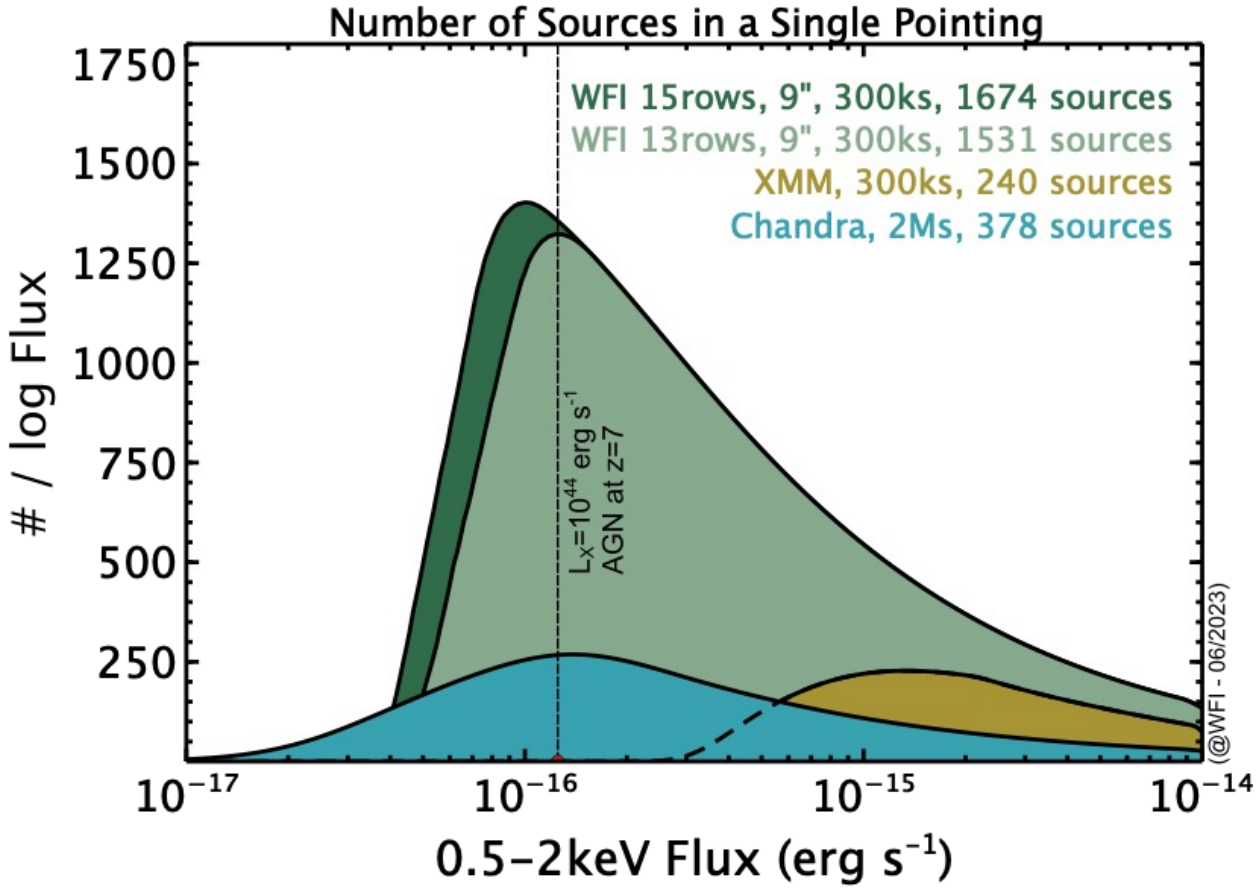
WHAT IS NEWATHENA:WFI

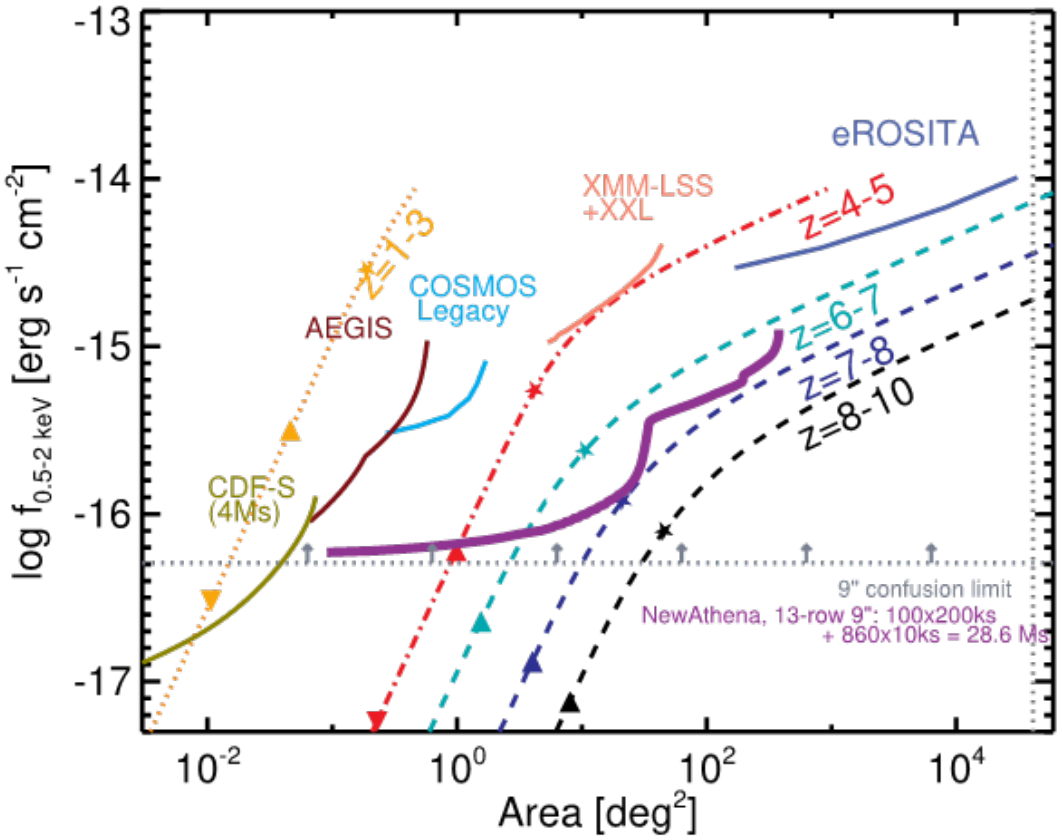
Credit: WFI Consortium

- **Wide Field Imager**: led by MPE (PI: Paul Nandra)
- DEPFET system with a 40'x40' FoV
- Complemented by a "Fast Detector", 2' diameter, for (time-resolved) spectroscopy of ≥Crab transients – 80μs time resolution
- ~CCD-like energy resolution (~170 eV @7 keV) and large grasp (>eROSITA)
- Simulation: 200 ks of the Chandra Deep Field South with WFI



KEY PERFORMANCE INDICATORS: WFI SURVEY SPEED



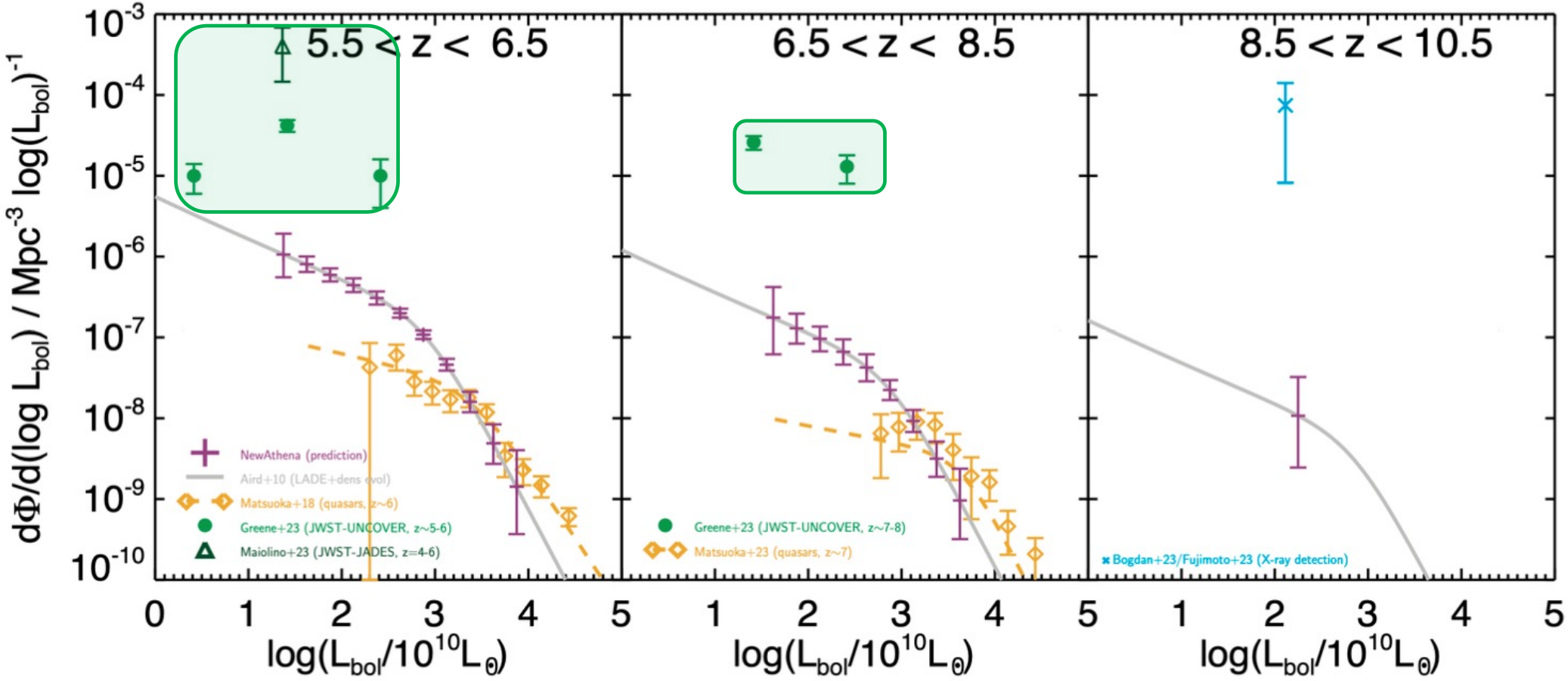


Enables the determination of the space density of obscured AGN down to z~8 and the discovery of galaxy groups (M≥5x10^{13} $M_\odot$) at z~1-1.5

Credit: A. Rau (MPE), J. Aird (UoE)

CENSUS OF THE AGN POPULATION WITH THE NEWATHENA WFI

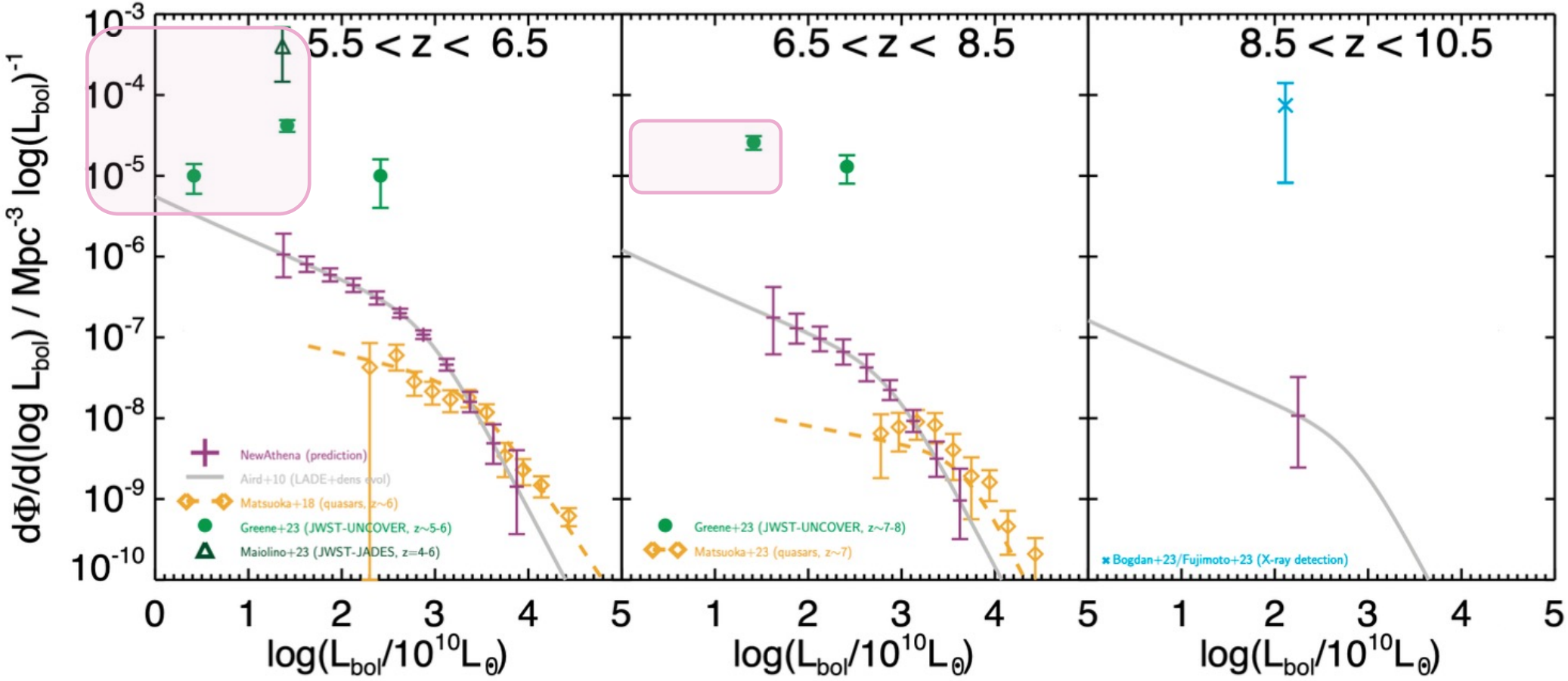
2024 Little Red Dots (Greene et al., 2024, ApJ, 964, 39)



Credit: J. Aird (Un. Of Edinburgh)

EXTENDING THE CENSUS OF THE AGN POPULATION

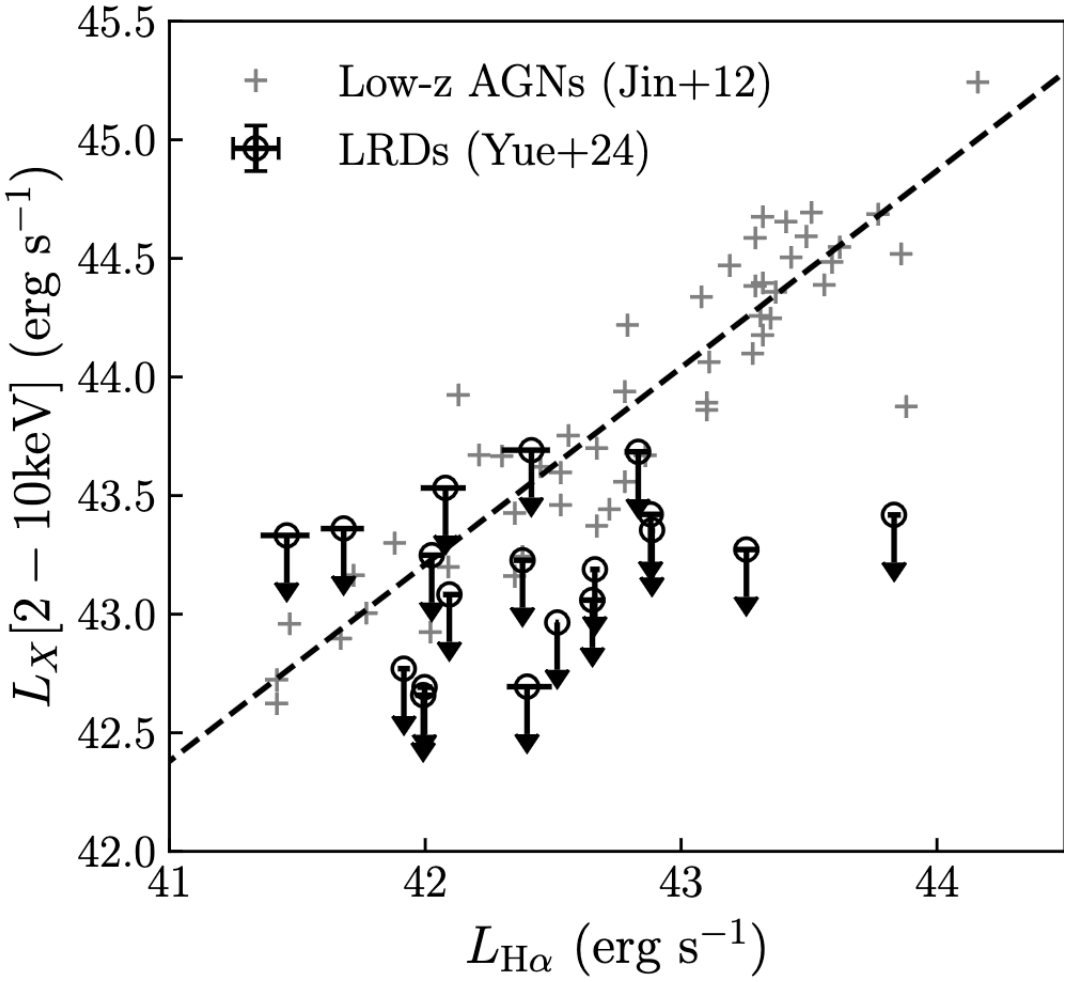
2026 Little Red Dots (Greene et al., 2026, ApJ, 996, 129)



Credit: J. Aird (Un. Of Edinburgh)

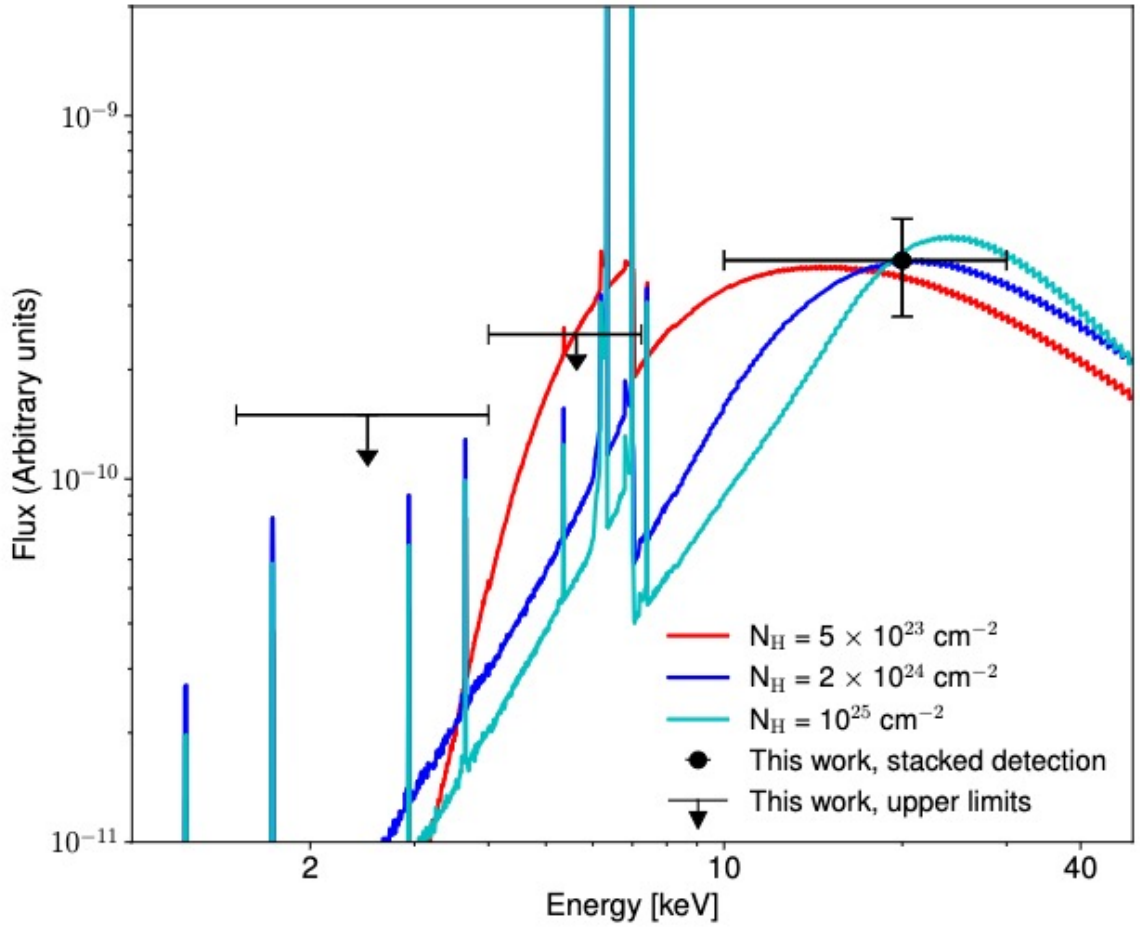
HIGH-REDSHIFT QUASAR X-RAY WEAKNESS: AN ISSUE?

Mostly X-ray upper limits for *individual* LRDs



Yue et al., 2026, ApJ, 974, 26

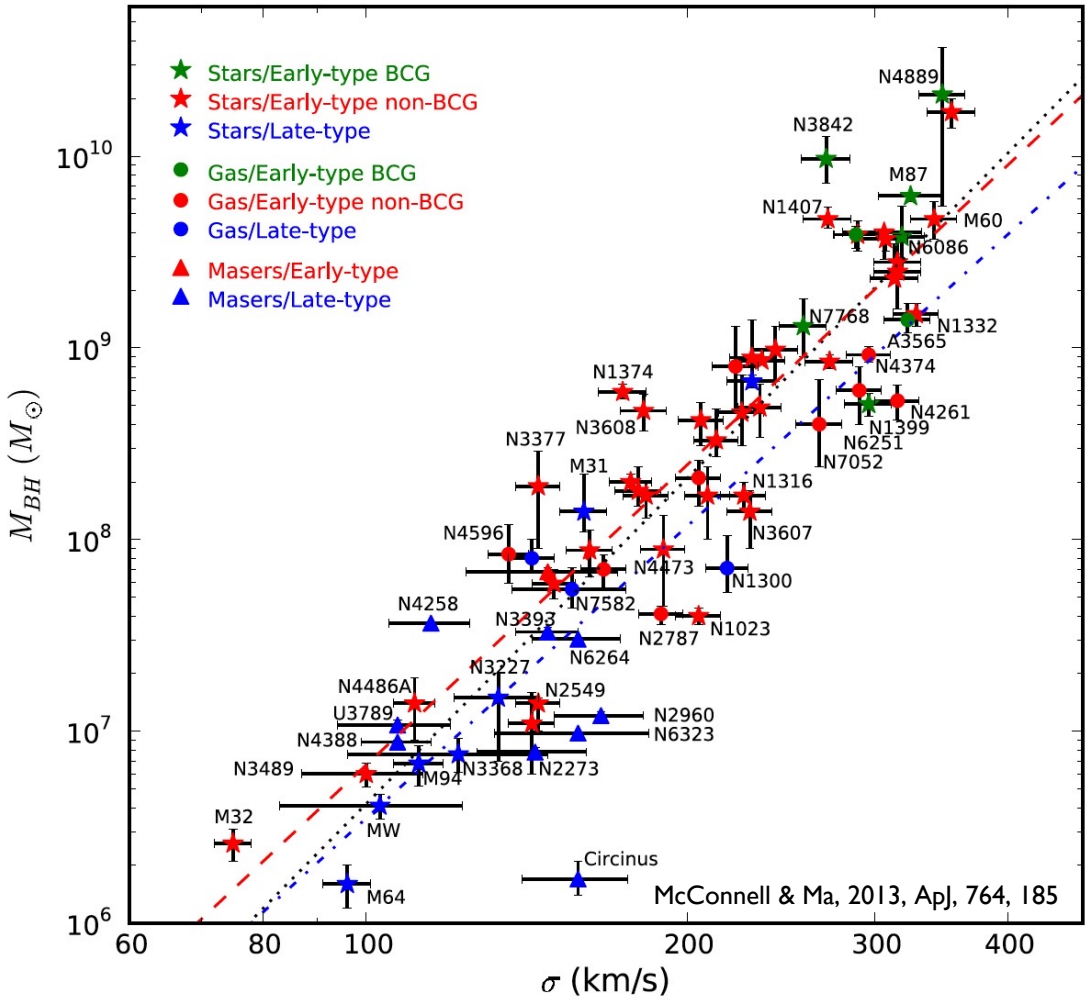
Chandra ACIS spectrum of stacked z>2 JWST AGN



Comastri et al., 2026, A&A, 706, 302

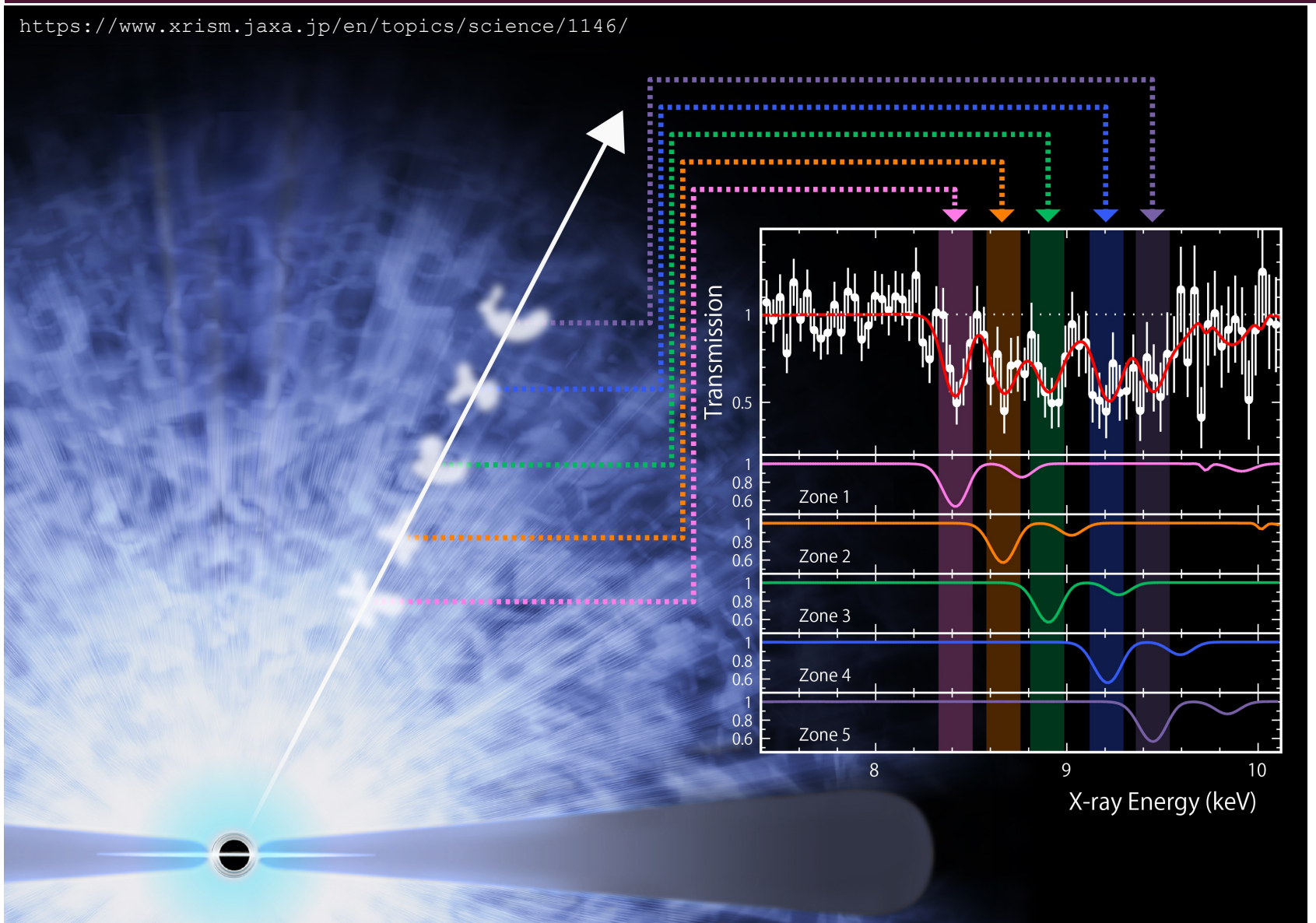
AGN "FEEDBACK"

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

HAS XRISM DISCOVERED THE ULTIMATE FEEDBACK MESSENGER?

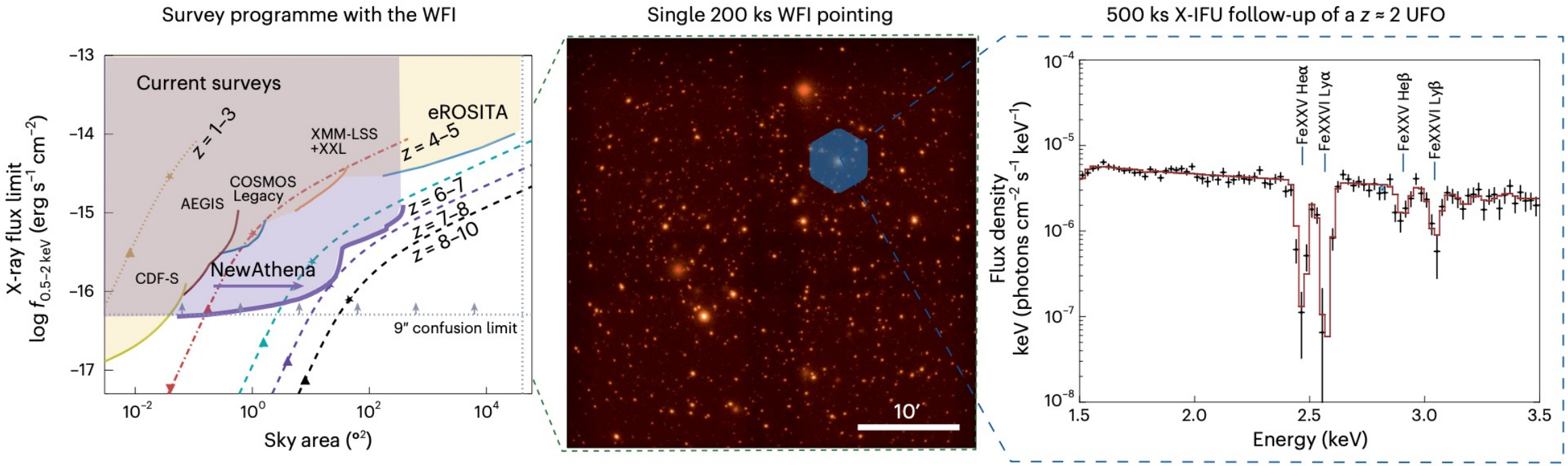


- **PDS456:** One of the most powerful quasars in the local Universe
- XRISM discovers of a system of relativistic (z~0.2-0.3 c) "Ultra-Fast Outflows"
- Millions of clumps within ~600 gravitational radii
- Wind kinetic power exceeds the Eddington luminosity
- UFO mass outflow comparable to molecular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

NEWATHENA WILL BRING THESE STUDY TO A MASSIVE SCALE

Cruise et al., Nature Astronomy, 2025, 9, 36

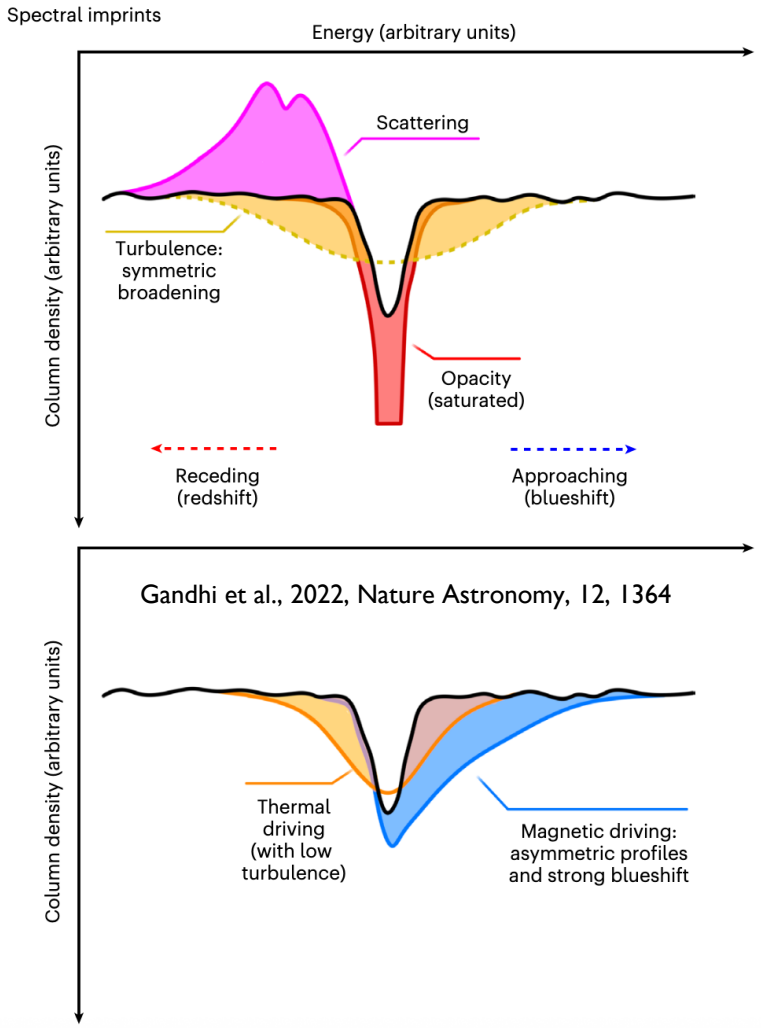
The WFI survey (~400,000 AGN) will enable to find many **AGN with strong UFOs at z~2-3**

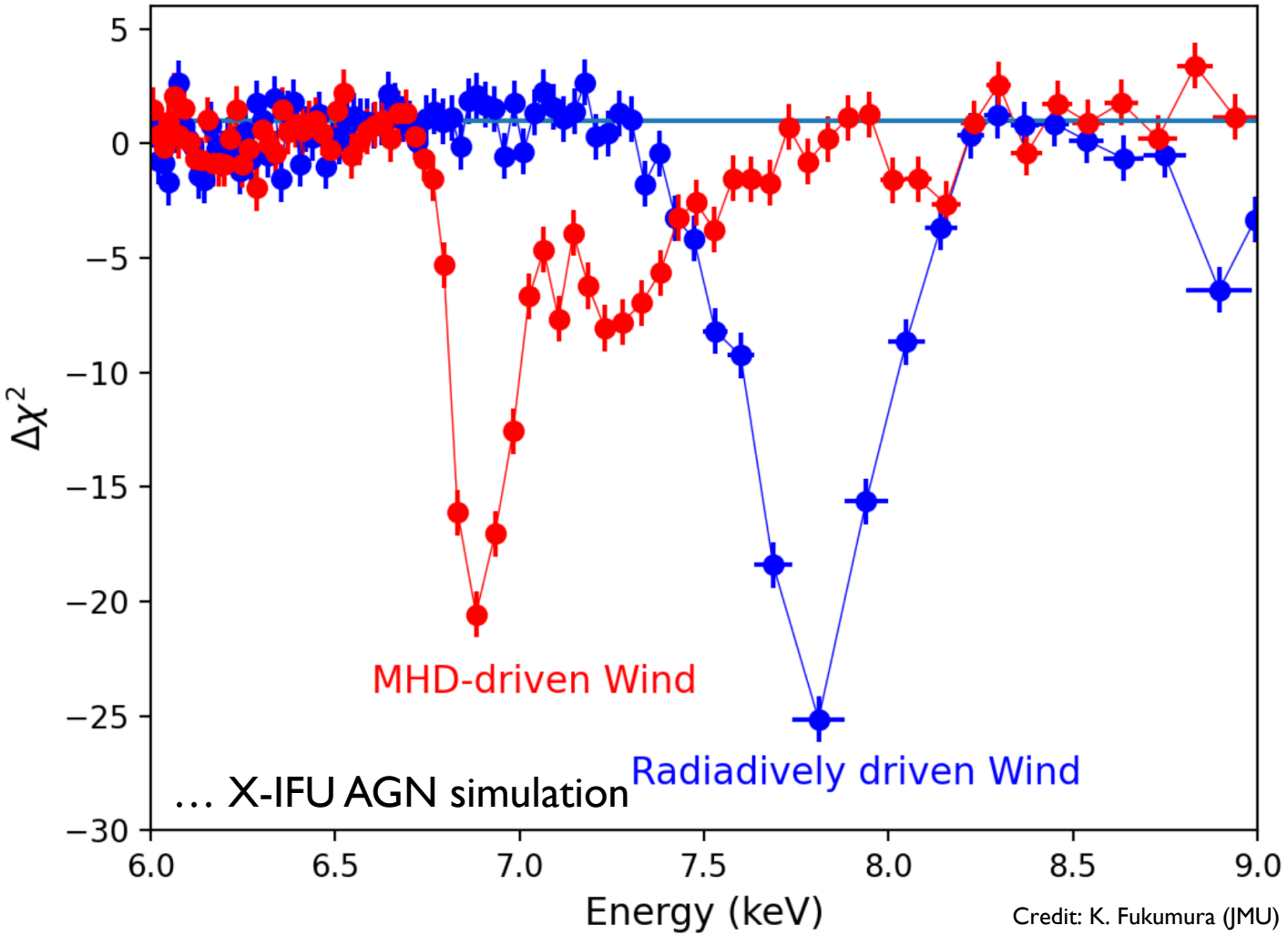


z~2-3 is the "Cosmic Noon", where the **density of accreting black holes** and the **star formation rate** peak

UNVEILING THE LAUNCHING MECHANISM VIA LINE PROFILE

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

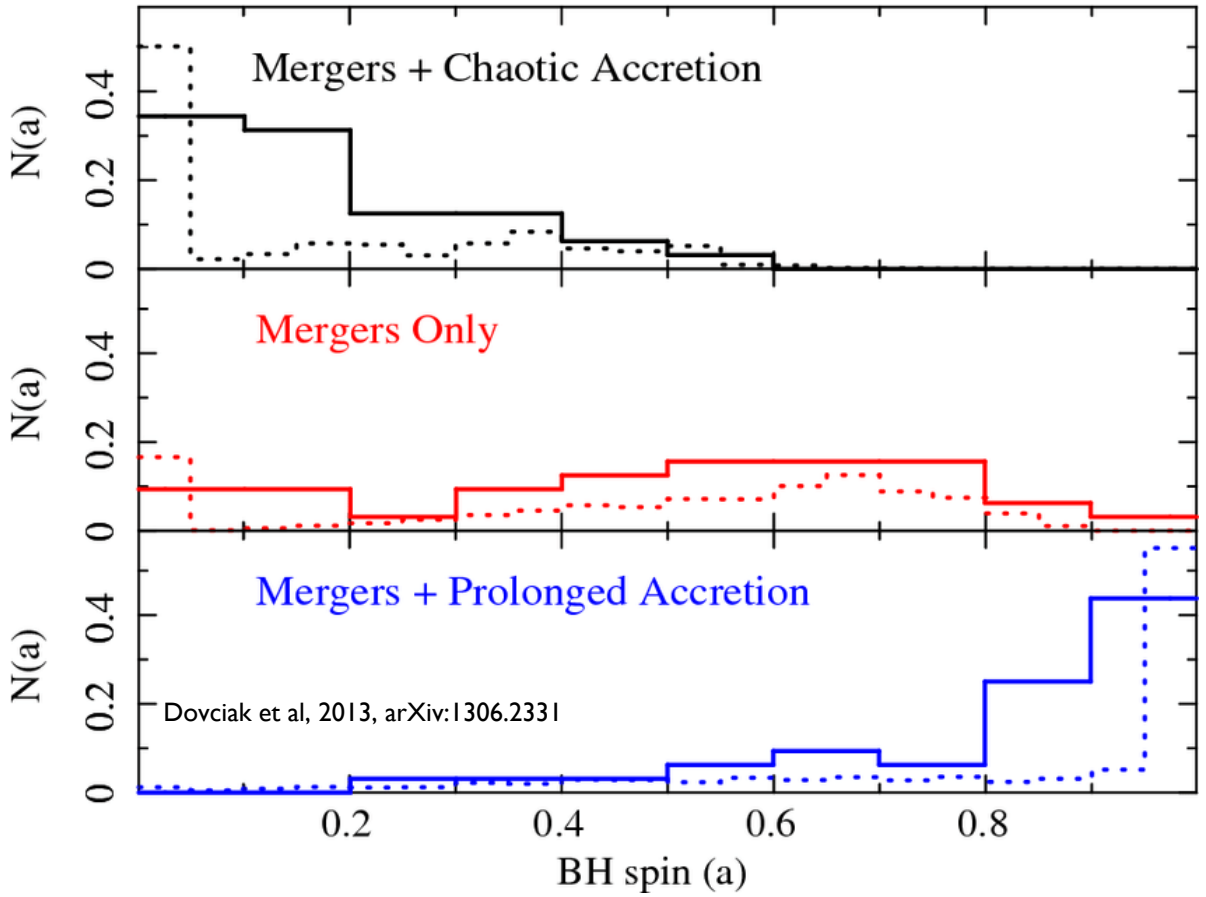




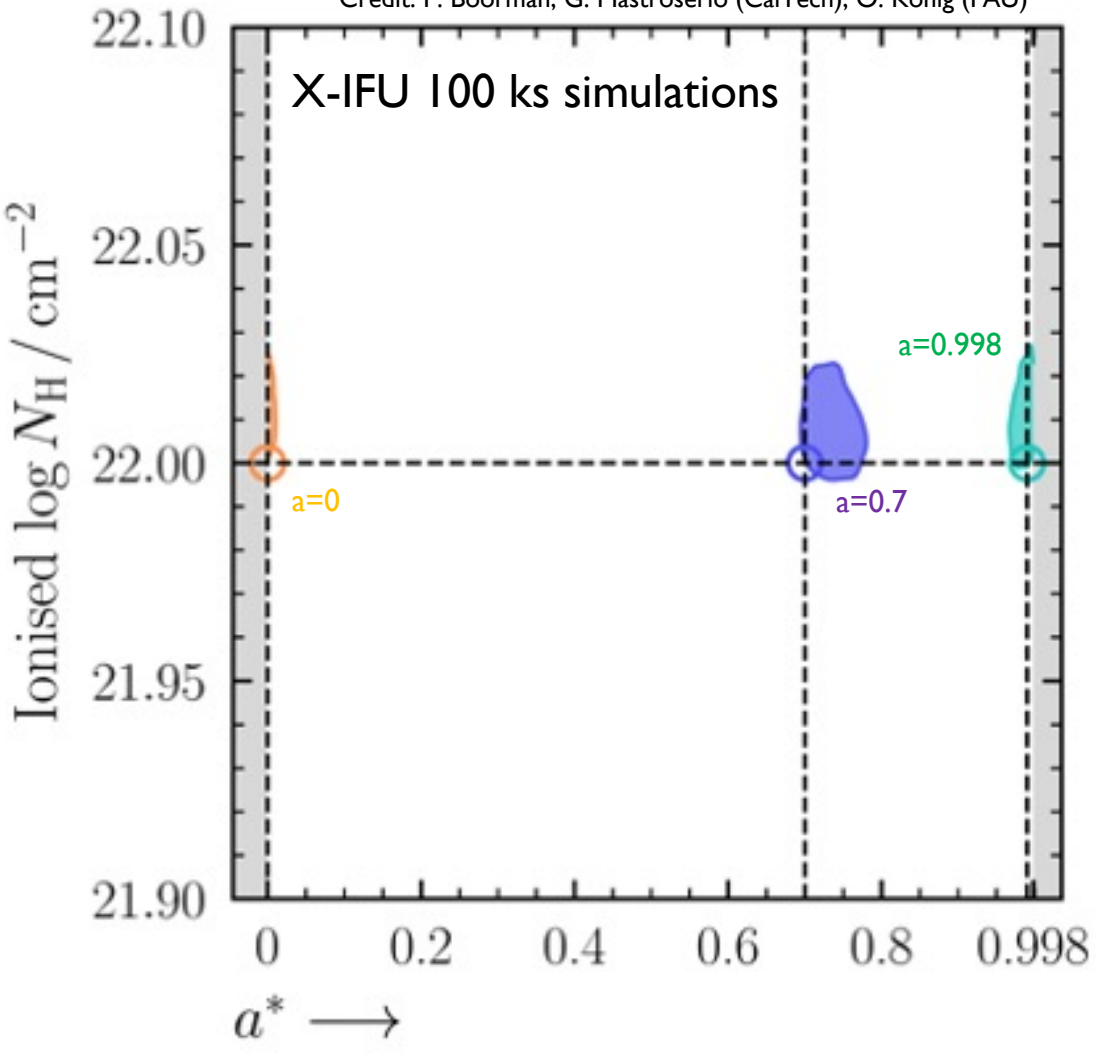
Credit: K. Fukumura (JMU)

THE DECADE-LONG QUEST FOR THE BLACK HOLE SPIN

Black hole spin distribution probe the host galaxy evolution



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

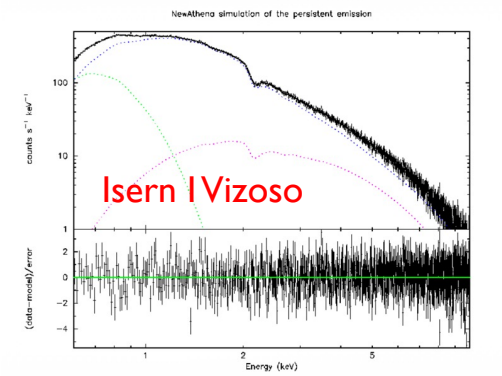


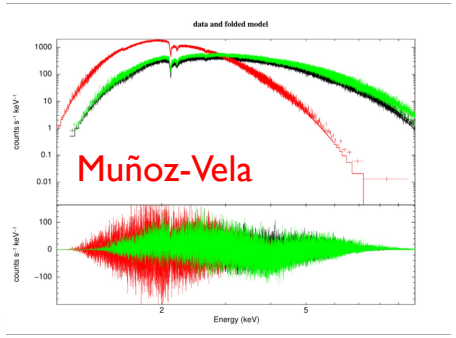
NEWATHENA IS A WIDE-RANGE X-RAY *OBSERVATORY*

- **"NewAthena Raising"** Workshop at ICE-CSIC, 2-5 June 2026
- Organized by Early Career Researchers (10 years from Ph.D)
- All speakers were ECRs
  - 7 sessions
  - 40 talks (10 keynote)
  - 68 in-person participants
  - 67 on-line participants
- Organized by a NewAthena Science Working Group to discuss the prospective NewAthena science on compact objects (black holes, neutron stars, white dwarfs)

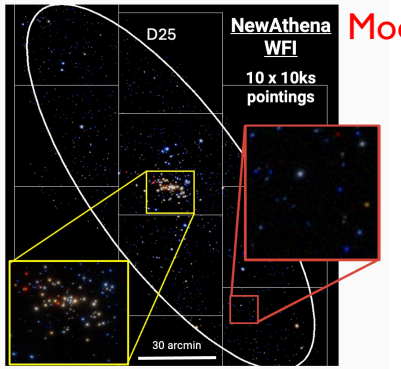
NEWATHENA IS A WIDE-RANGE X-RAY *OBSERVATORY*

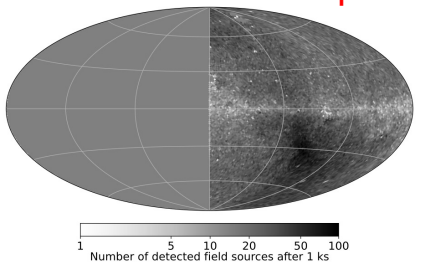
Thermonuclear X-ray bursts



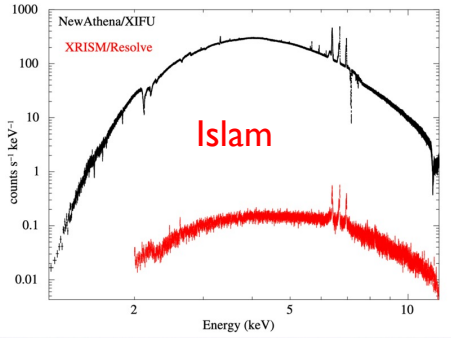


Population studies

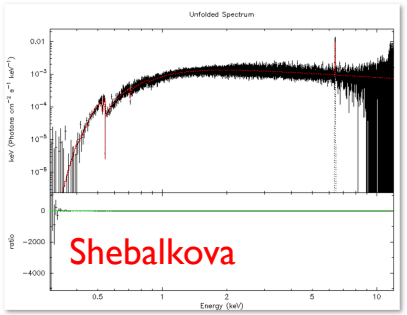


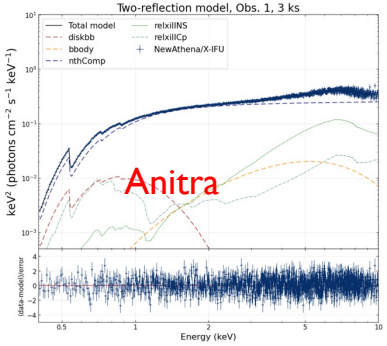


WD masses

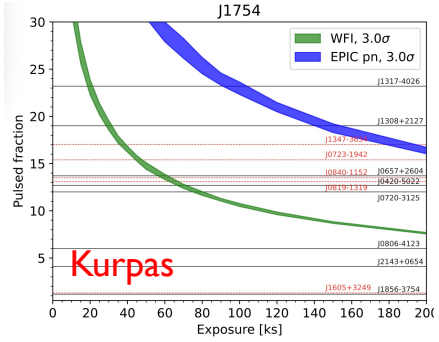


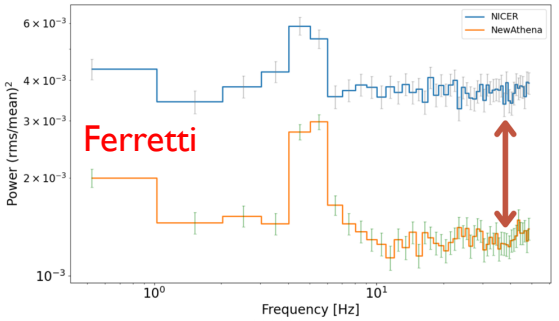
Disk spectroscopy

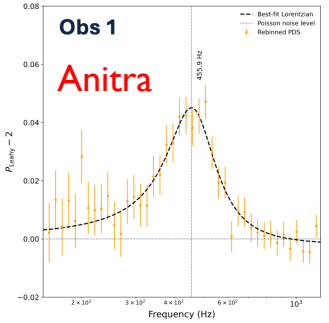




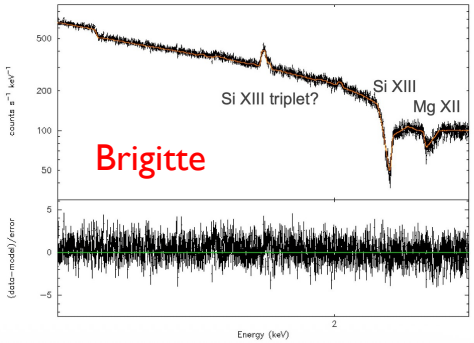
Timing

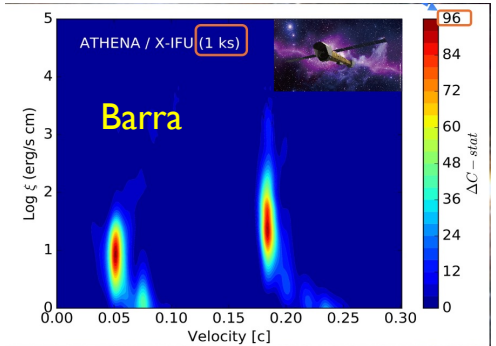


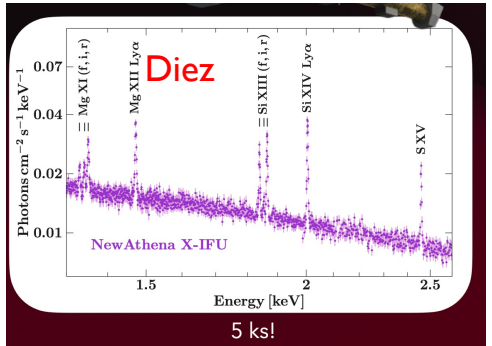




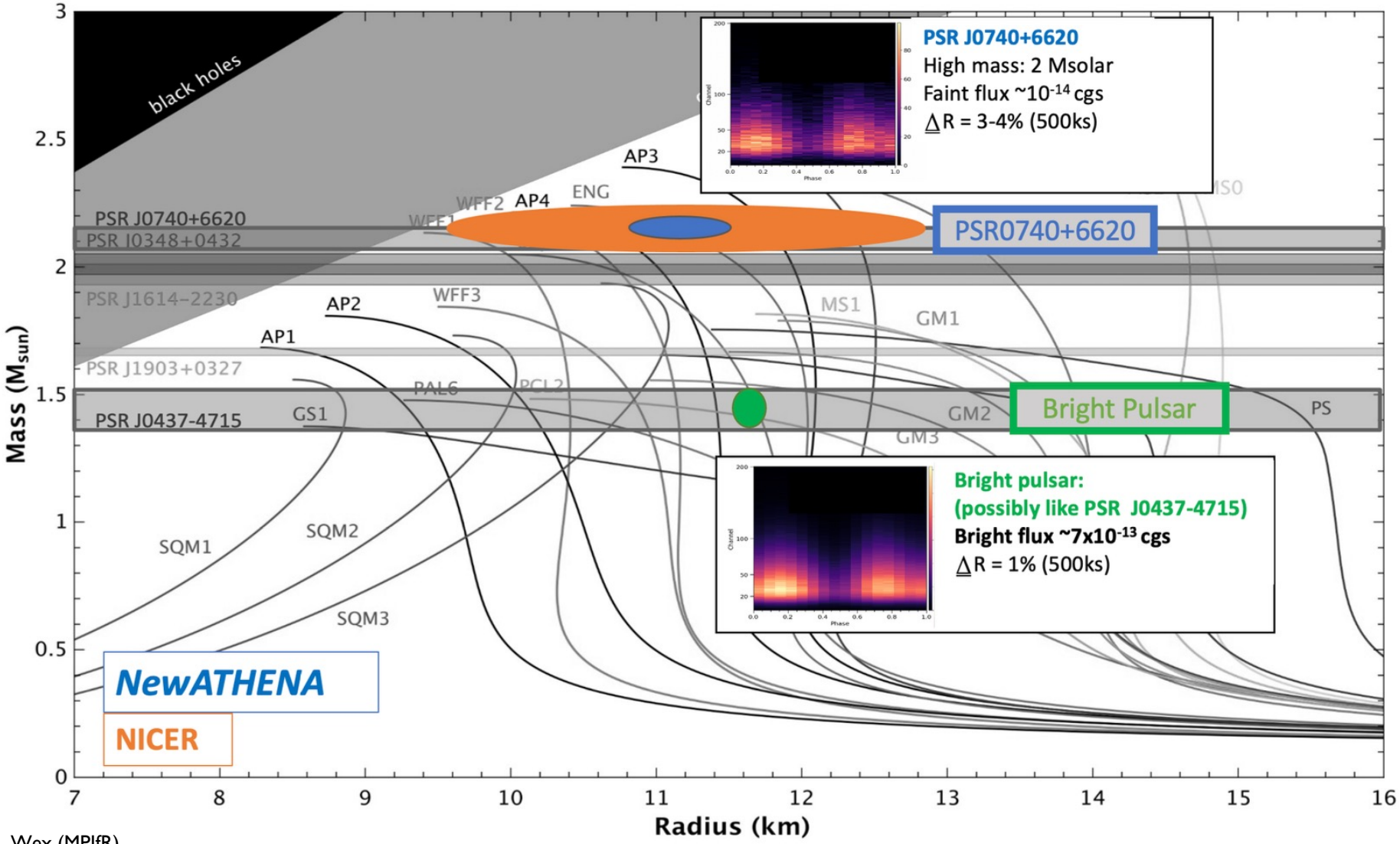
Stellar winds and outflows







NAILING THE EQUATION-OF-STATE OF NEUTRON STARS



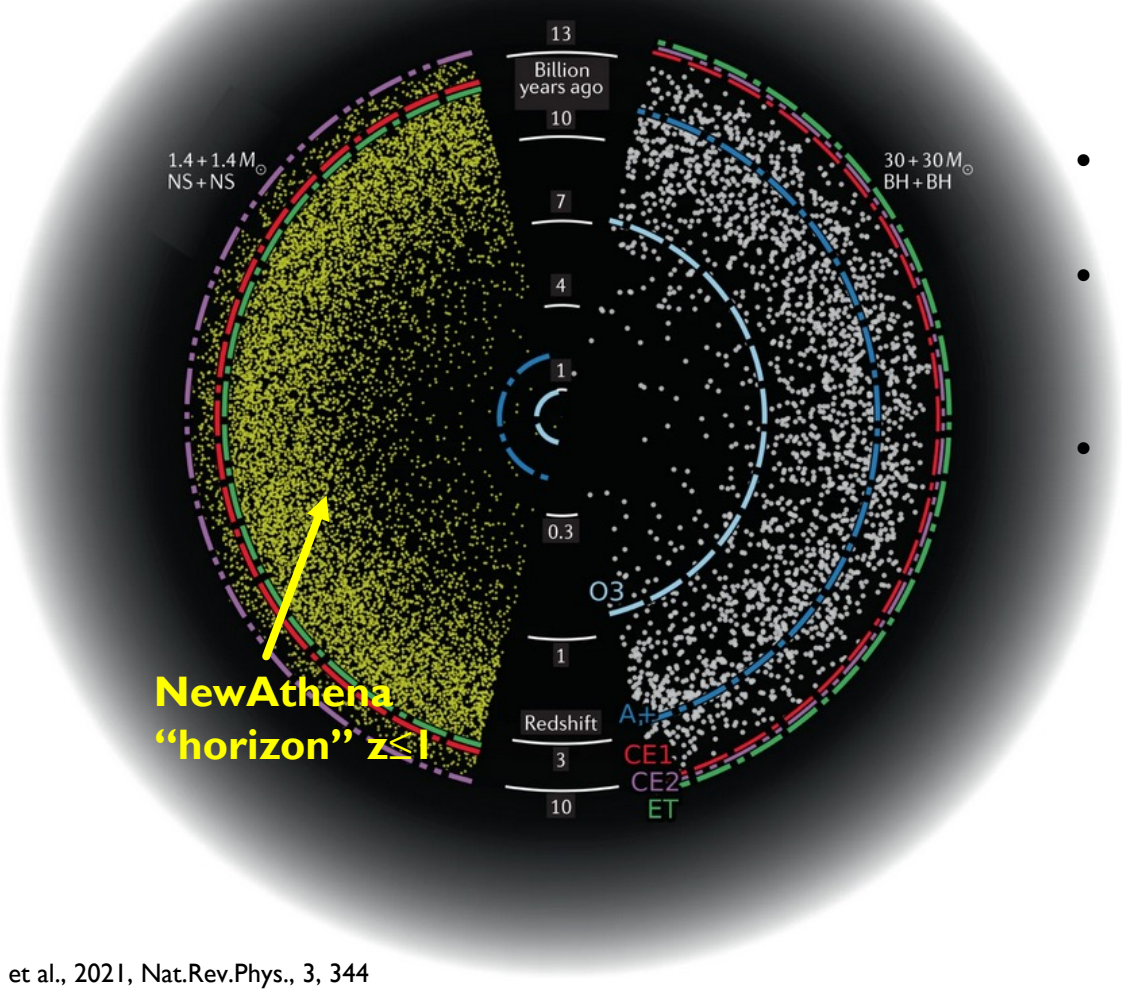
From ~15% (NICER) to ≤3% (NewAthena) error on the NS radius via modeling of the energy-dependent pulse profile

This corresponds to an error on the radius ±300-400 m [Mauviard et al. in prep.]

Credit: N. Wex (MPIfR)

MULTI-MESSENGER ASTROPHYSICS

Network	N(detected) [yr^{-1}]	Median loc. [deg^2]	N(<1 deg^2) [yr^{-1}]
HLVKI	15	7	0
3Voyager	800	20	5
1ET+2Voyager	6,100	21	20
1ET+2CE	320,000	12	4,500



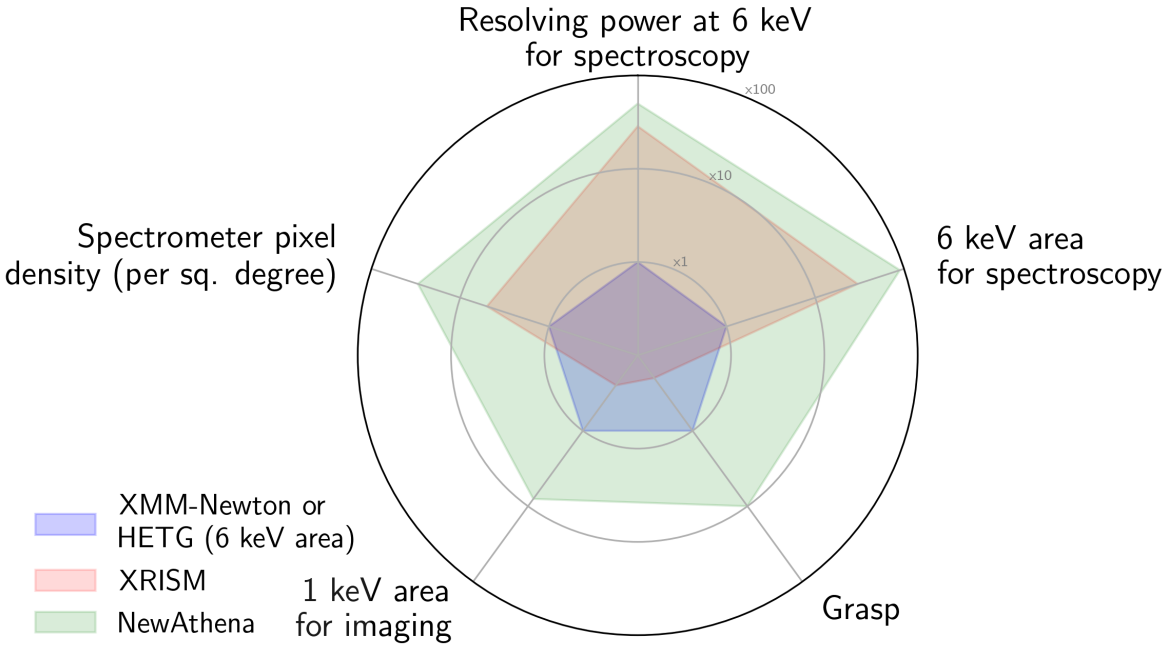
- NewAthena may enable arcseconds locatization on a ~a few tens neutron star[2] merging events over the 5-years nominal operations
- Enabled by ≥34[0] field-of-regards and ≤12h ToO response time
- **NewAthena enables accurate jet inclination for most binary systems**
- Main science areas:
  - Cosmology (through joint Gravitational Wave and electromagnetic observations)
    - X-rays break the degeneracy between inclination and luminosity distance
  - Nature of the remnant compact object through X-ray variability
  - Accurate metallicity in kilonovae through disentangling non-thermal contribution

Bailes et al., 2021, Nat.Rev.Phys., 3, 344

MISSION STATUS

Credit M. Martine-Lagarde (ESA)

- NewAthena is on track for **Adoption in spring 2027**
  - Mission Adoption Review (MAR) to start in Sept. 2026
- The "Definition Study Report" (a.k.a. "The Red Book") must be delivered by February 2027
- It will be accompanied by a special issue on the Journal of High-Energy Astrophysics – **published ≤June 2027**
  - 79 papers on astrophysical topics
  - 16 papers on mission/data analysis/modeling
- Implementation phase **≥9 years**



from M. Cruise presentation to the SPC

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