Athena status and a focus on its timing capabilities

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Athena science

- Scientific theme: The Hot and Energetic Universe
  - How does ordinary matter assemble in large scale structures?
    - Probe: X-ray emitting gas in clusters
  - How do black holes work, grow and shape the Universe?
    - Probe: Accretion powered X-rays onto compact objects
- A multi purpose observatory:
  - **Observatory science** from planets, stars, supernova remnants, interstellar medium…
  - **Discovery science** enabled by its giant leap in spectral-imaging sensitivity and a fast ToO capability to respond to transient alerts

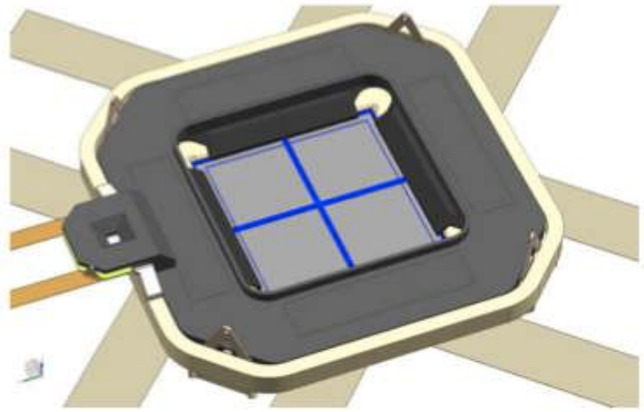
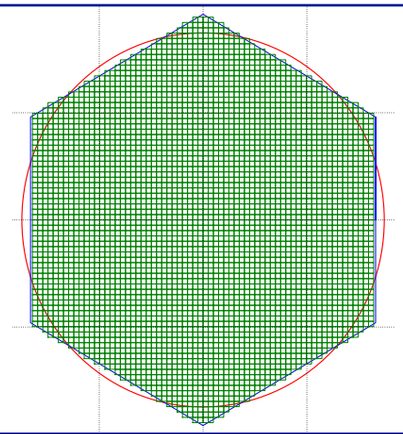
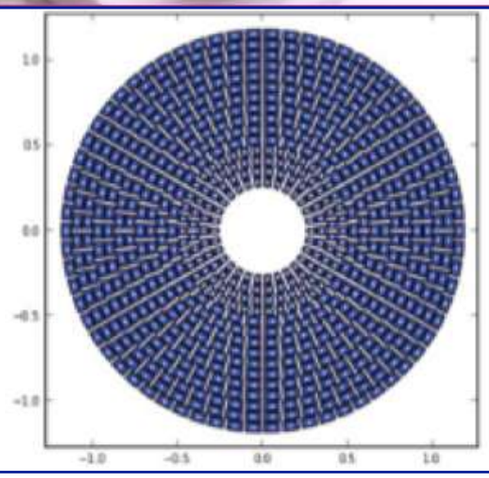
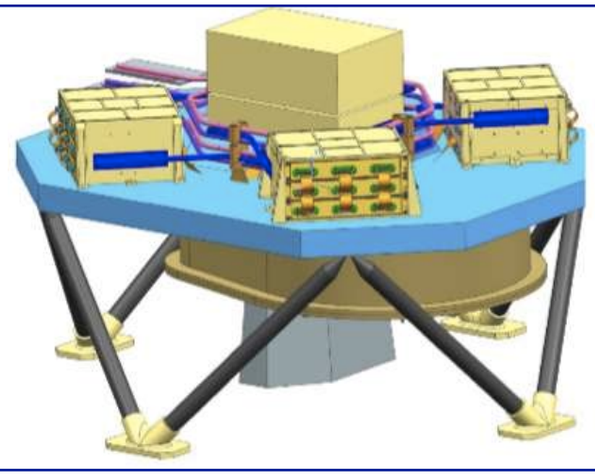
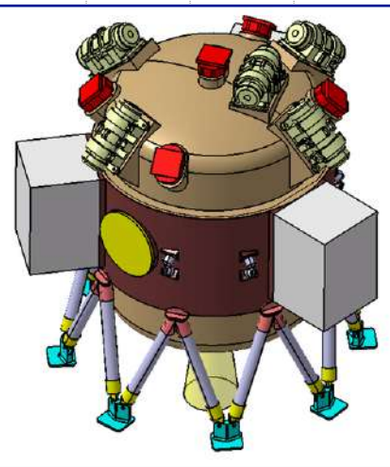
Need to combine a large aperture X-ray telescope, wide field imaging, high-resolution spatially resolved spectroscopy and an agile spacecraft

Athena in a nutshell

- Second Large (L) mission of the ESA Cosmic Vision 2015-2035
- Launch year: end of 2028
  - with the newly developed Ariane 6 (64)
- A 7 ton spacecraft to be placed in a L2(L1) orbit
- Unprecedented collecting area in X-rays:
  - 2 m^2 at 1 keV and 0.17 m^2 at 7 keV
  - 5'' angular resolution

- Two focal plane instruments with a movable mirror assembly:
  - The Wide Field Imager (WFI) for fine imaging and timing — **Medinger+, SPIE 2016**
  - The X-ray Integral Field Unit (X-IFU) for high-resolution spectroscopy — **Barret+, SPIE 2016**

Athena science payload

Optics	Wide Field Imager	X-ray Integral Field Unit
Light-weight Si-pore optics Qualification model level	Active Pixel Sensors based on DEPFETs A fast DEPFET chip for bright sources	Cryogenic imaging spectrometer, based on a large format of Transition Edge Sensors cooled at 50 mK with an active background shielding
5'' (HEW) **2 m^2 at 1 keV**	**40' x 40' arcmin field of view** **Dedicated fast chip for bright sources**	**2.5 eV spectral resolution** **5' equivalent diameter field of view**
		
		
ESA & industry	Consortium led by MPE (K. Nandra), with other European partners and NASA/JAXA	Consortium led by IRAP/CNES-F (D. Barret), with SRON-NL (J.W. den Herder), INAF/IAPS-IT (L. Piro) and other European partners, NASA and JAXA.

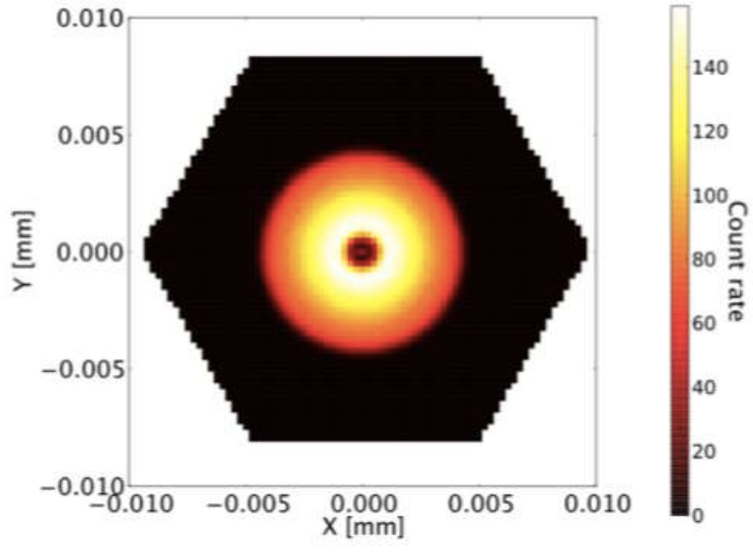
Athena status

- Currently in the middle of its feasibility study phase (ends Q4/17)
  - Involves ESA, two industrial Primes and the WFI and X-IFU consortia
- On-going delta Mission Consolidation Review (ends Q1/17)
  - Strong focus on system level optimization (including the payload)
    - to fit the total mass within the Ariane 6-4 lift off capability at L2 (7 tons)
    - to define a stable baseline configuration for follow-up studies
  - Cost at completion consolidation work on-going in parallel by ESA
  - International partner contributions being defined (NASA and JAXA)
- The Athena Science Ground Segment will involve ESA and two Instrument Science Centers
- Vigorous technology development plans on critical components to reach TRL 5/6 at mission adoption (Q1/20), e.g. coolers

Driver for high count rate capabilities

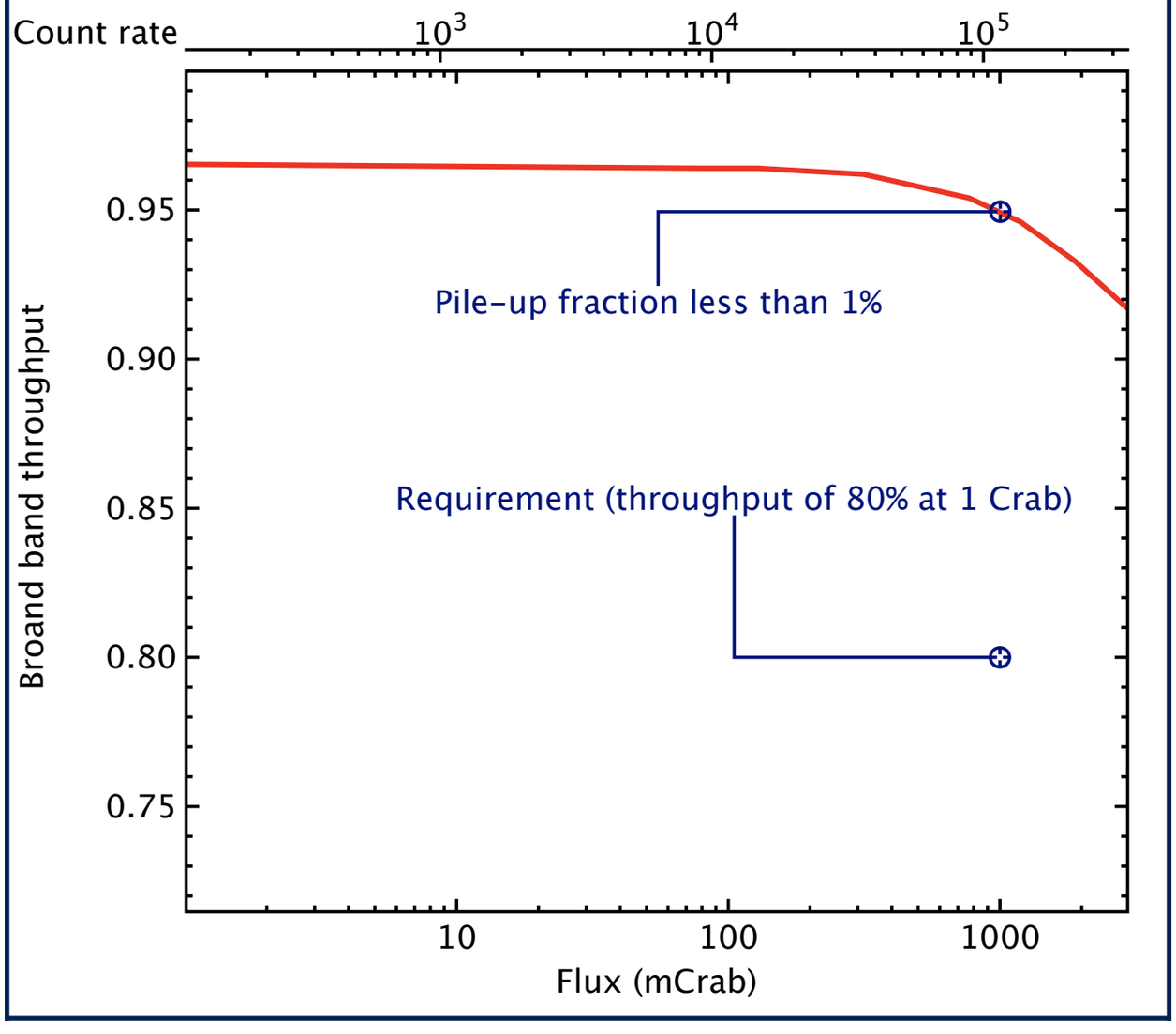
- Athena Core science goal: « *Athena shall measure black hole spins of Galactic Black Holes (GBH) and Neutron Stars (NS) to provide insight into black hole birth events (GRBs and/or SN) that set stellar-mass black hole spins, and to study the relationship between accretion and outflows (winds and jets).* »
  - Measure spins of 10 GBH and 10 NS through various methods and probe their accretion geometry and jet properties through **reverberation mapping**
  - Measure winds in the same 10 GBH and 10 NS **through absorption line spectroscopy**

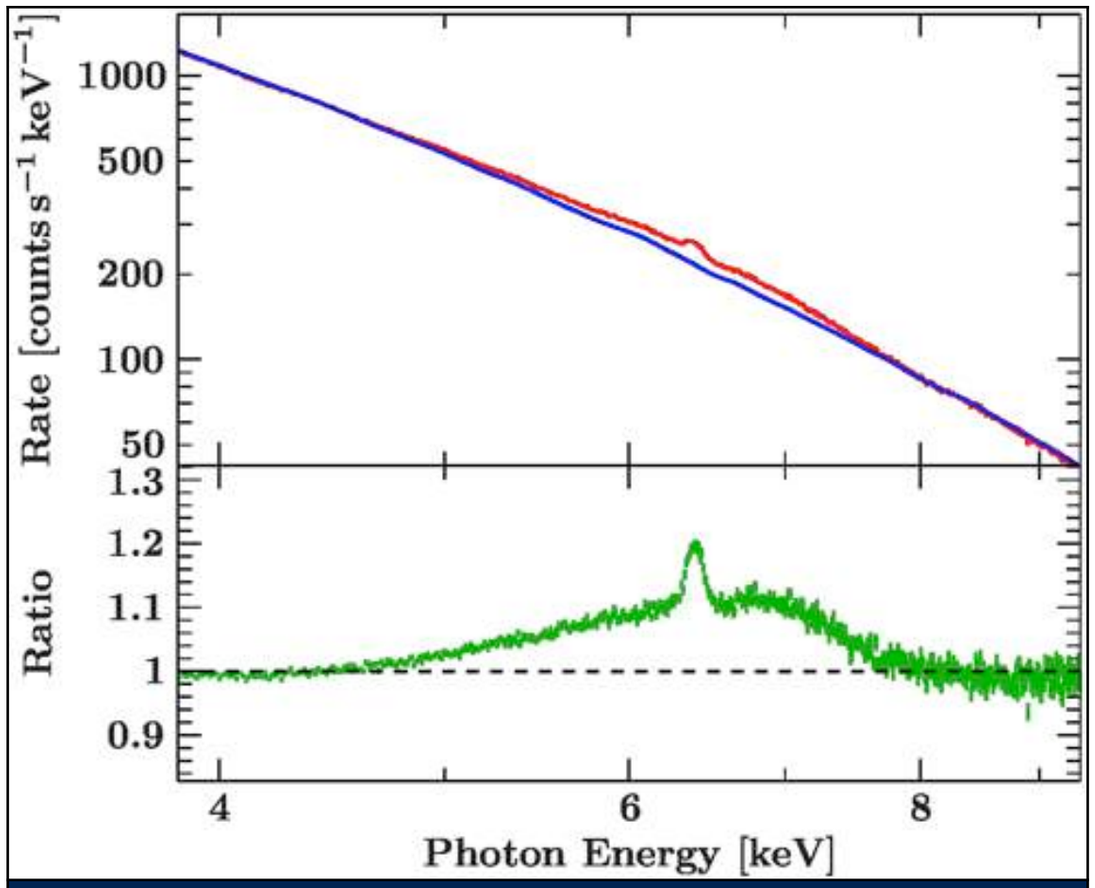
1 Crab = 90 000 - 100 000 cps (depending on detector)	
WFI (fast chip defocussed)	**X-IFU (TES array defocussed)**
80% (2-10 keV) throughput 170 eV spectral resolution <1% pile-up	30% (2-10 keV) throughput (tbc) <30 eV spectral resolution <1% pile-up



WFI fast chip performance

Readout time per pixel = 2.5 µs
64 x 64 pixels split in two halves read in parallel
Time resolution = 32 (lines) x 2.5 µs = 80 µs

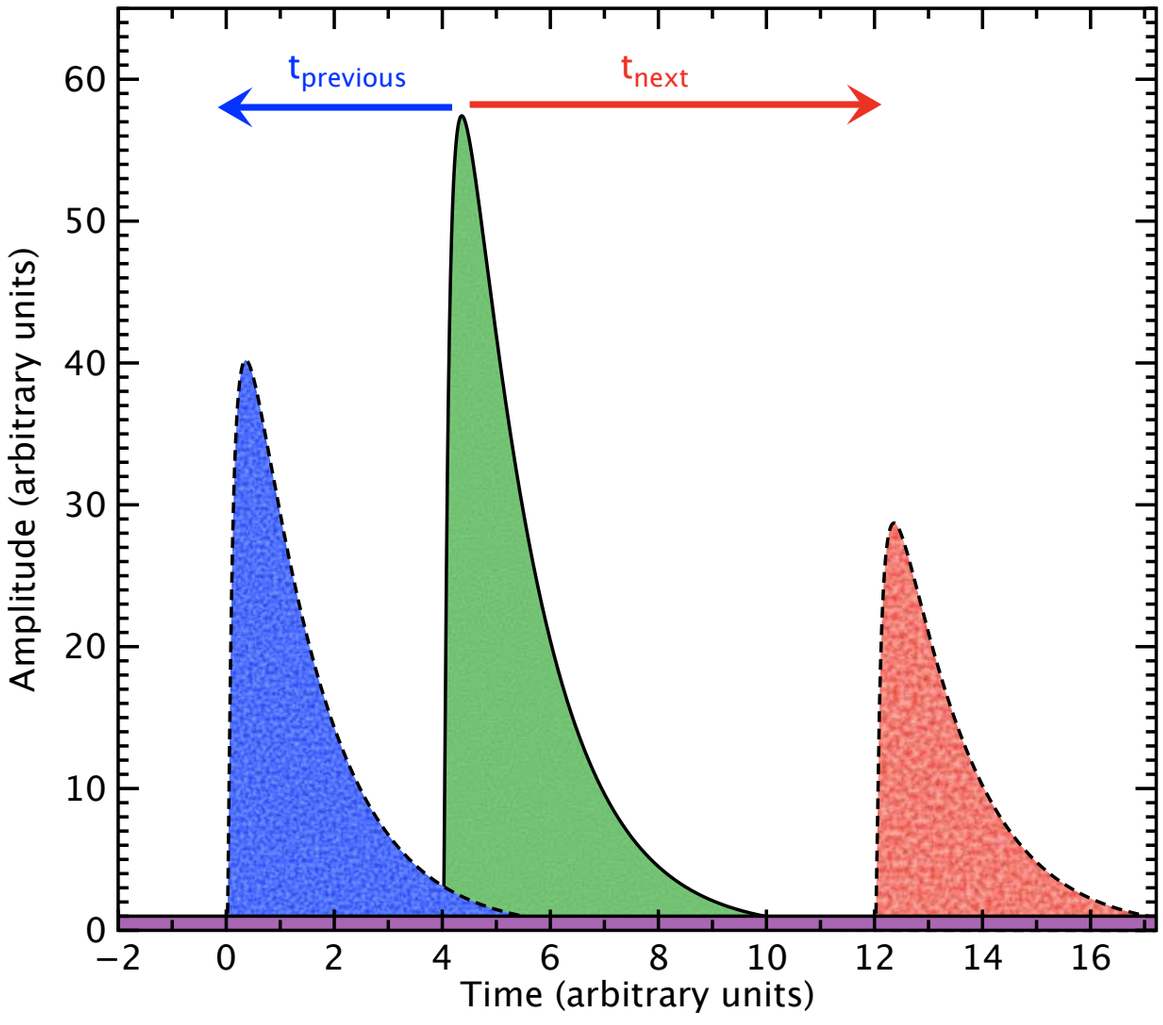




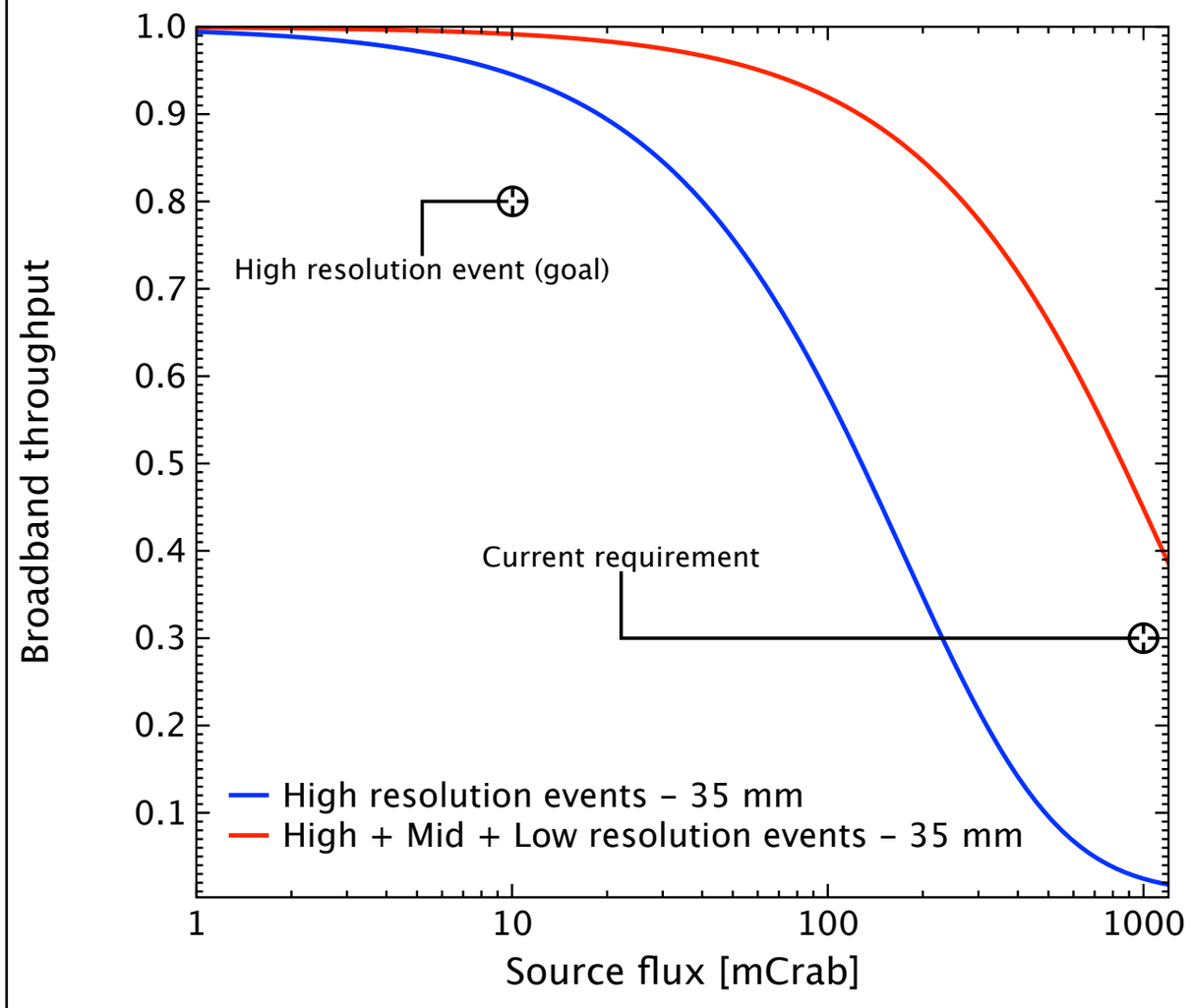
WFI FC Cygnus X-1 spectrum (10 ks). The iron line profile consists of a skew symmetric relativistic line originating close to the black hole, and a narrow core from material further away rom the black hole. — *Motch, Wilms et al., Athena supporting paper.*

X-IFU fast count rate capabilities

Time resolution = 10 µs (pile-up negligible)
Spectral grade depends on pulse separation

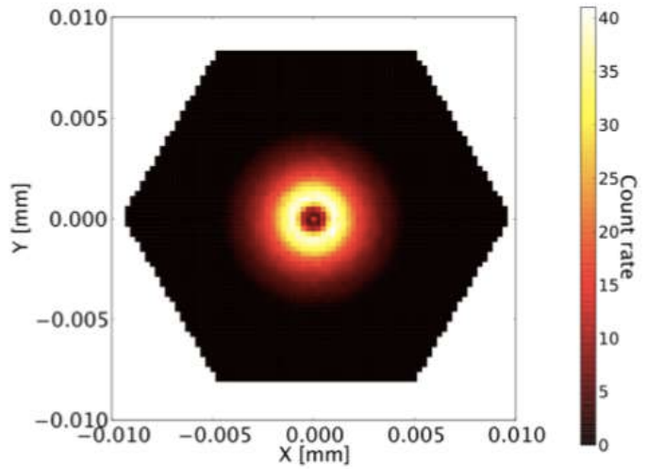


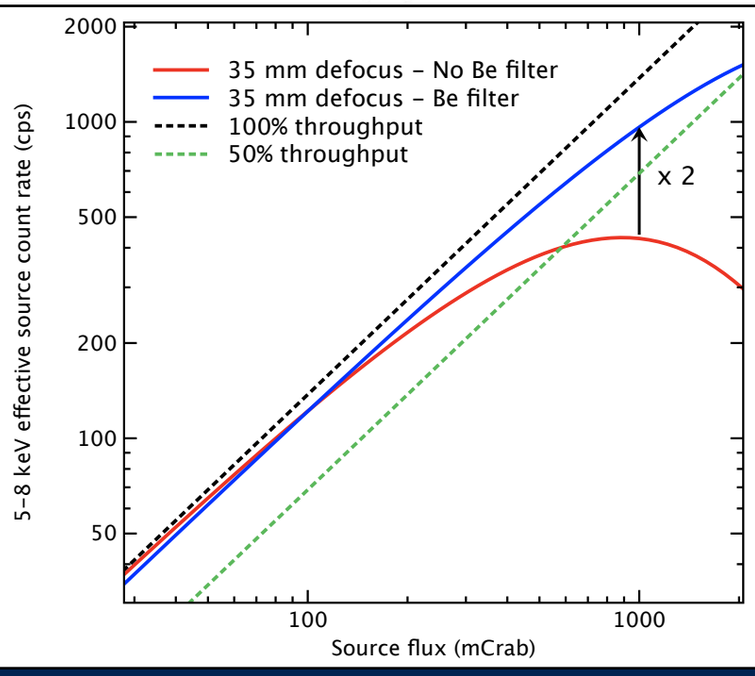
35 mm optics defocussing
Cross-talk not considered (under assessment)



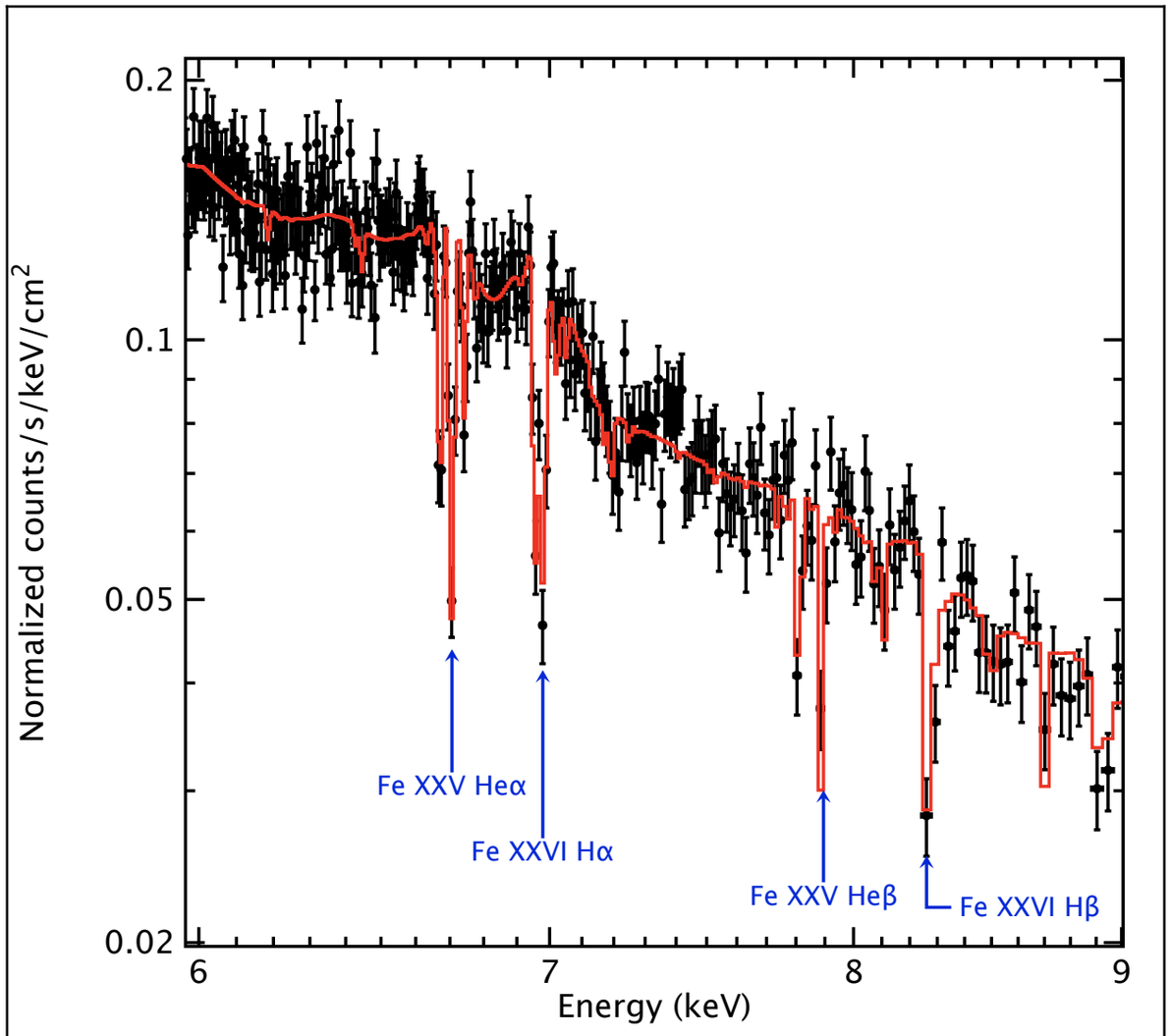
Addition of a Be filter

X-IFU defocussed image of a bright point source





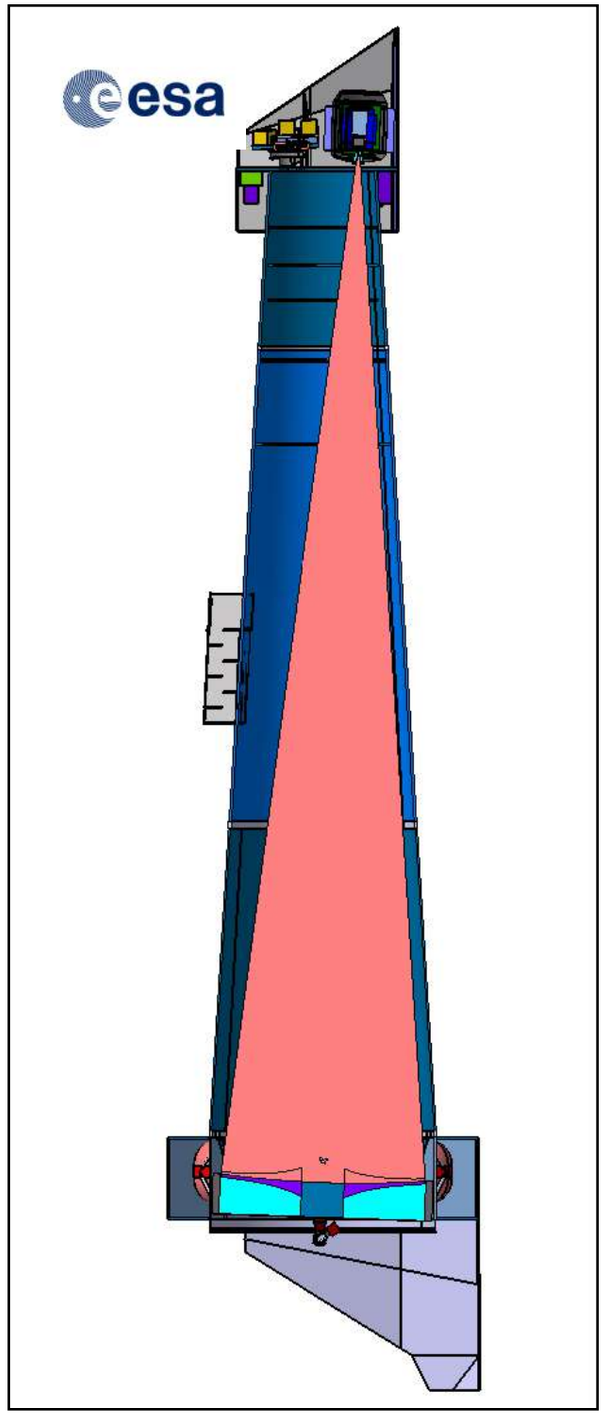
5-8 keV effective count rate with and without the Be Filter (cross-talk under assessment)



X-IFU simulated observation lasting only ~1000 seconds of the Black Hole binary GRS1915+105. Strong spectral features can be clearly seen in the spectrum, enabling unprecedented studies of the structure of the disk winds. ***Courtesy. J. Miller — Barret+ SPIE 2016***

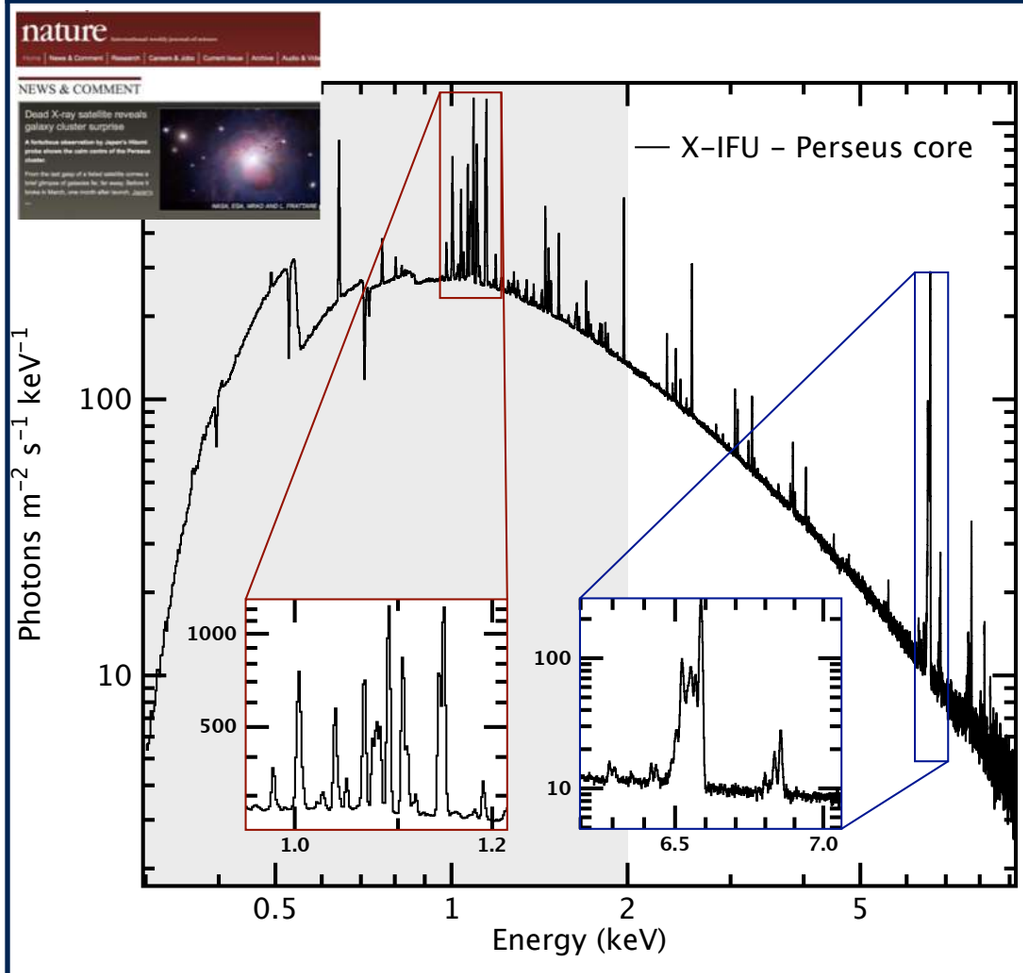
Conclusions

- Athena will provide breakthrough capabilities in wide field imaging and high resolution spatially resolved X-ray spectroscopy
  - Athena feasibility studies are progressing well with the large mirror configuration as the current baseline (2 m^2 at 1 keV)
- S/C and P/L baseline configurations being optimized
  - Science impact of a modest reduction (~20% level) in P/L capabilities being currently assessed by the Athena science panels
- Athena will provide high count rate capabilities:
  - to study accretion/ejection physics in the stellar mass range
  - to respond to observatory and discovery science with « obvious » synergies with facilities like EXTP, with e.g. its wide field monitor for GRBs (WHIM studies & first black hole probes) and transients



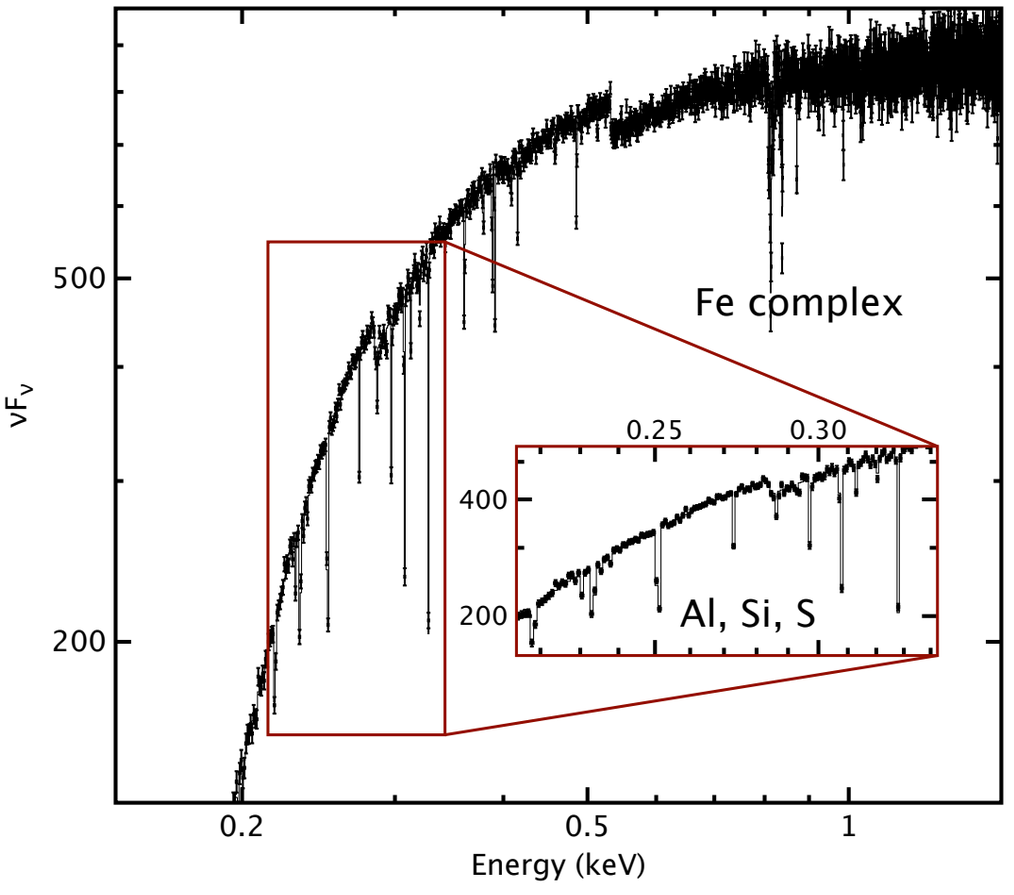
Hold on and thank you for your support

The wealth of information provided by such a spectrum, that will be measured on sub-arc minute scales enables in depth studies of the physical properties of the hot cluster gas (e.g. temperature, density, turbulence, bulk motion, abundance, . . .)



Perseus core X-IFU simulated spectrum based on Hitomi - Model courtesy of C. Pinto and A. Fabian

High-z GRB afterglows probing the ISM composition at z>7-10 and tracing the first generation of stars to understand cosmic re-ionization, the formation of the first seed black holes, and the dissemination of the first metals.



Barret et al. (2016) - Courtesy of L. Piro