

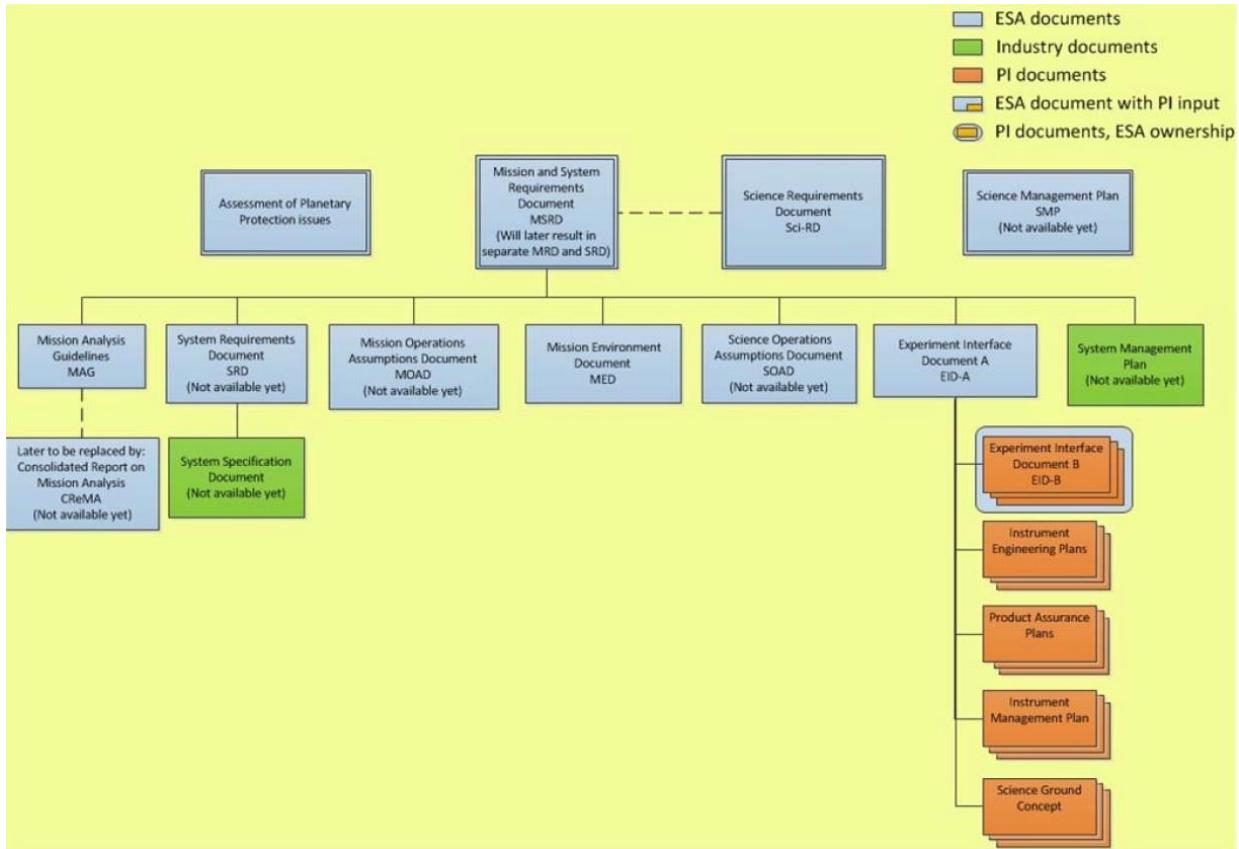
Athena science requirements

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on behalf of the *Athena* Science Study Team: D. Barret, A. Decourchelle, J.-W. den Herder, H. Matsumoto, K. Nandra, L. Piro, R. Smith, R. Willingale, X. Barcons, D. Lumb

1. What is Athena?

Typical documentation architecture of an ESA Study



- The SciRD is at the top of the mission document tree
- ESA document – formal deliverable of the Science Study Team

The Athena Science Requirement Document



ESA UNCLASSIFIED - For Official Use

Requirement Document / Specification (System, Subsystem, Unit,
Equipment level)



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Athena Science Requirements Document

Link available from:
<https://www.cosmos.esa.int/web/athena/study-documents>

- Version 1.0 (18/1/2016) → 2.2 (10/9/2018)
- 41 science objectives (23 “core science”), 105 requirements
- “L1”: *Mission science performance*: sensitivity, area and grasp, positional accuracy, angular and energy resolution, count rate capabilities, systematic accuracy of basic observables (kT , Z , Δt ...)
- “L2”: *Implementation requirements*: mirror and instrument effective area, mirror angular resolution, instrument spectral resolution and field-of-view, timing, count rates, background, astrometry, observations, ToO, pointing, data latency

The Athena Study in a nutshell



An X-ray astronomy mission for European Space Agency Horizon 2000 programme was studied from the early 1980's, culminating in a mission presentation at an ESA workshop held in Lyngby, Denmark in June 1985. In the papers presented at this conference [1] the mission design contained 12 low-energy and 7 high-energy telescopes with a collecting area of 13000 cm^2 and 10000 cm^2 at 2 and 6 keV respectively. The scientific goal was to maximise collecting area for spectroscopy, complementing the imaging science of the NASA AXAF programme. When the report of the telescope working group [2] was delivered in 1987, the consideration of practical constraints had reduced the number of telescopes to a more modest total of 7.

Lumb et al., arXiv:1202.1651

XMM-Newton: 3 telescopes,
collecting area $\sim 2000 \text{ cm}^2$ and $\sim 1500 \text{ cm}^2$ at 2 and 6 keV



Athena “as proposed” mission profile

Table 4: Key parameters and requirements of the *Athena+* mission. The enabling technology is indicated.

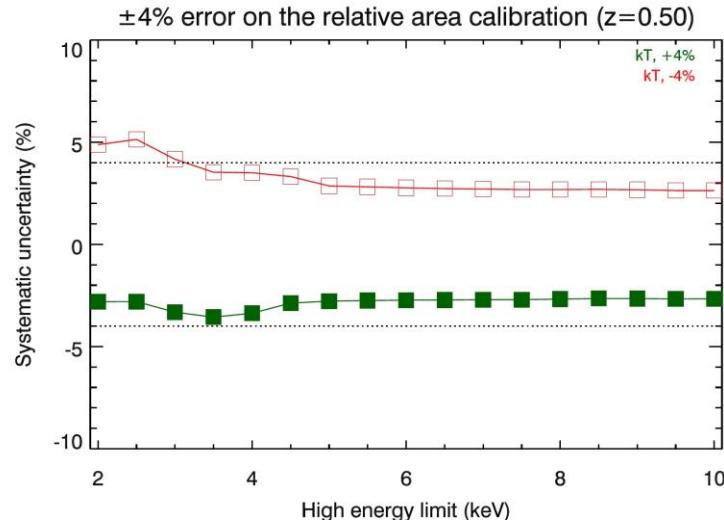
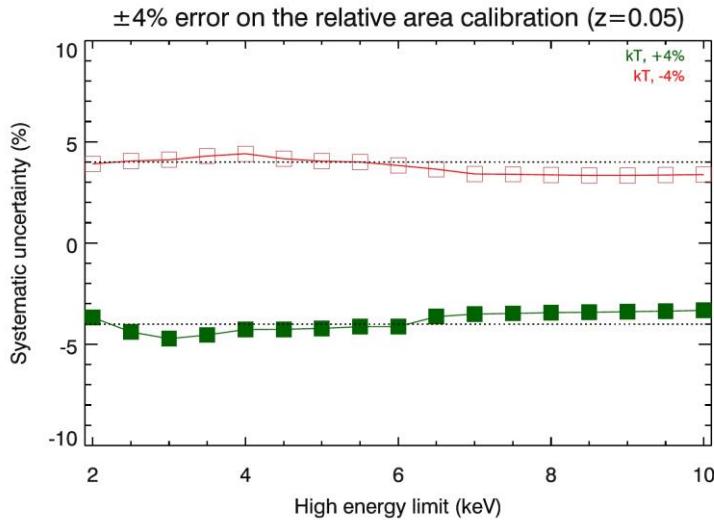
Parameter	Requirements	Enabling technology/comments
Effective Area	2 m ² @ 1 keV (goal 2.5 m ²) 0.25 m ² @ 6 keV (goal 0.3 m ²)	Silicon Pore Optics developed by ESA. Single telescope: 3 m outer diameter, 12 m fixed focal length.
Angular Resolution	5" (goal 3") on-axis 10" at 25' radius	<i>Detailed analysis of error budget confirms that a performance of 5" HEW is feasible.</i>
Energy Range	0.3-12 keV	Grazing incidence optics & detectors.
Instrument Field of View	<i>Wide-Field Imager: (WFI): 40' (goal 50')</i>	Large area DEPFET Active Pixel Sensors.
	<i>X-ray Integral Field Unit: (X-IFU): 5' (goal 7')</i>	Large array of multiplexed Transition Edge Sensors (TES) with 250 micron pixels.
Spectral Resolution	WFI: <150 eV @ 6 keV	Large area DEPFET Active Pixel Sensors.
	X-IFU: 2.5 eV @ 6 keV (goal 1.5 eV @ 1 keV)	<i>Inner array (10"x10") optimized for goal resolution at low energy (50 micron pixels).</i>
Count Rate Capability	> 1 Crab ³ (WFI)	<i>Central chip for high count rates without pile-up and with micro-second time resolution.</i>
	10 mCrab, point source (X-IFU) 1 Crab (30% throughput)	<i>Filters and beam diffuser enable higher count rate capability with reduced spectral resolution.</i>
TOO Response	4 hours (goal 2 hours) for 50% of time	<i>Slew times <2 hours feasible; total response time dependent on ground system issues.</i>

Example: calibration requirement validation

Requirement: 4%

Table 1 - Systematic error on the intra-cluster gas temperature for different values of the relative effective area systematic uncertainties and galaxy cluster redshift (nominal value $kT=5$ keV)

	S=0.03	S=0.04	S=0.05
z=0.05	2.0%	2.7%	3.3%
z=0.5	2.6%	3.4%	4.3%



Evolution of Athena science requirements



- July 2016:
 - X-IFU angular resolution: 6" (HEW)
 - mirror defocussing: goal → requirement
 - X-IFU: 2×10^{-8} erg s⁻¹ cm⁻² with $\geq 50\%$ throughput [$\Delta E \leq 10$ eV, 5-8 keV]
- August 2016: Quick Look data for ToO: requirement → goal
- March 2017: Straylight count rate: 10% → 27% (no baffle)
- November 2017: from 20- to the 15-row mirror (~30% area loss at 1 keV)
- February 2018: absolute A_{eff} calibration requirement 8% → 12%
- June 2018: spacecraft astrometric accuracy: 3" → 4.5" (3σ)
- September 2018: revised calculations of effective area @7/10 keV

Take-home message

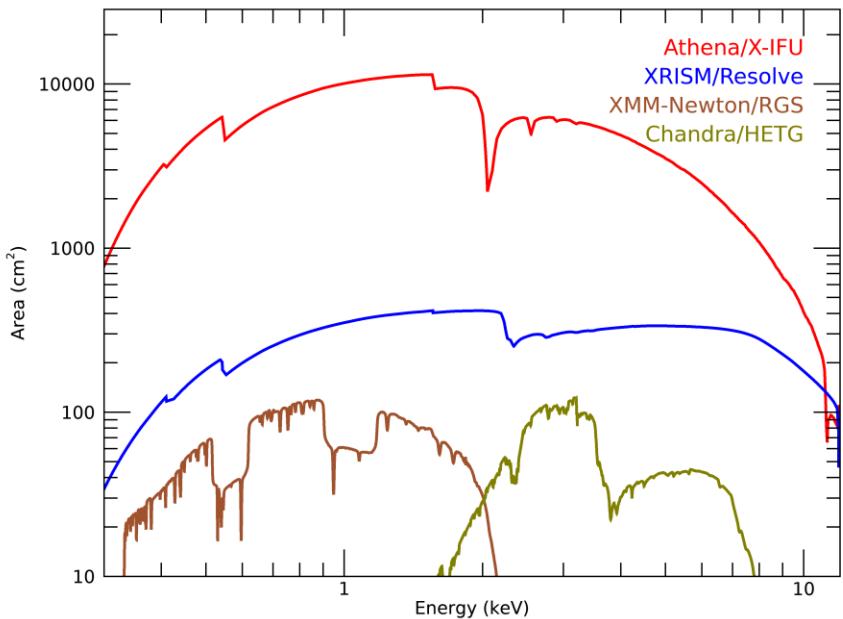


Athena represents an improvement by ≥ 1 order-of-magnitude over several performance parameter spaces *simultaneously* with respect to any existing or planned X-ray missions

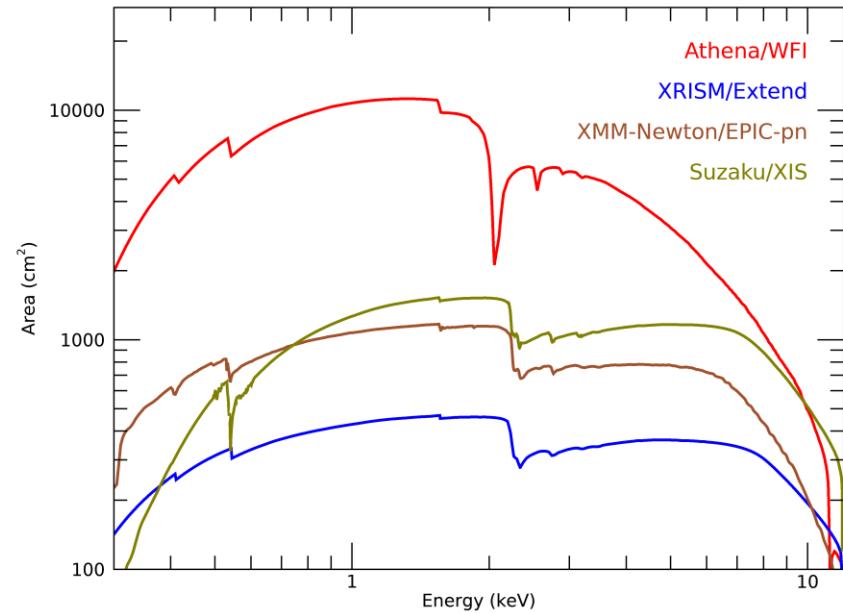
Athena remains a large effective area mission



X-IFU+mirror collecting area



WFI+mirror collecting area



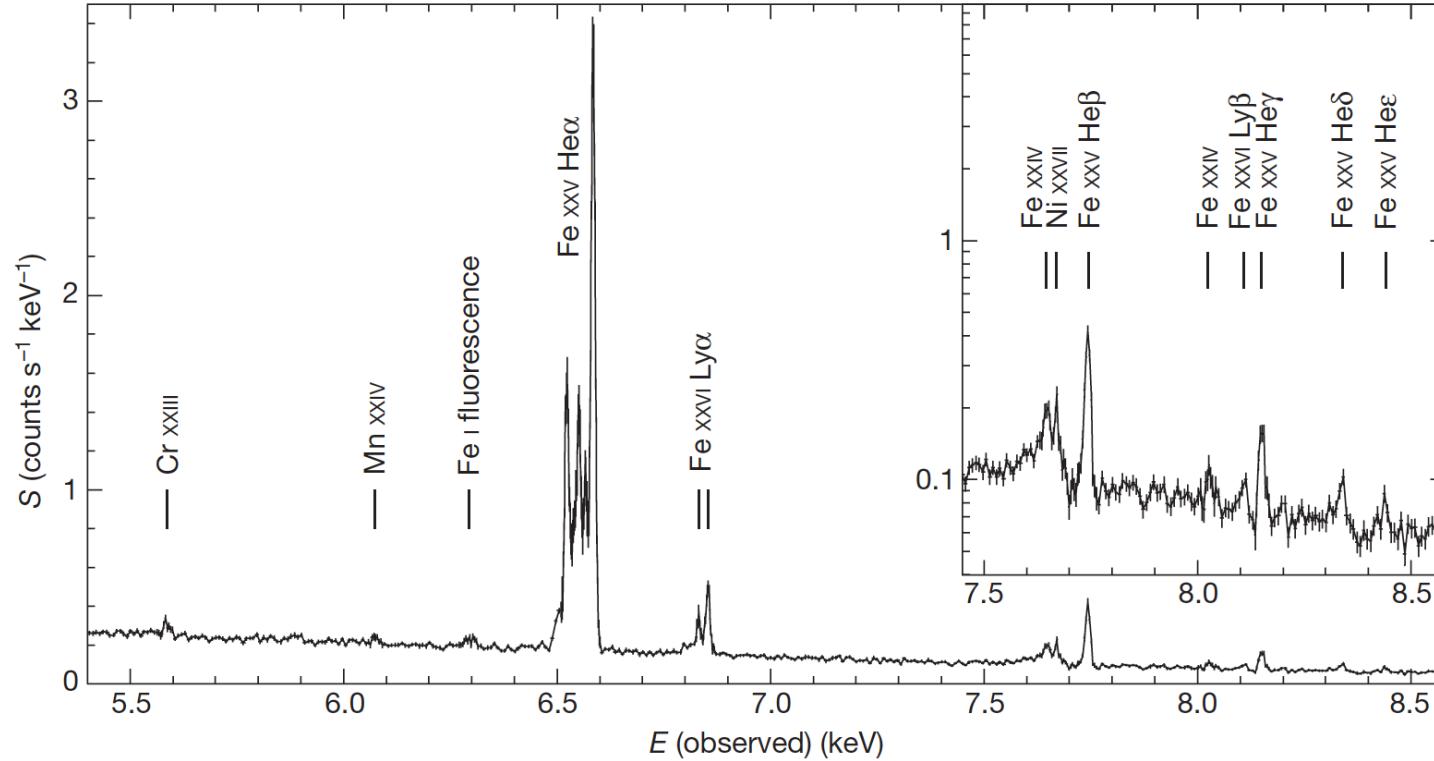
Guainazzi & Tashiro, 2018, arXiv:1807.06903



The ひとみ(Hitomi) heritage ...



Spectrum of the Perseus Cluster with the Hitomi/SXS



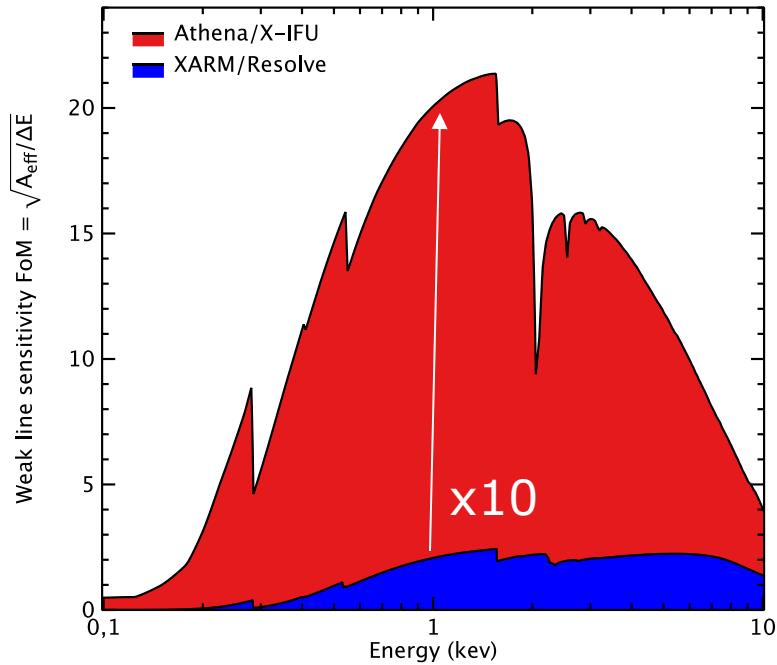
Hitomi collaboration, 2016, Nature, 535, 177; talk by Ohashi先生



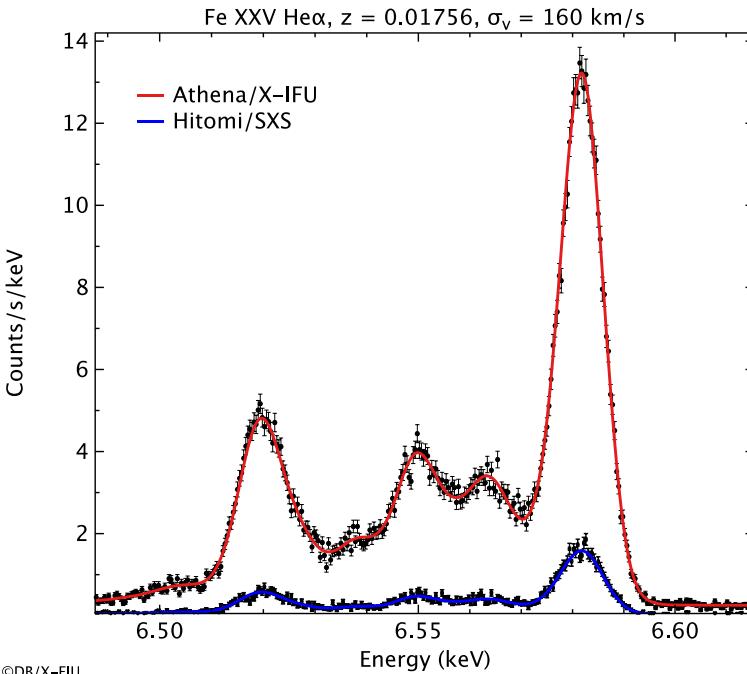
A giant leap in high-resolution spectroscopy



X-IFU weak line sensitivity



X-IFU vs. the best-quality existing high-resolution spectrum @6 keV

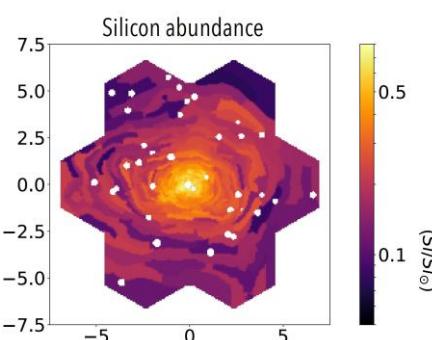
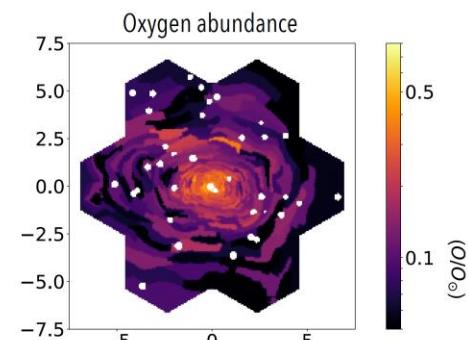
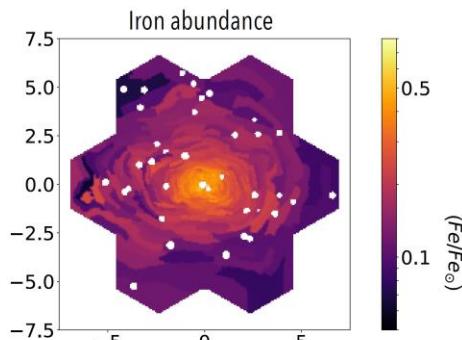
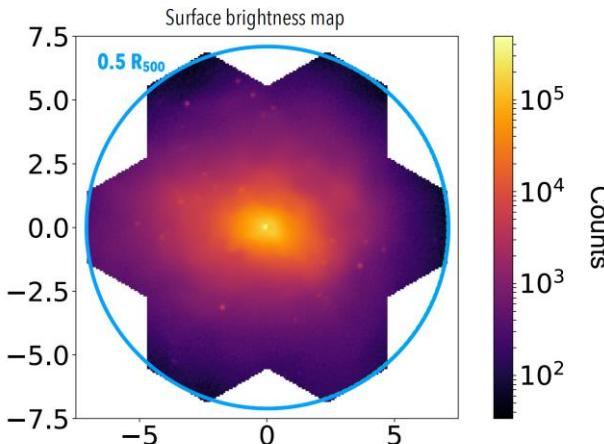
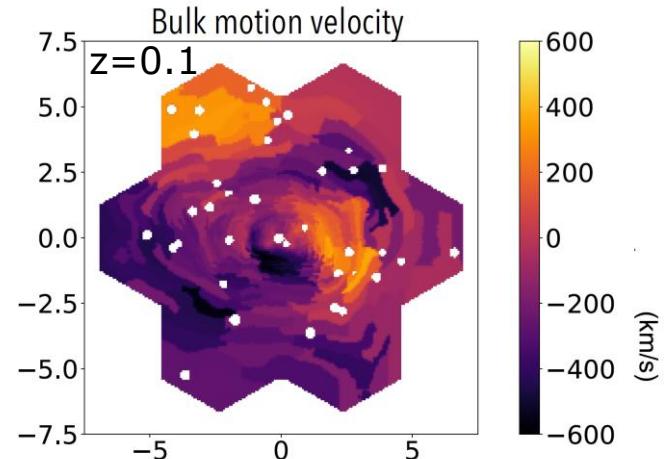
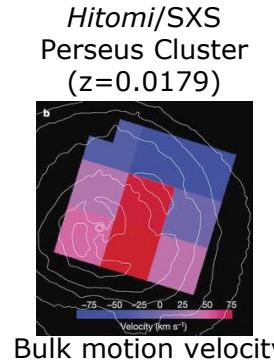


Courtesy D.Barret (IRAP)



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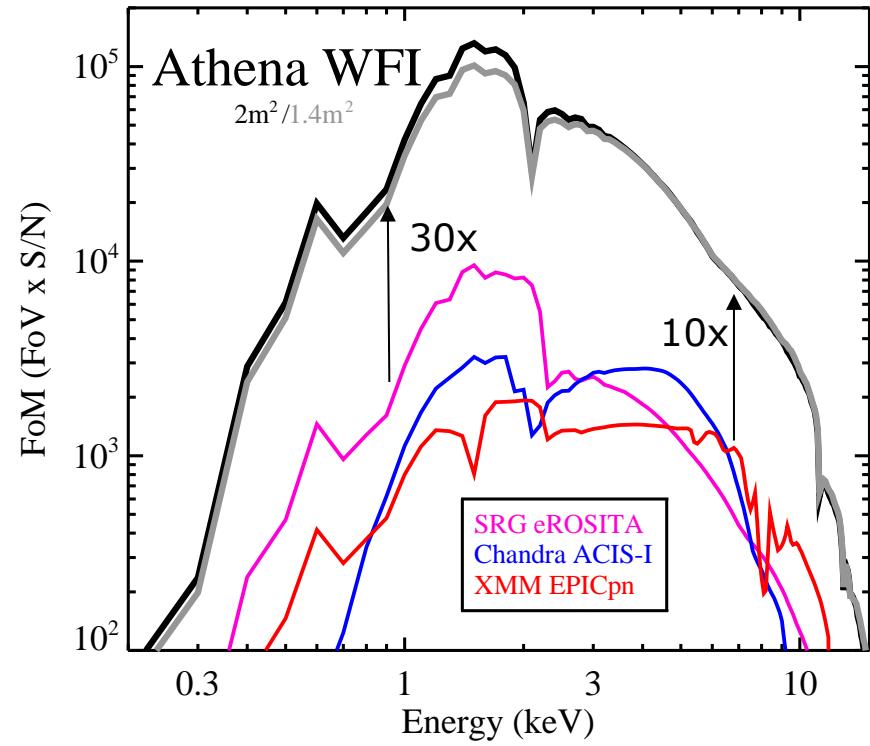
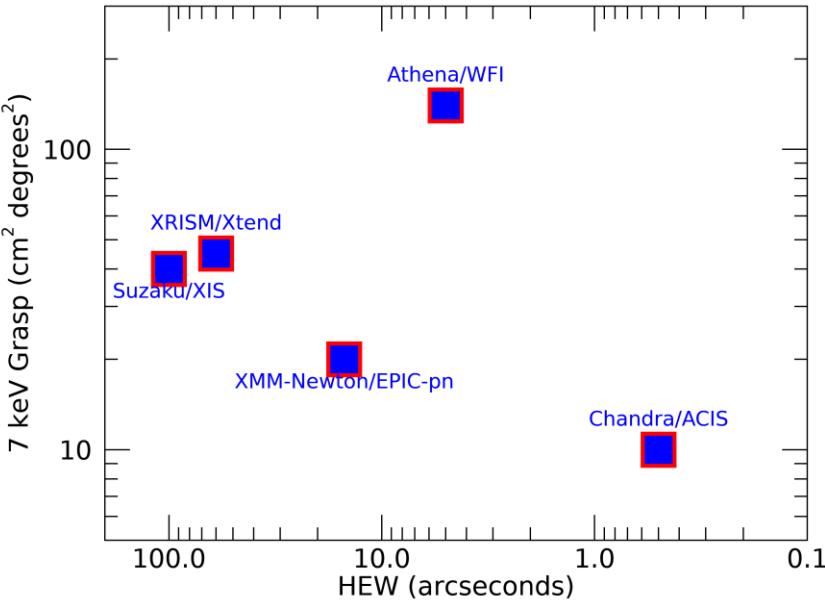
... followed by the *Athena* revolution



Athena: a powerful survey machine (I.)



Guainazzi & Tashiro, 2018, arXiv:1807.06903



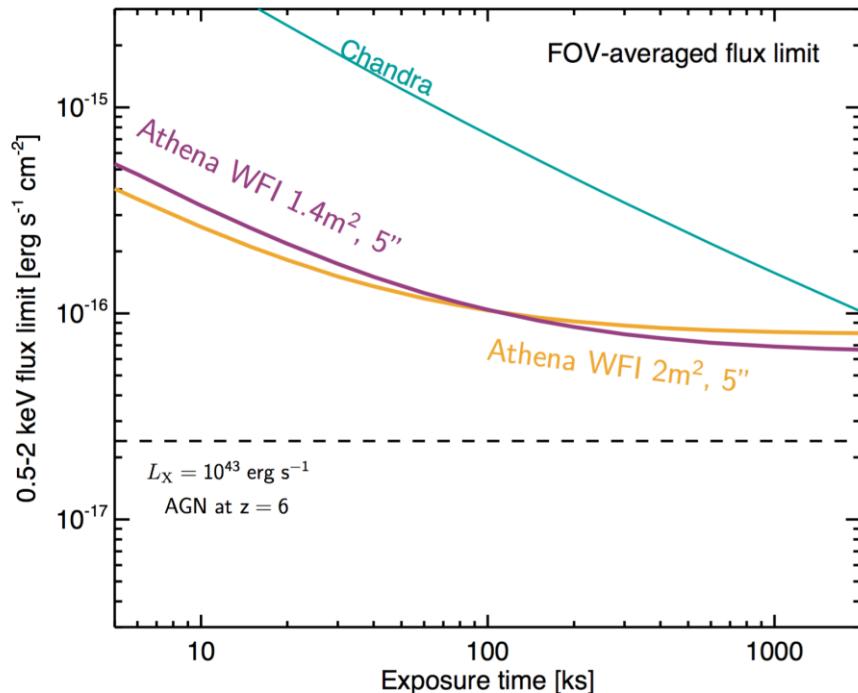
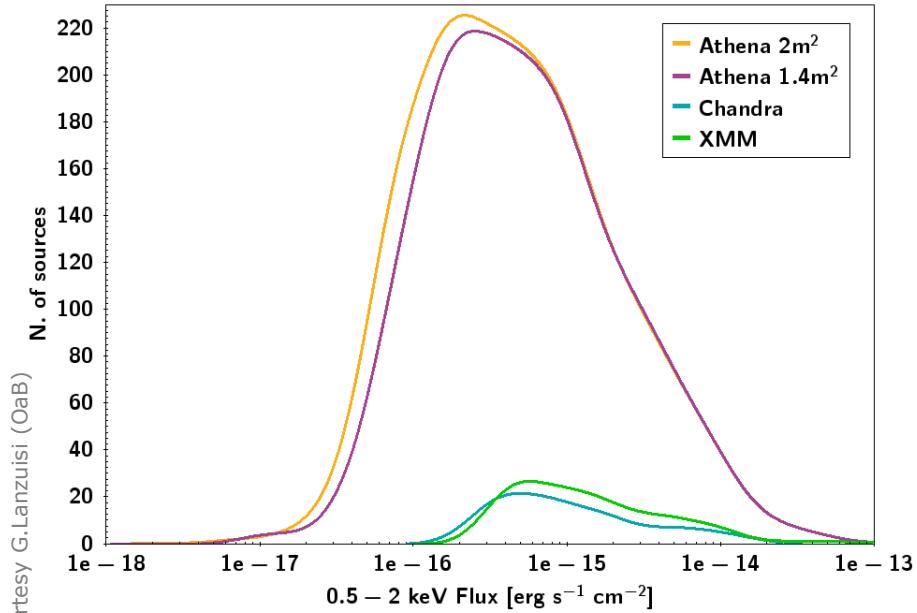
Courtesy A.Rau (MPE)



Athena: a powerful survey machine (II.)



Number of sources per 100 ks obs.



Athena survey over the nominal 4 year mission: 4x1 Ms – 3x700ks – 10x600 ks - 103x60ks

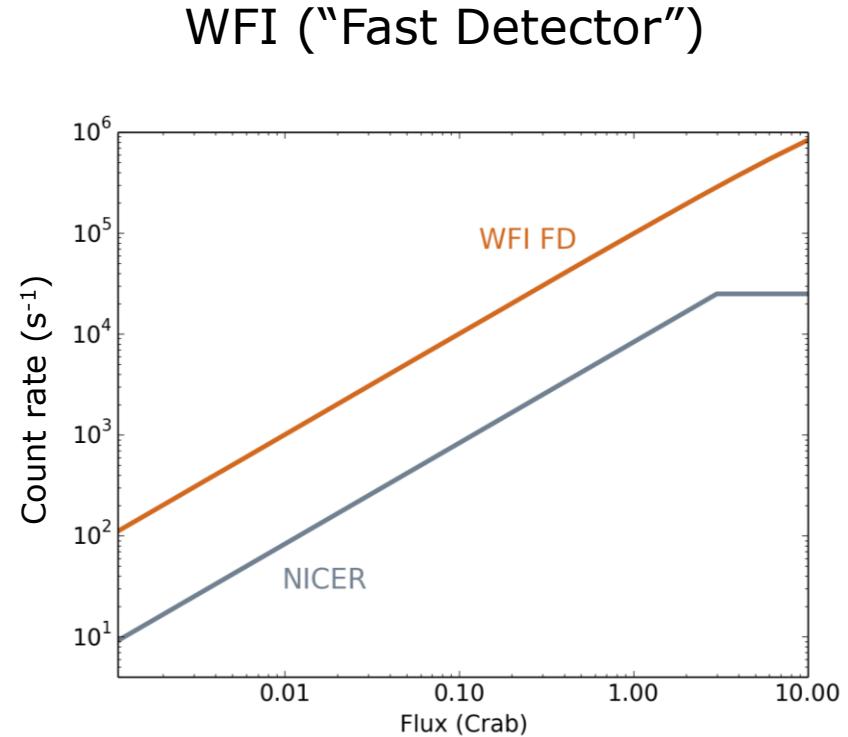
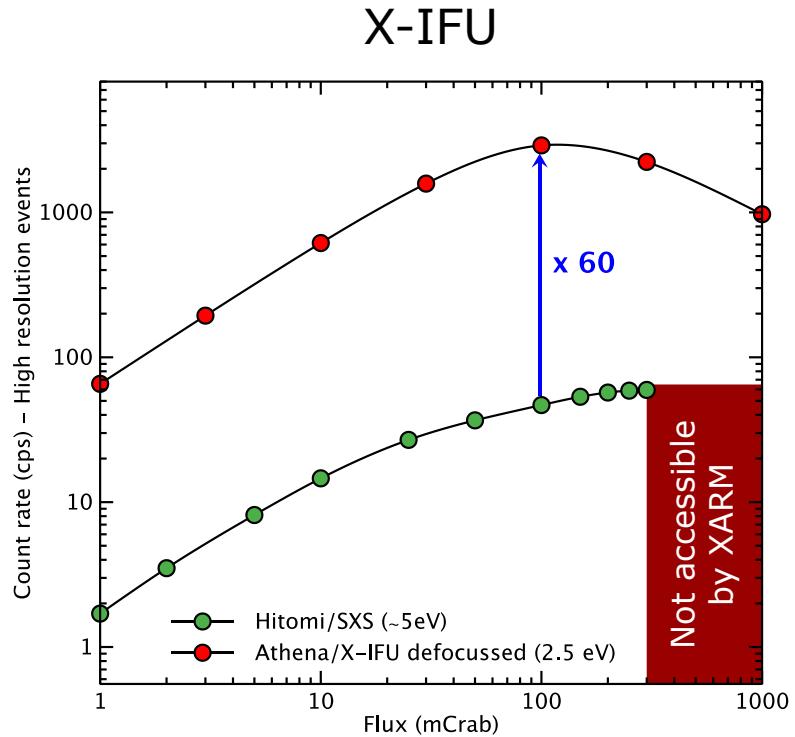


European Space Agency

Athena count rate capabilities



Courtesy D.Barret (IRAP)



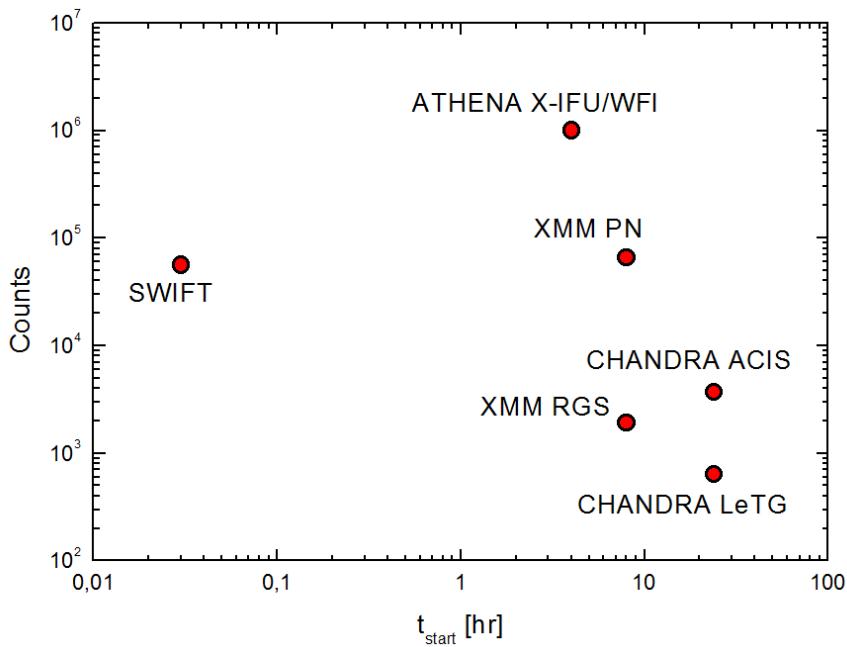
Courtesy P.Nandra, A.Rau (MPE)



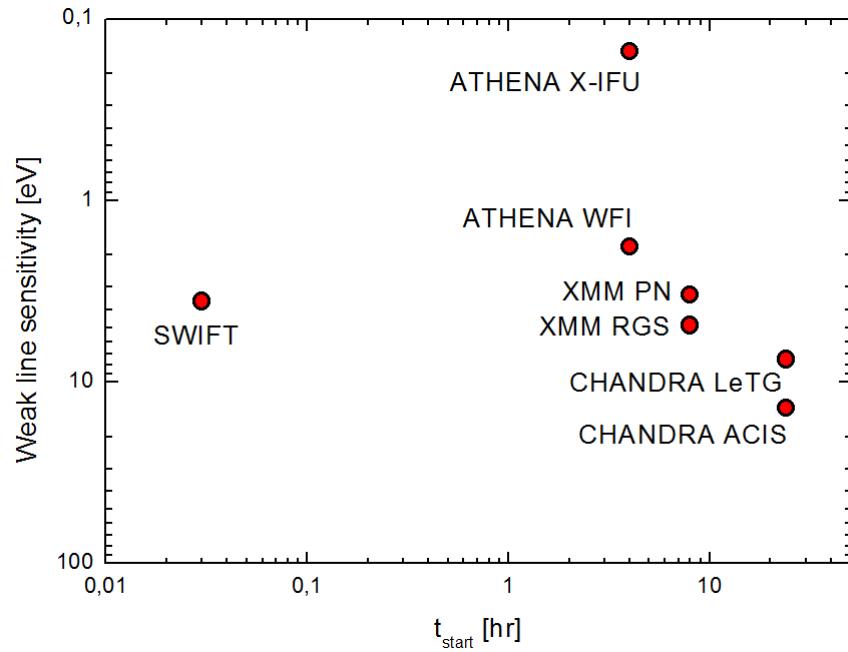
Athena ToO capabilities



Counts vs. time



Weak line sensitivity



Summary



The Athena science requirements have been a living body in Phase A

- *Athena* has lost some of the capabilities with respect to the “As Proposed”
 - Increase of the straylight count rate (no baffle)
 - Loss of effective area due to the reduction of the mirror diameter
 - Loss of spacecraft astrometric accuracy
- *Athena* has also *gained* some capabilities:
 - Mirror defocusing opened a new parameter space for spectroscopy (X-IFU)
- *Athena* represents an improvement by ≥ 1 order-of-magnitude over several performance parameter spaces *simultaneously* with respect to any existing or planned X-ray missions