Athena

Entering a new industrial study phase

Didier Barret, X-IFU Principal Investigator, February 2024
On behalf of the X-IFU Consortium

XMM2Athena

Not a straight path

Outline

Where do we stand after the completion of the reformulation phase ?

How did we make it fit the bill?

How was the flagship status of the mission preserved?

Where do we stand in terms of performance?

How the new X-IFU looks like?

Conclusions - I

A successful reformulation of Athena

From May 2022 to November 2023, the Athena mission was reformulated to fit within an acceptable enveloppe for the ESA Science program :

- The reformulation was successful both technically, programmatically and scientifically
- The reformulated mission was declared flagship by the Science Redefinition Team

➡ The ESA Science Program Committee recommended to re-start a phase A/B1 for Athena

This was not granted at the start, but made possible through the engagement of the instrument consortia, international partners and the ESA study team

Conclusions - II

Prime impacts on X-IFU

The reformulation affected primarily X-IFU (and to some extent the WFI)

- Use of passive cooling
- Simplification of the cooling chain enabled by the use of a powerful 4K cooler to be provided by NASA
- Transfer of many responsibilities from ESA to the X-IFU Consortium/NASA, e.g. the Dewar, cooler

IFU
ATHENA X-ray Integral Field Unit

Conclusions - III

A clear path exists for Athena

Upcoming milestones and challenges

- Athena industrial activities are now starting Q1/2024
- Appointment of the Athena Science Study Team (KO April 2024)
- Ramping up of the technologies by mid-2026 (the higher the better)
- Adoption of the mission in 2027 with the mission adoption review starting in Mid-2026
- Launch in 2037-8

➡ Development time about 9 years

Overall there is a credible plan forward for Athena ! and this requires some wine !

A new programmatic landscape

The adoption of LISA

ATHENA IFU X-ray Integral Field Unit

The LISA mission was adopted early 2024 (together with EnVision) — LISA is out of the way, but

- at a cost-at-completion above the original cost cap thought to apply to Athena and LISA
- with several sub-systems having a low technology readiness level (per the SPC paper)

  ➡ Concerns raised by several SPC delegations that this may impact the Athena schedule. Guarantees given by ESA that this will not impact Athena. Written statements to be expected in the next SPC paper (March timeframe).

  ➡ Presentation of the long-term implementation plan with Athena and M7

- The good side is that many member state delegations (re-)expressed their total support to Athena and their willingness to have it adopted as soon as possible

How did we make it fit the bill?

Bring the cost down to 1.3 G€ (E.C. 2022)

Boundary conditions set by ESA to reduce costs (reducing the ESA perimeter off loading to consortia)

#	Change
1	Smaller mirror diameter with reduction of number of mirror modules (two outer rows removed)
2	On-board metrology removed
3	Athena high-energy particle monitor removed
4	Field of regard reduced with associated hardware simplifications on solar array and mirror sunshield
5	Science instrument module simplified (no cryocoolers, no cryostat but new V-grooves) under S/C Prime responsibility
6	Passive cooling by V-grooves down to 55 Kelvin
7	Cryostat part of X-IFU instrument responsibility to be provided by member state partner as CFI to X-IFU
8	Active cooling system under X-IFU instrument responsibility: 4K cooler to be provided by NASA as CFI to ESA
10	New WFI design
11	TRL 5/6 demonstration by MAR for X-IFU and WFI (by mid-2026)

From Athena (2022) to today

Mission profile

	Athena (2022)	Athena (2024)	Comments
Orbit	L1	L1	
Launcher	Ariane 64	Ariane 64	
Lifetime	4 years	5 years	Compensate for the reduction of the mirror area (for non variable sources)

From Athena (2022) to today

Science performance

	Athena (2022)	Athena (2024)	Comments
Mirror effective area	1.4 m2 at 1 keV	1.1 m2 at 1 keV	13 rows instead of 15 rows
Angular resolution	5 arcsec	9 arcsec	8 arcsec demonstrated today on row 8 including coatings
X-IFU energy resolution	2.5 eV	4 eV	Eases verifications and relaxes schedule. X-IFU to retain a design goal of 3 eV.
X-IFU number of pixels	2448 (5 arcmin, FOV)	1536 (4 arcmin, FOV)	Simplfy readout and reduces heat loads
WFI field of view	40 x 40 arcmin2	40 x 40 arcmin2	Unchanged
Field of regard	40%	34% (goal of 40%)	GRB-ToO: response less than ≤12 hours for ≥50 ks for ≥67% of pursuable targets. 2 ToOs/month (5)

From Athena (2022) to today

Spacecraft resources

	Athena (2022)	Athena (2024)	Comments
Launch mass	7586 kg	6818 kg	Ariane64 expected capability of 7850 kg
X-IFU assembly mass	312 kg (X-IFU) + 546 kg of cryostat and active coolers	359 kg with 50 K cryostat + 96 kg of NASA cooler	V-grooves mass is not included
WFI assembly mass	280 kg	280 kg + Thermal Control System	TCS is moved to the WFI consortium
Payload power allocation	6250 W	4250 W	Significant margins

Let's look at the bright side of life

We have a flagship mission ahead

SRDT conclusions

"NewAthena offers an unprecedented advance in X-ray sensitivity and spectral resolution over previous missions. It will address a range of seminal science questions in cosmology and astronomy and, being designed to lead development in X-ray astrophysics in the next few decades, it will support the wide astronomical community with the opportunity to study astrophysical processes only accessible to X-ray instruments.

*In both the quantity of science outcomes and the uniqueness of observational data it will make available, **NewAthena fully qualifies as an ESA Flagship mission**."*

The flagship status was preserved

Moderate cuts

In terms of performances:

- Moderate cuts in a few performance parameters
- Performances preserved in some other places, e.g. the WFI field of view
- Extension of the mission lifetime

➡ Retaining overall breakthrough capabilities

And it remained true that

- Athena will match the large observational facilities of the 2030s, in particular in the field of multi-messenger astrophysics
- Athena will serve a large and vibrant astronomical community, which keeps building up on XMM-Newton and Chandra

What about the science case?

Builds upon the Hot and Energetic Universe theme

Athena will provide unique observational clues to address fundamental questions such as:

- How does accretion onto Super-Massive Black Holes (SMBHs) work?
- What causes violent SMBH outflows, and what impact do they have on galaxy cosmological evolution?
- How is gravitational energy in large-scale structures channeled into bulk and turbulent velocity fields?
- How does feedback from SMBH in clusters affect the intra-cluster gas?
- Where are the most common baryonic reservoirs in the Universe, how do they evolve?
- Why most baryons in the Universe are hot, and stay hot?
- What is the equation of state of dense matter in neutron stars?
- What are the explosion mechanisms of supernova remnants?

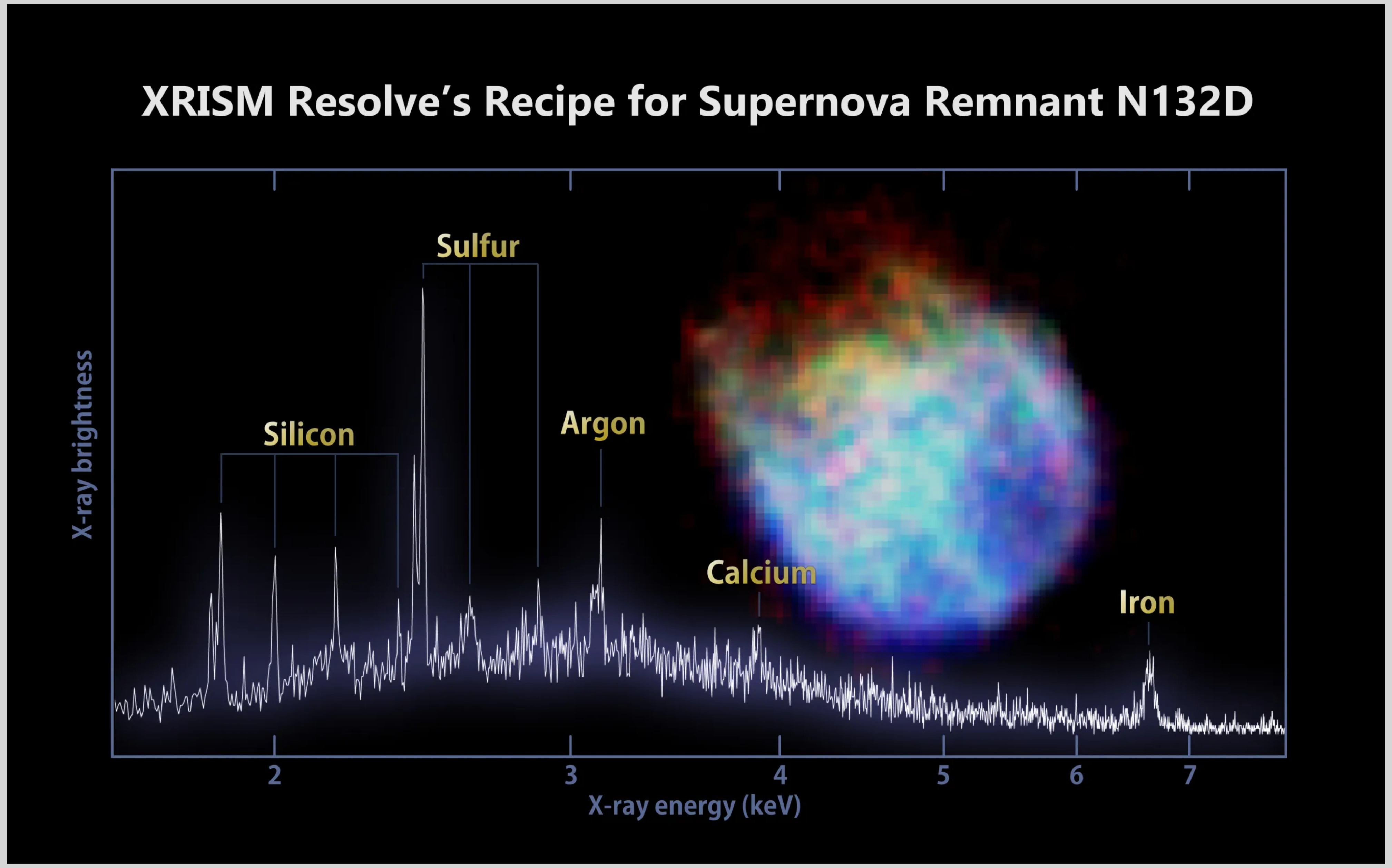
Nothing really new, but a better accounting of the changes in the scientific landscape and reduced capabilities in studying representative samples of objects and going deeper in redshifts

A new scientific landscape

The launch of XRISM to boost the field

XRISM was successfully launched and the Resolve spectrometer is performing extremely well (despite the gate valve closed)

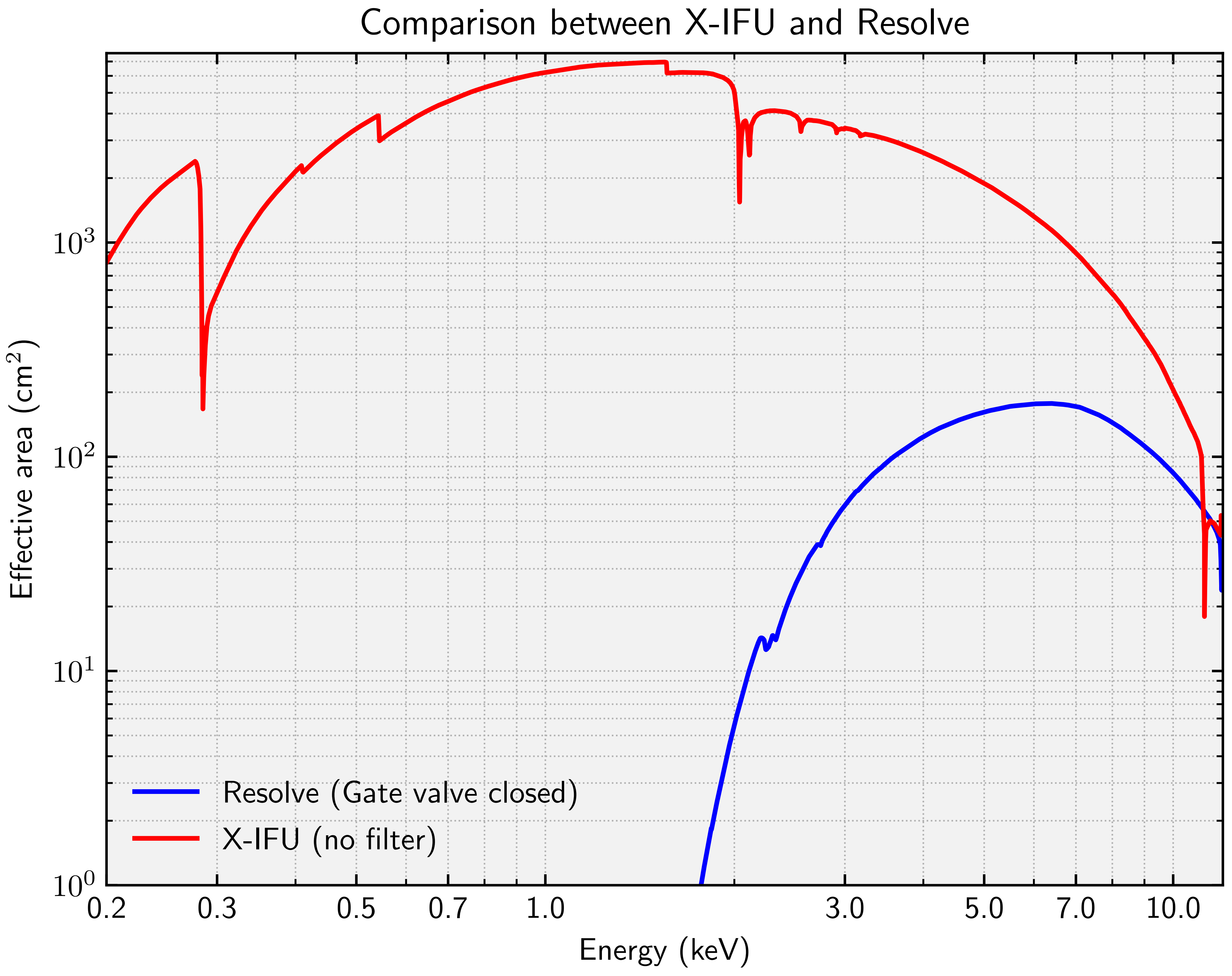
- This will open an entirely new window on spatially-resolved high-resolution spectroscopy
- XRISM will call for better data in terms of spatial and spectral resolution, sensitivity (and coverage below 2 keV)

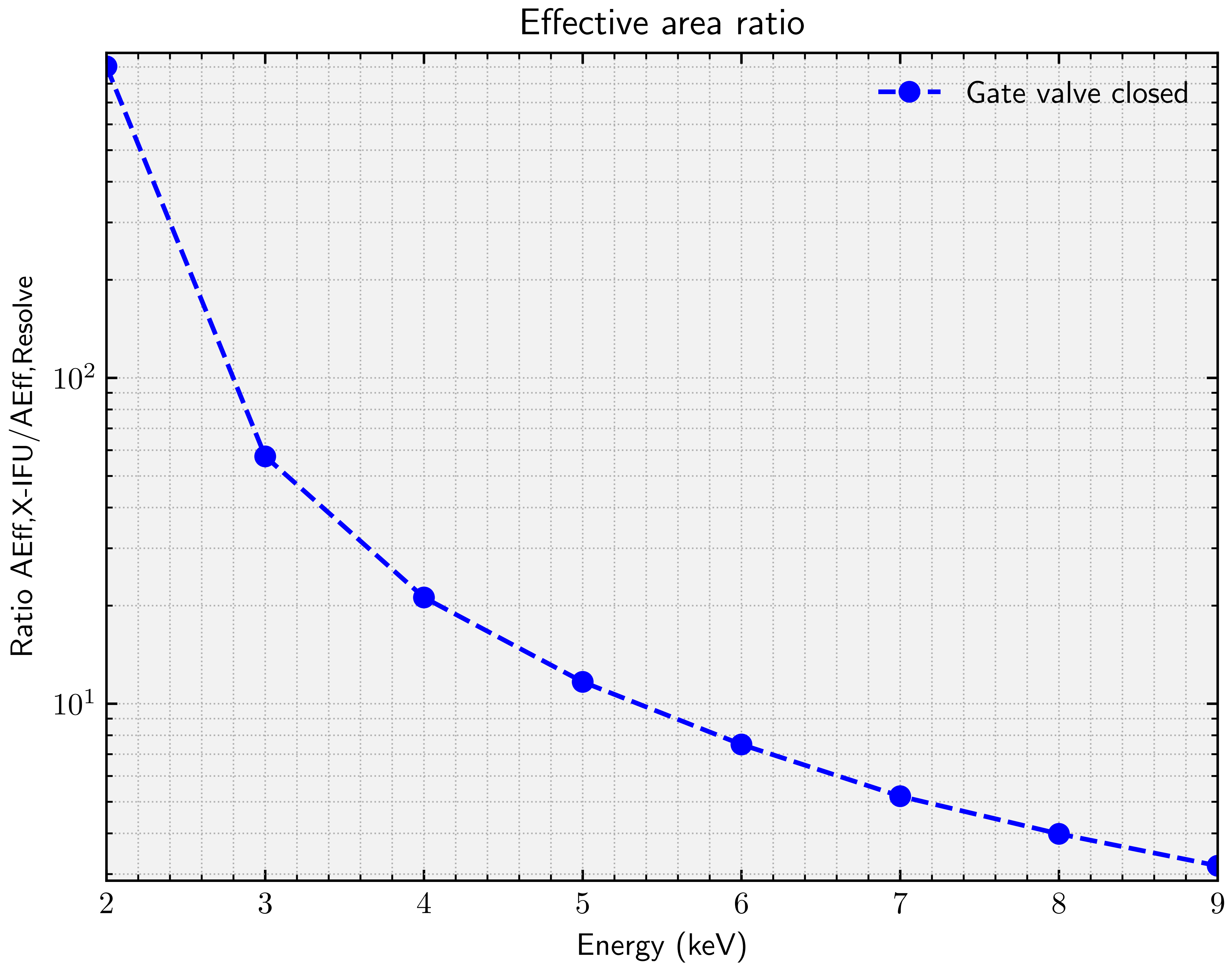


From XRISM to Athena

Resolve versus X-IFU

Still hoping that the gate valve will open 🤞

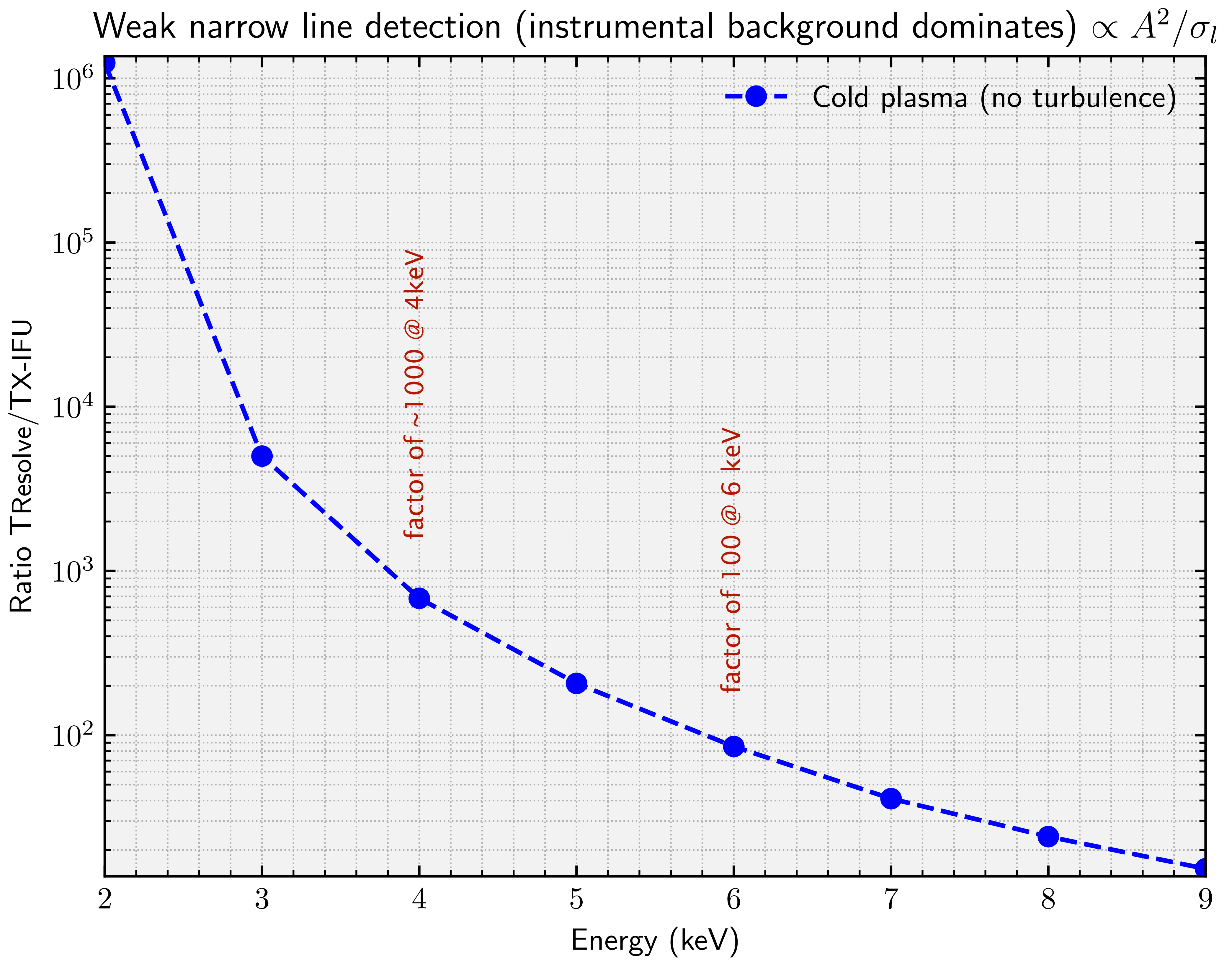


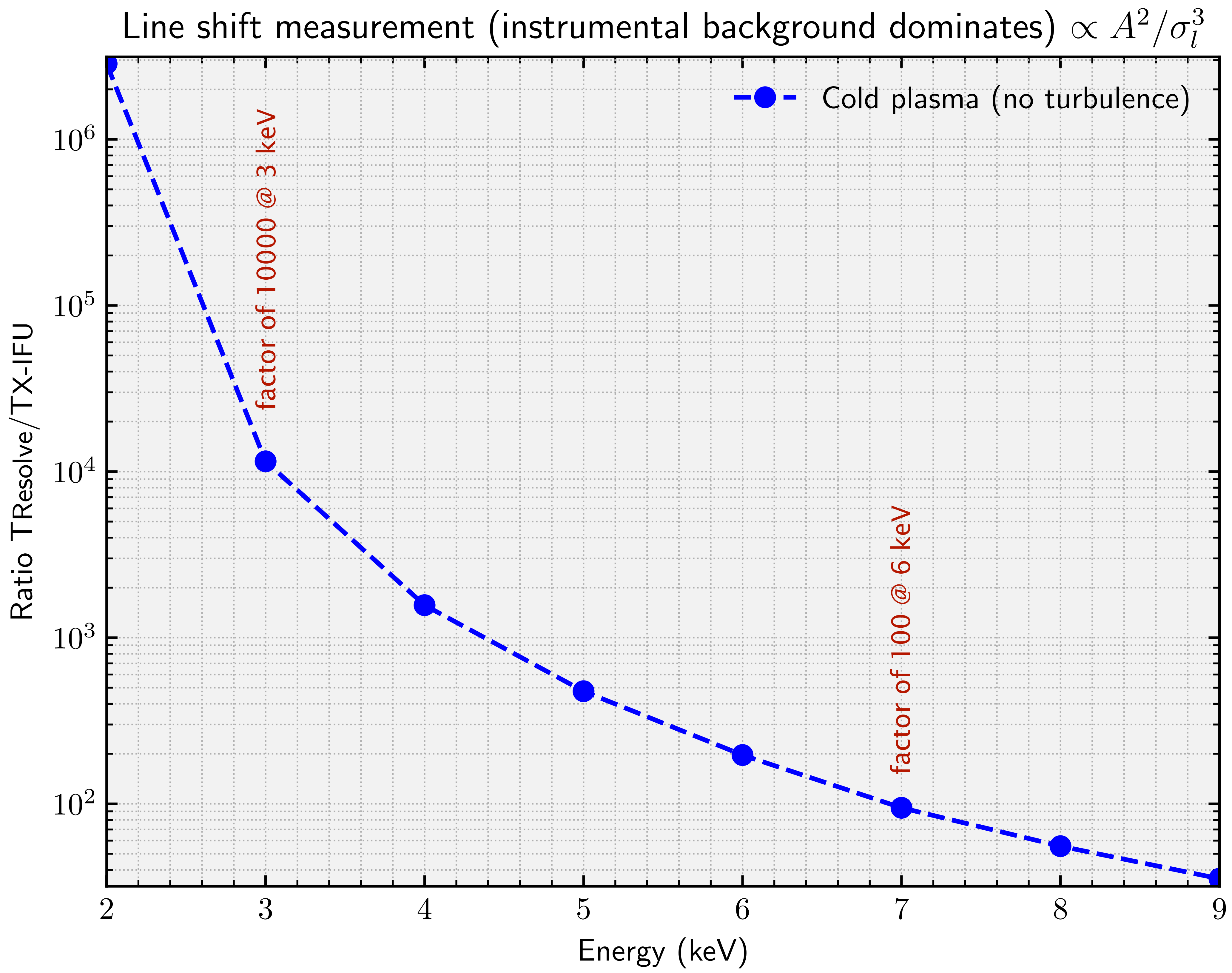


X-IFU performance

Comparison with XRISM/Resolve

Comparison based on scaling relations translated into observing times required to reach a given signal to noise ratio or an accuracy





X-IFU performance

Gain in spatial resolution

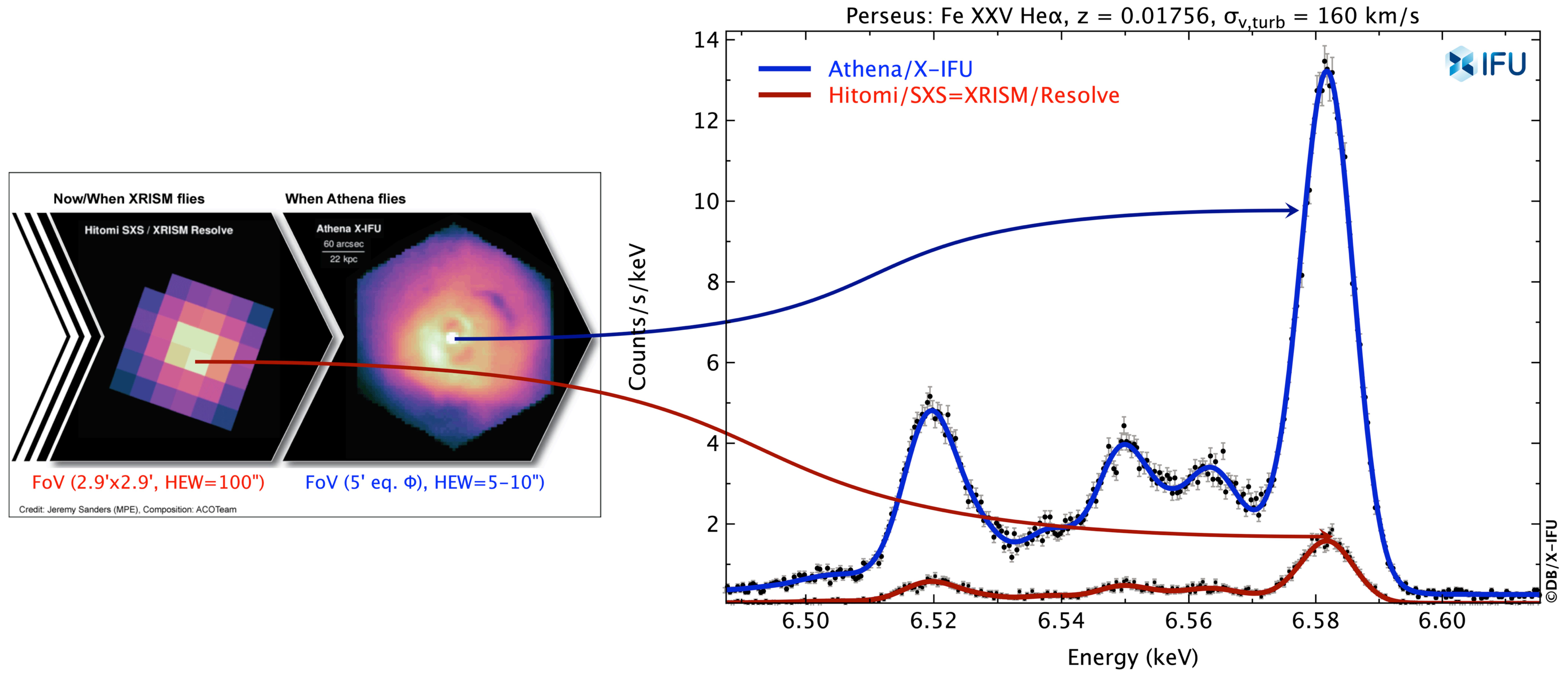
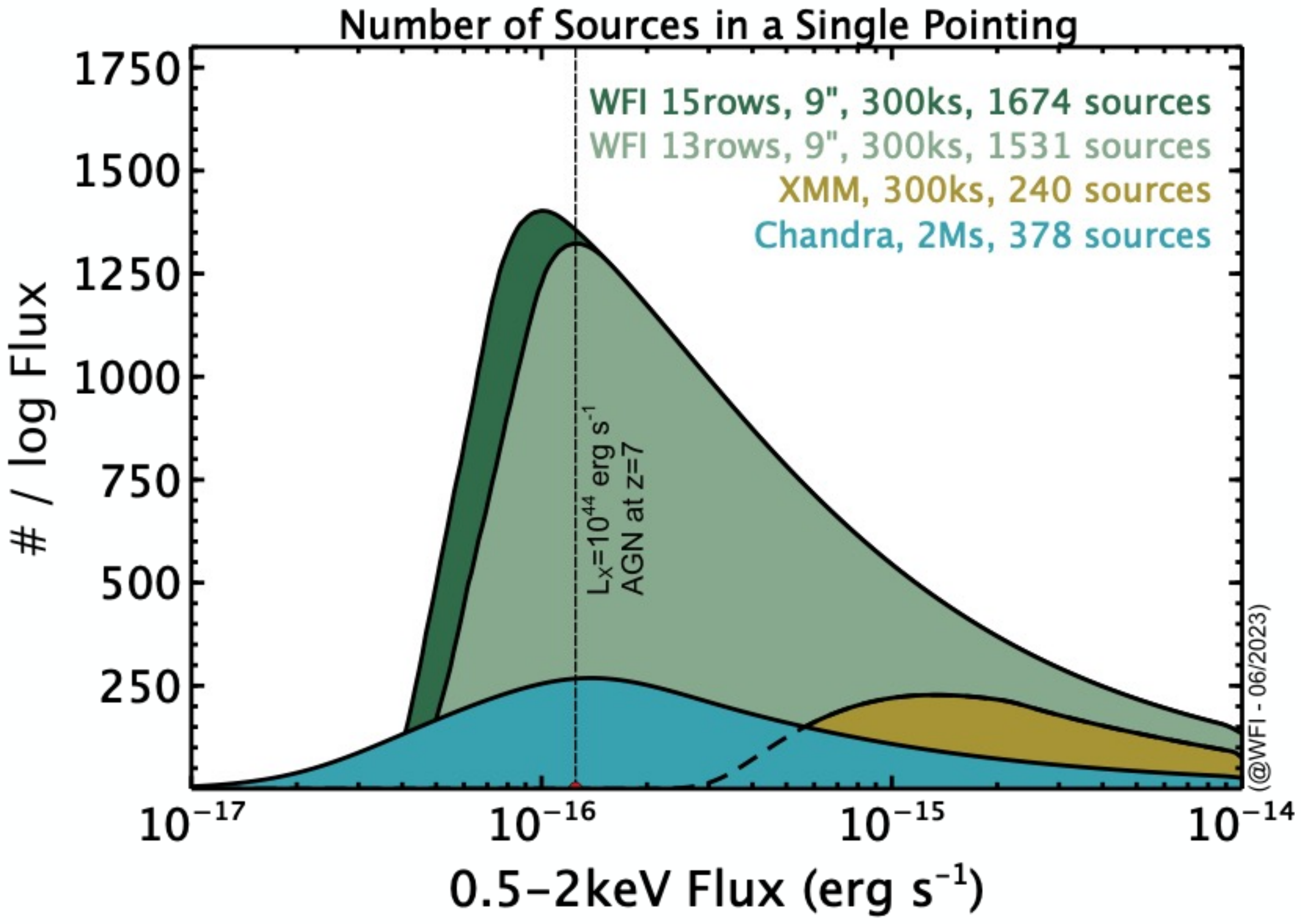
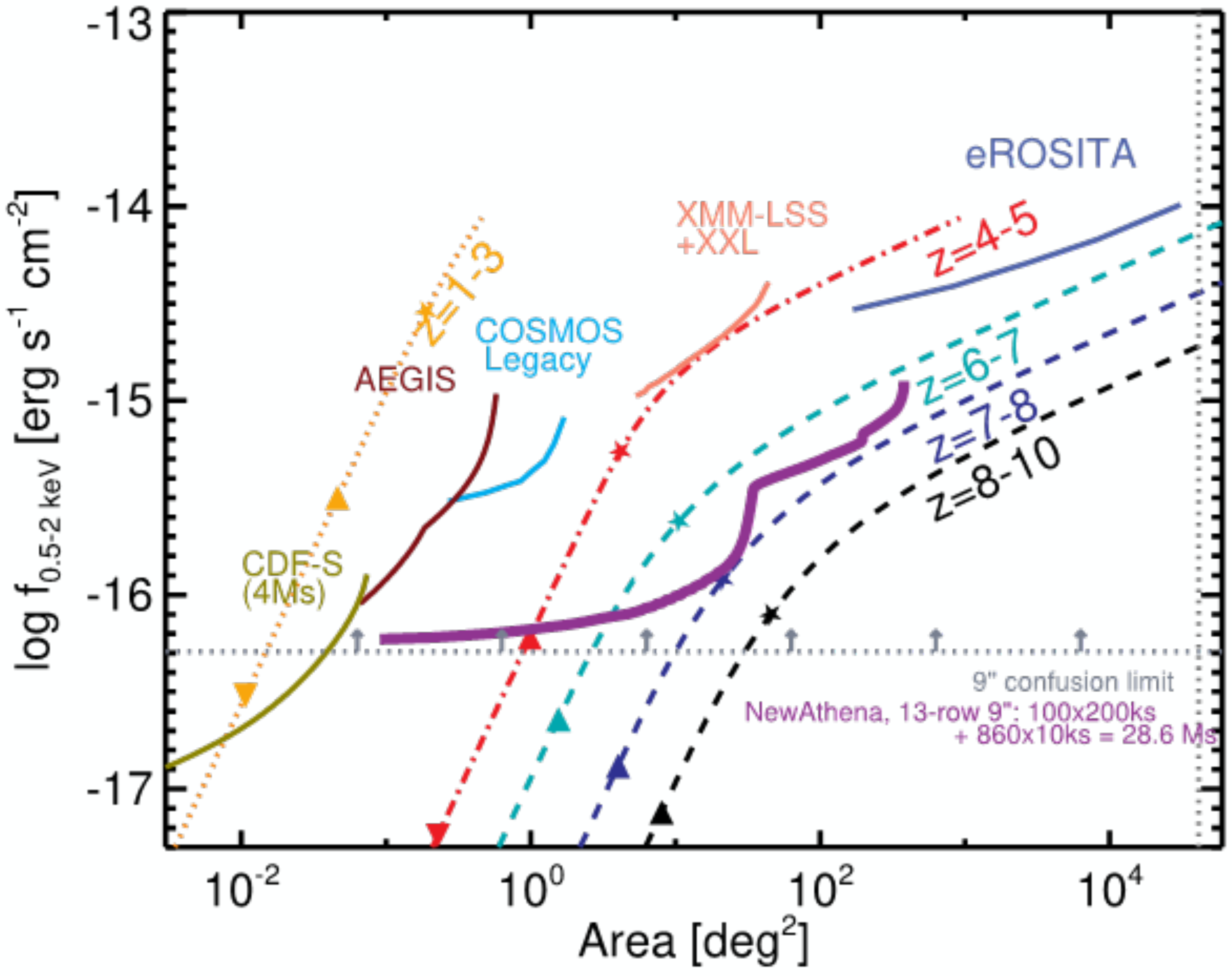


Illustration of the gain in spatial resolution (left) and sensitivity (counts/bin, right) between XRISM/Resolve and Athena/X-IFU (@J. Sanders, ACO, X-IFU). To be updated with the new response files

WFI performance
Survey depth and coverage

Prime impact on the high-z science of WFI (angular resolution and 1 keV area)





The new X-IFU

Major changes in the cooling assembly

Passive cooling à la Planck, Ariel

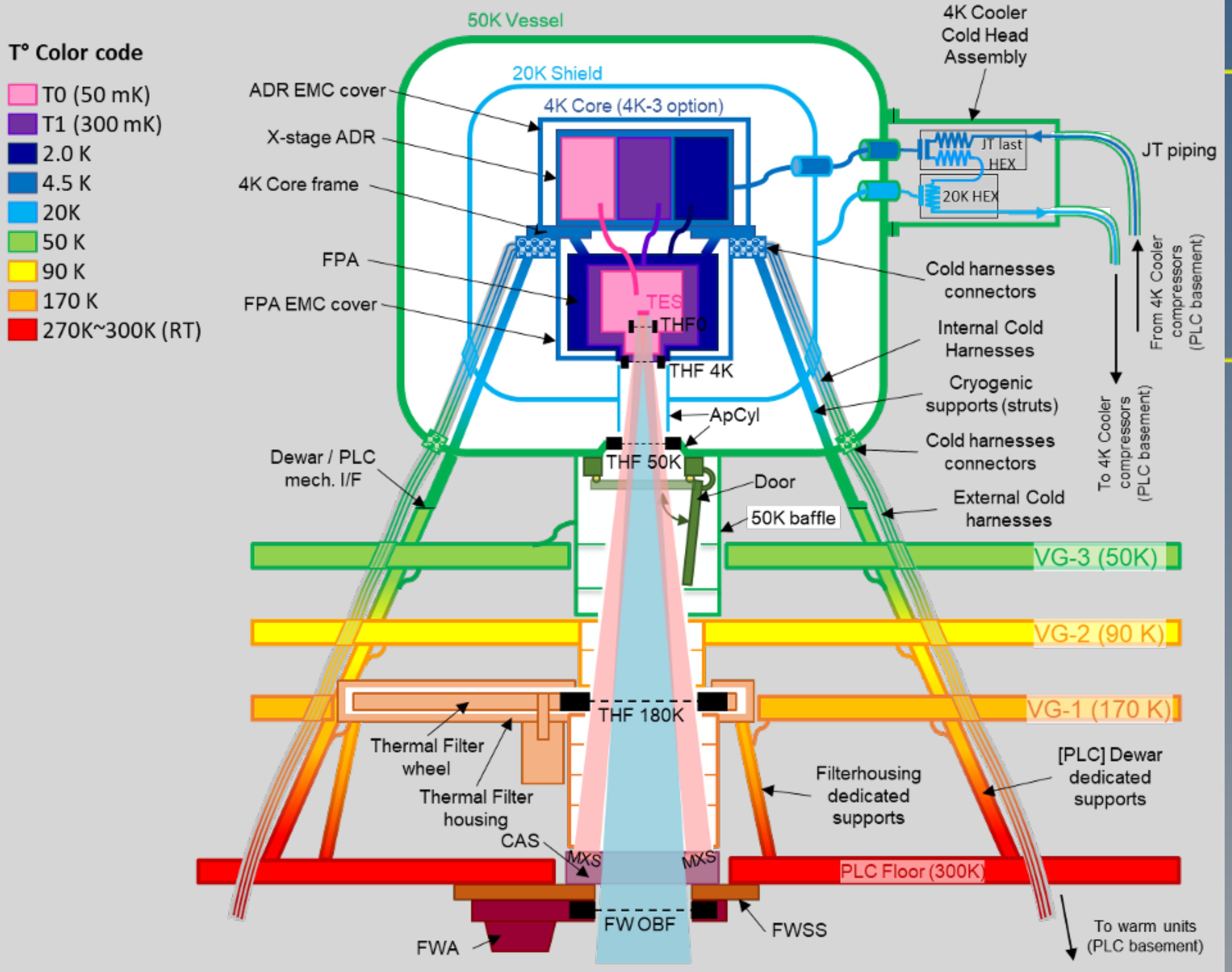
Reduced number of coolers to 1 from 55K to 4K and double stage ADR from 4K to 50 mKs

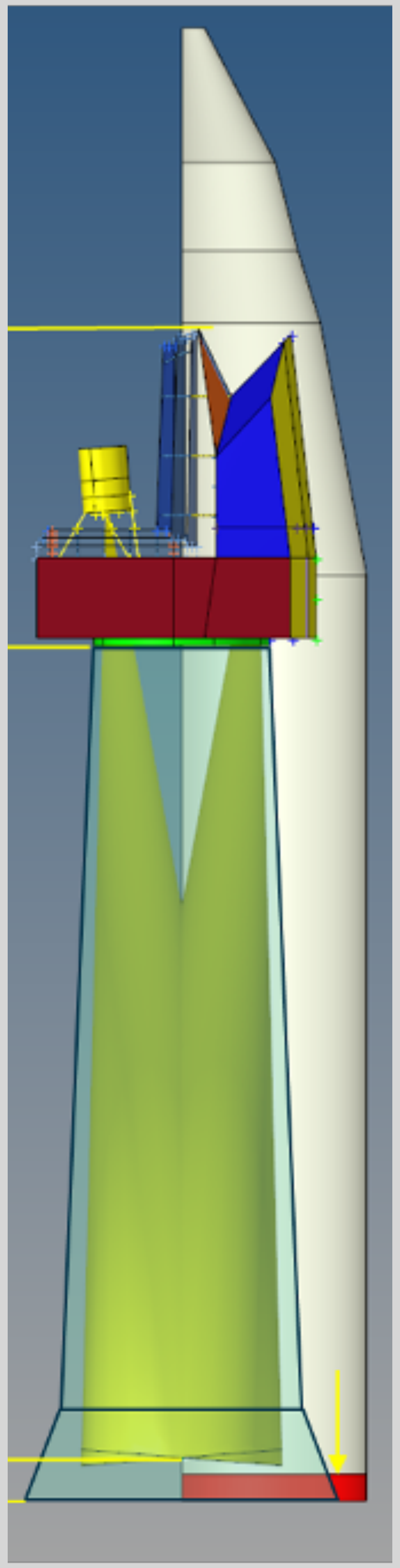
X-IFU to be delivered as an integrated instrument

Simplification of the readout, but no change to the electronic architecture of the instrument

No changes to the ancillary equipments, e.g. filter wheel, calibration assembly….

Japan left, US/Spain/France to take a larger share





Conclusions (again)

The path forward