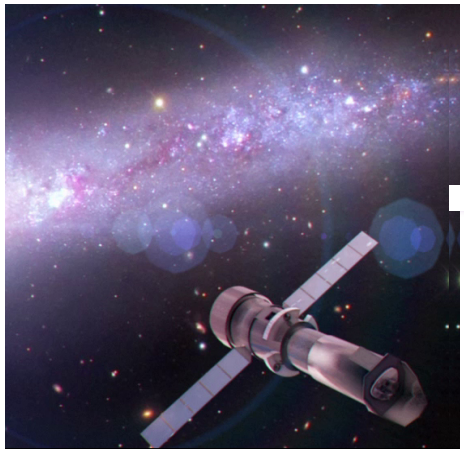
ATHENA

How super-massive black holes grow and shape galaxies: the promise of Athena

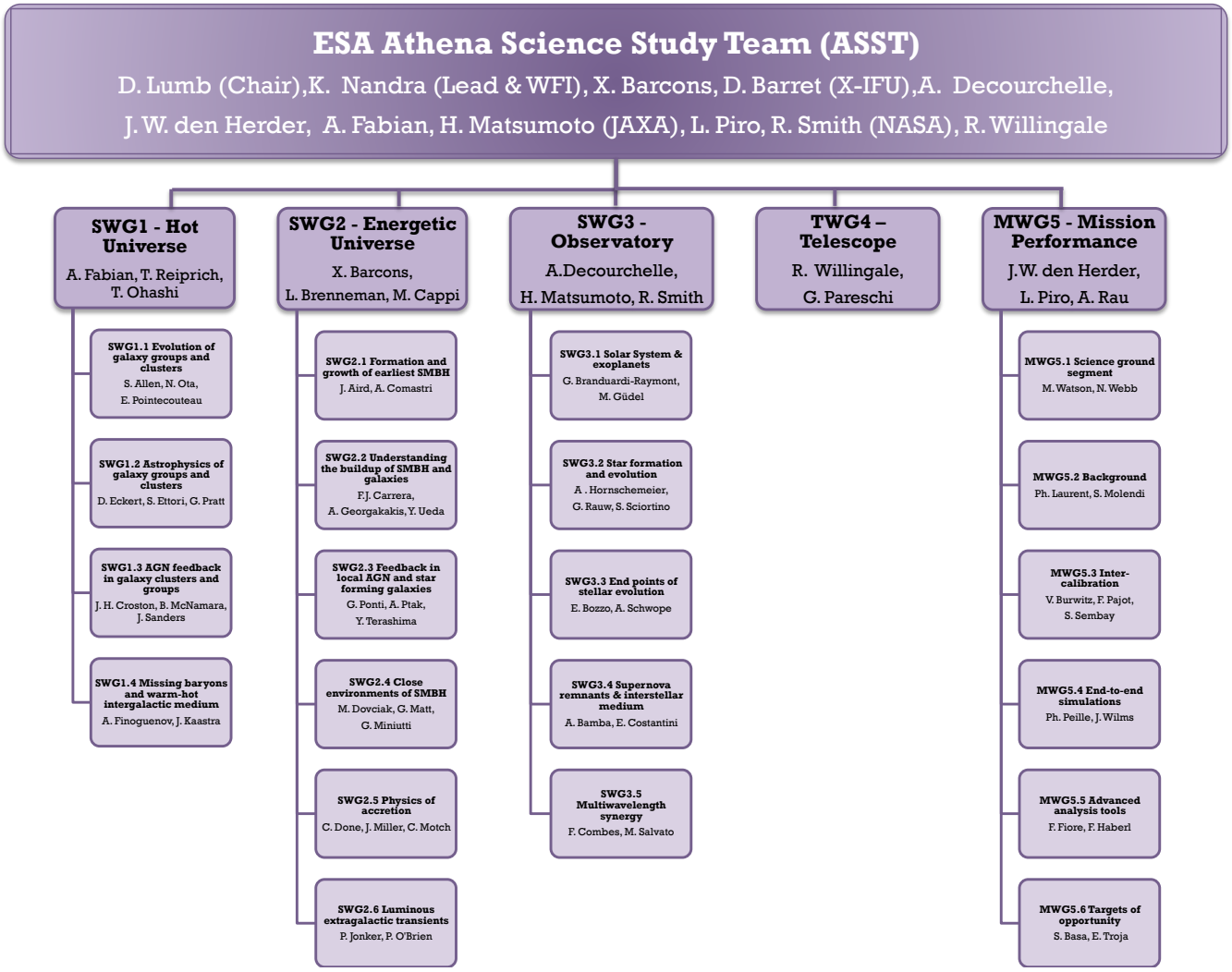


Xavier Barcons

Instituto de Física de Cantabria (CSIC-UC)
Santander, Spain

AGN, what's in a name? ESO, 27 Jun – 1 Jul 2016

Many thanks to the whole Athena team

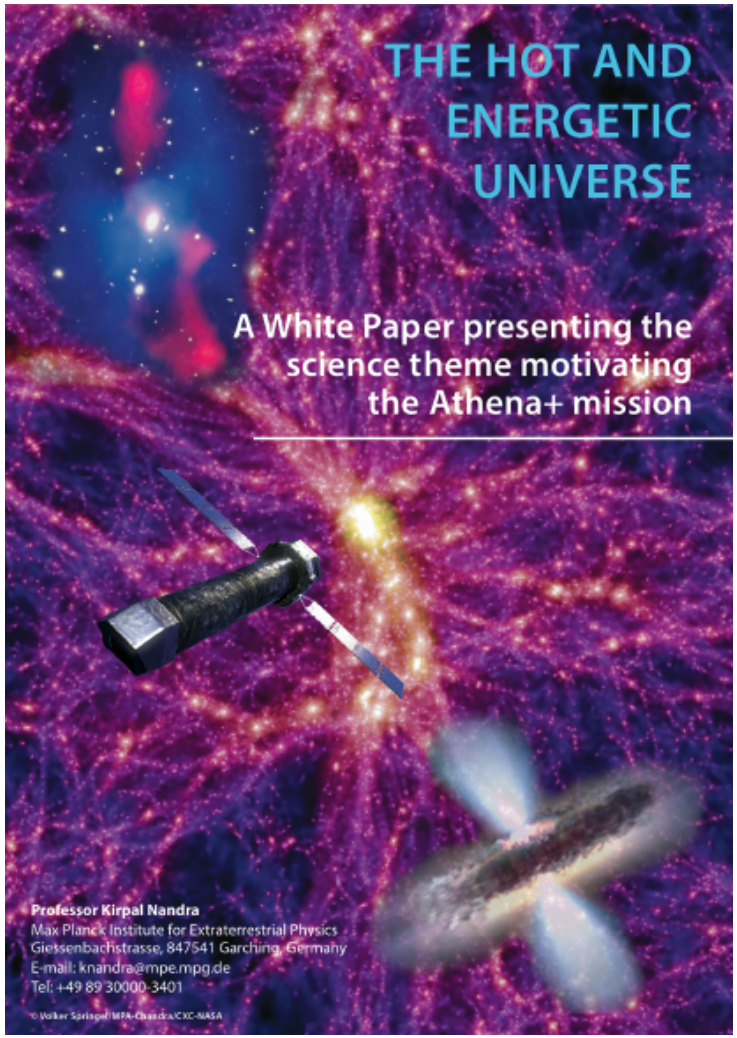


Especially:

ASST
J Aird
D Barret
L Brenneman
M Cappi
FJ Carrera
J Croston
A Comastri
A Georgakakis
G Matt
G Miniutti
K Nandra
E Pointecouteau
A Ptak
J Sanders

Advanced Telescope for High-Energy Astrophysics

- Second Large (L) mission of ESA Cosmic Vision 2015-2035
- Science theme: The Hot and Energetic Universe
  - How does ordinary matter assemble in the large-scale structures?
  - How do black holes grow and shape galaxies?
- In addition:
  - Fast ToO capability to study transient sources
  - Observatory science across all corners of Astrophysics

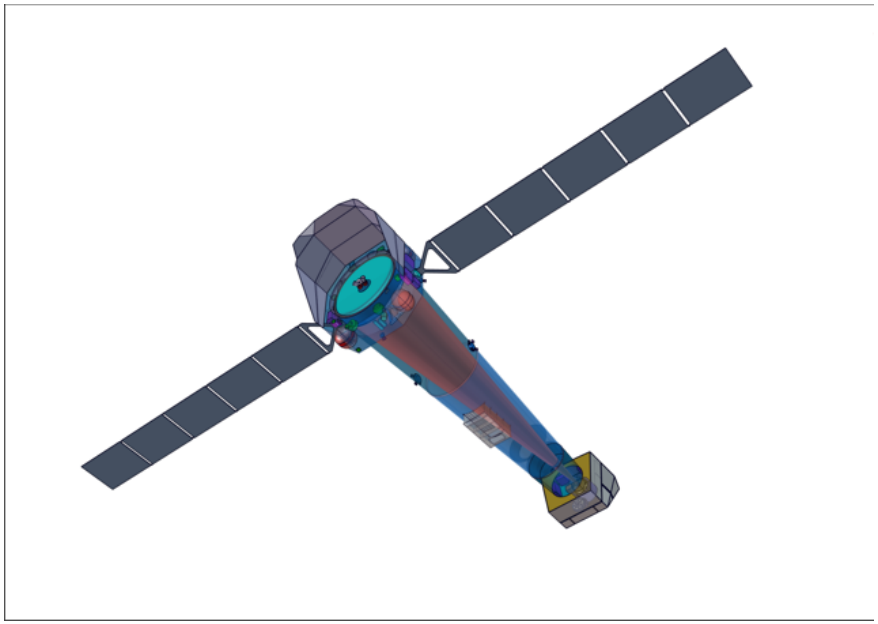


Athena Science Requirements

Parameter	value	enables (driving science goals)
Effective area at 1 keV	2 m^2	Early groups, cluster entropy and metal evolution, WHIM, high redshift AGN, census AGN, first generation of stars
Effective area at 6 keV	0.25 m^2	Cluster energetics (gas bulk motions and turbulence), AGN winds & outflows, SMBH & GBH spins
PSF HEW (< 8 keV)	5'' on axis, 10'' off axis	High z AGN, census of AGN, early groups, AGN feedback on cluster scales
X-IFU spectral resolution	2.5 eV	WHIM, cluster hot gas energetics and AGN feedback on cluster scales, energetics of AGN outflows at z~1-4
X-IFU FoV	5' diameter	Metal production & dispersal, cluster energetics, WHIM
X-IFU background	< 5 10^{-3} counts/s/cm^2/keV (75%)	Cluster energetics & AGN feedback on cluster scales, metal production & dispersal
WFI spectral resolution	150 eV	GBH spin, reverberation mapping
WFI FoV	40' x 40'	High-z AGN, census AGN, early groups, cluster entropy evolution, jet-induced cluster ripples
WFI count rate	80% at 1 Crab	GBH spin, reverberation mapping, accretion physics
WFI background	< 5 10^{-3} counts/s/cm^2/keV (75%)	Cluster entropy, cluster feedback, census AGN at z~1-4
Recons. astrometric error	1'' (3s)	High z AGNs
GRB trigger efficiency	40%	WHIM
ToO reaction time	< 4 hours	WHIM, first generation of stars

Athena mission concept

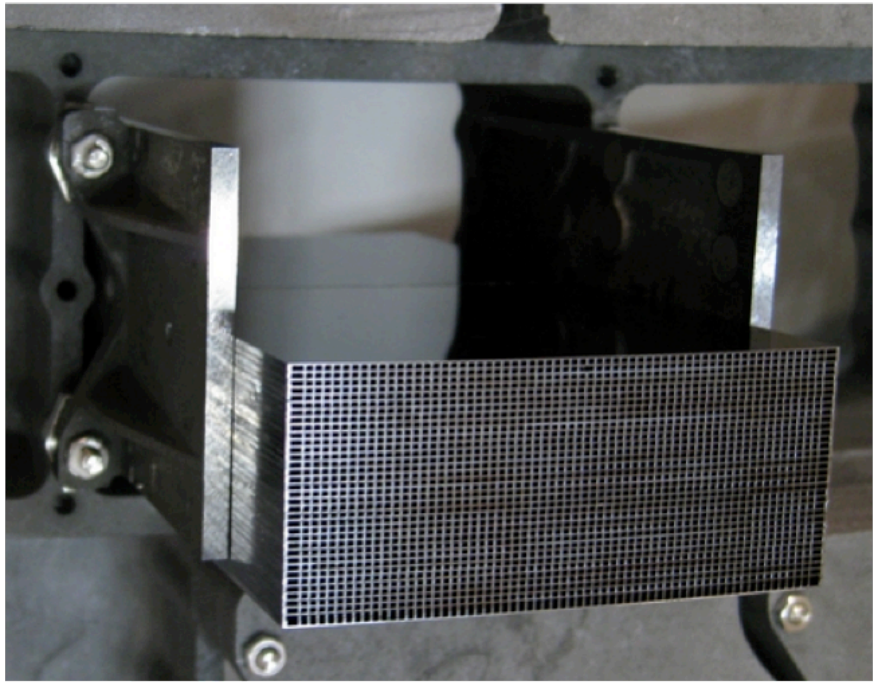
- Single telescope, using Si pore optics. 12m focal length
  - WFI sensitive imaging & timing
  - X-IFU spatially resolved high-resolution spectroscopy
- Movable mirror assembly to switch between the two instruments
- Launch 2028, Ariane 64
- L2 halo orbit (TBC)
- Lifetime > 5 yr



Athena concept, ESA CDF

The Athena telescope

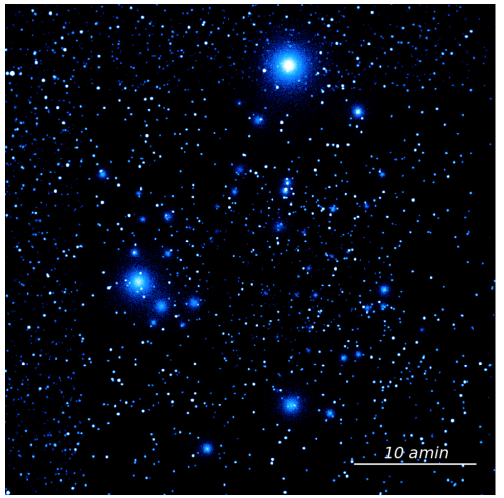
- Light-weight Si-pore optics:
  - 5” HEW on-axis
  - Graceful degradation off-axis, <10” @ 15’
  - 2 m^2 effective area @ 1 keV, with 3.6 m aperture diameter
  - Limited vignetting at 1 keV
- Athena optics development:
  - Grazing incidence optics, Wolter-I type (paraboloid-hyperboloid), largely with conical approximation
  - Vigorous development programme at ESA and industry.

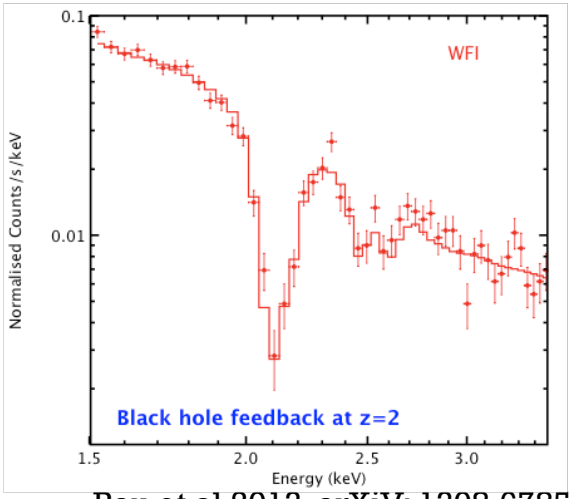


Willingale et al 2013, arXiV: 1308.6785

Wide Field Imager (WFI)

- Based on Si detectors, using Active Pixel Sensors based on DEPFETs.
- Key performances;:
  - 120-150 eV spectral resolution,
  - 3” pixel size (PSF oversample)
  - Field of view: 40’x40’
  - Separate chip for fast readout of brightest sources
  - Readout speed up to ~30 MHz
- Consortium led by MPE, with other European partners and NASA
- Optimized for sensitive and wide imaging and intermediate resolution spectroscopy, up to very bright sources

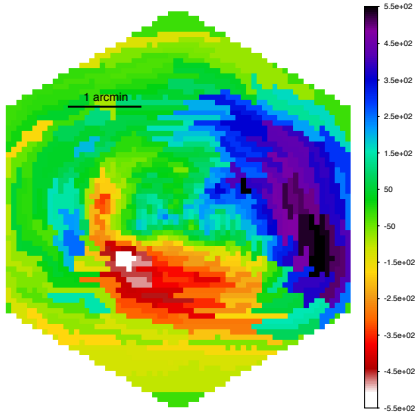




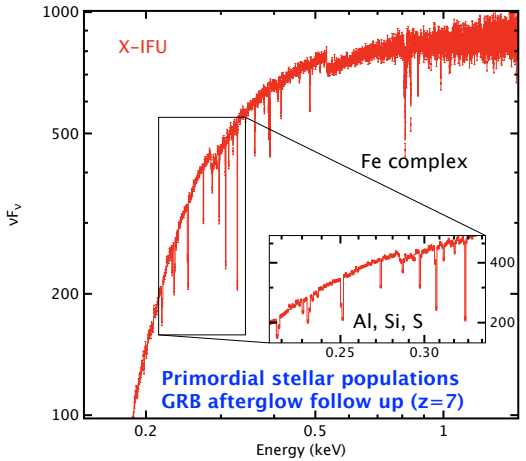
Rau et al 2013, arXiV: 1308.6785

X-ray Integral Field Unit (X-IFU)

- Cryogenic imaging spectrometer, based on Transition Edge Sensors, operated at 50 mK featuring an active cryogenic background rejection subsystem
- Consortium led by CNES/IRAP-F, with SRON-NL, INAF-IT and other European partners, NASA and JAXA.
- Key performance parameters:
  - 2.5 eV energy resolution <7 keV
  - FoV 5' diameter
  - Pixel size <5"

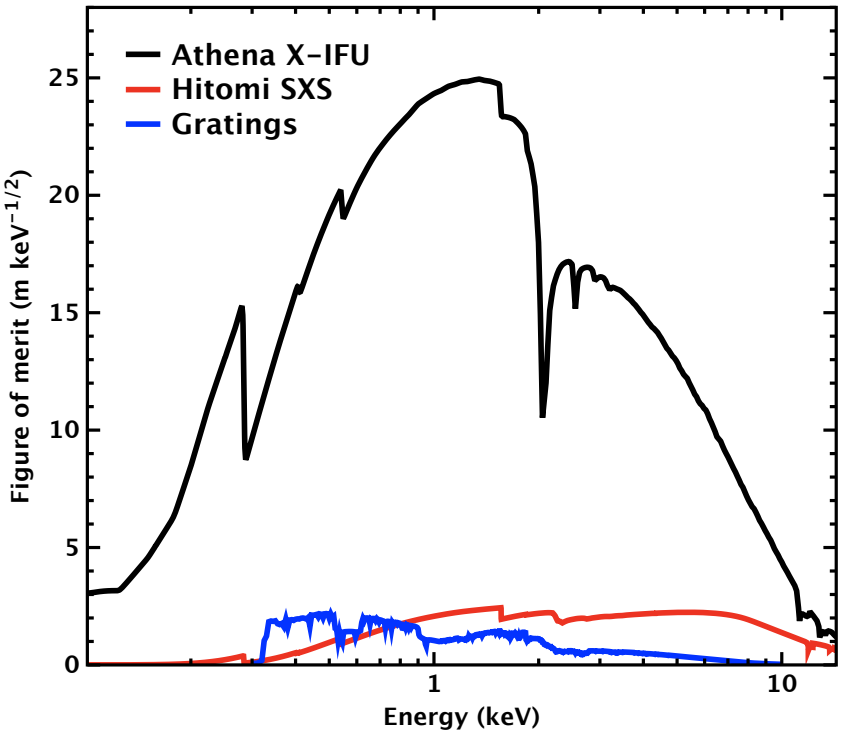


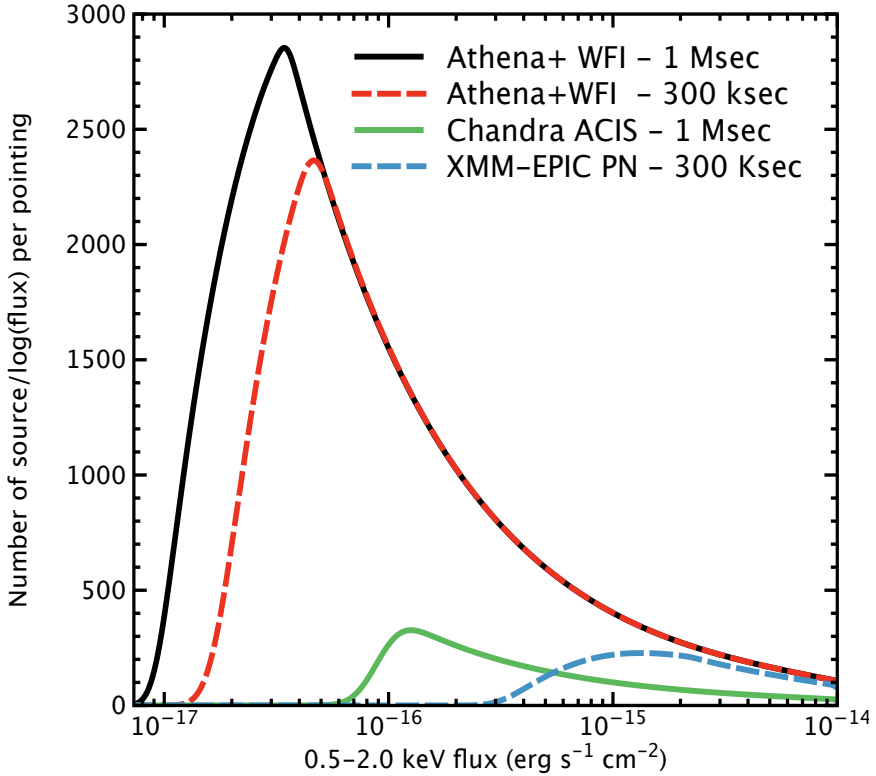
E. Pointecouteau, P. Peille, E. Rasia, V.Biffi, S. Borgani, J. Wilms



Barret et al 2013, arXiV: 1308.6784
http://x-ifu.irap.omp.eu/

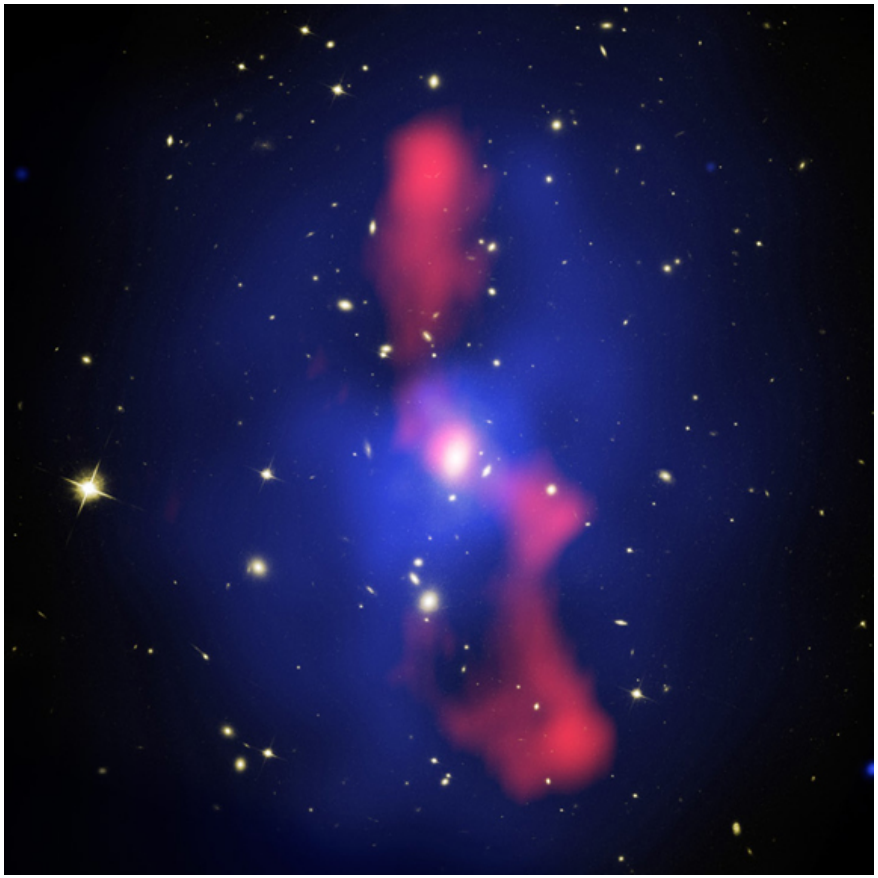
Athena: a revolutionary observatory





SMBH growth with Athena

- AGN energetics and feedback:
  - Radiative
  - Mechanical: QSO mode
  - Mechanical: radio-mode
- Obscured AGN census (z~1-3)
- Early SMBH growth (z>6)
- Accretion vs mergers?

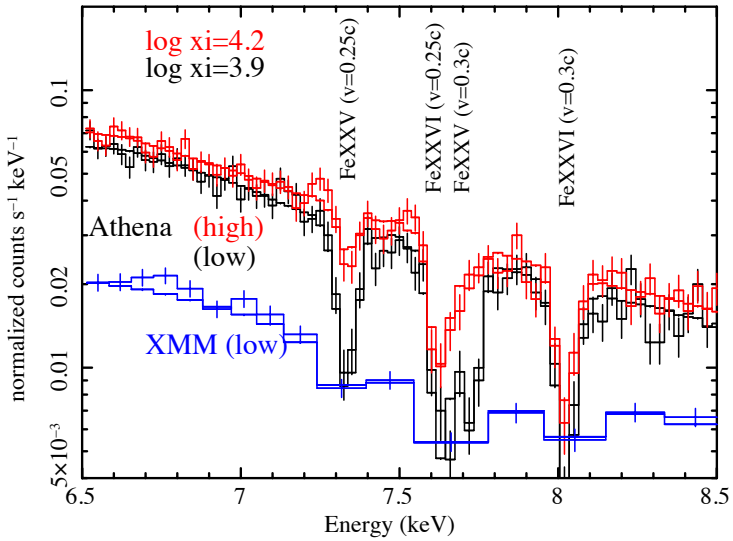


MS0735.6+7421 McNamara et al 2005

AGN winds and outflows

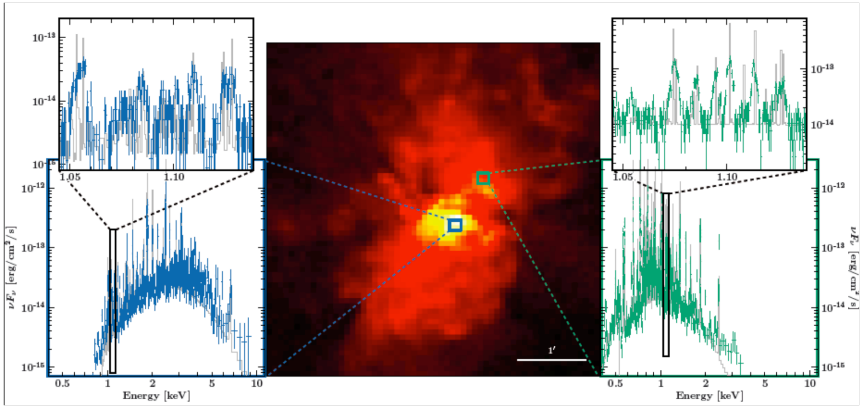
Feedback effective if
$L_{mech} > 1\% L_{bol}$

Mechanical energy released in ultra-fast outflows ~v^3



Cappi, Done et al 2013, arxiv:1306.2330

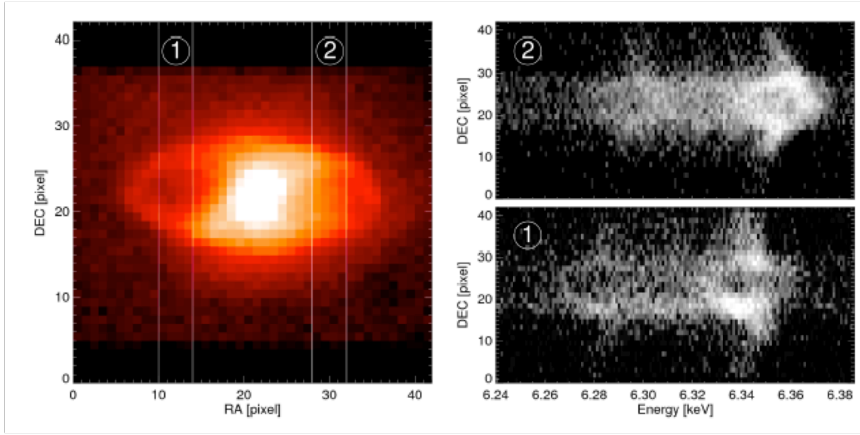
Gas, metals and mechanical energy ejected in the circum-galactic medium by AGN and Starbursts



A. Ptak and the Athena simulation team (in progress)

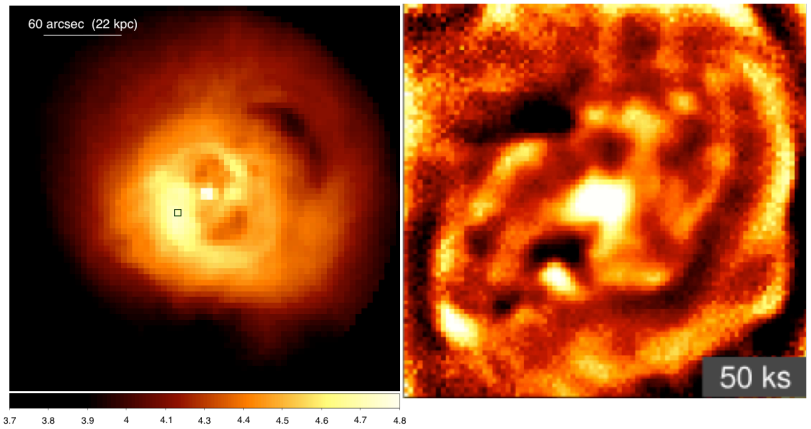
Radio mode feedback – effects on cluster scales

- How do jets from Active Galactic Nuclei dissipate their mechanical energy in the hot intracluster medium, and how does this regulate gas cooling and black hole fuelling?
  - Energy stored in hot gas around bubbles via bulk motions and turbulence.
  - History of radio cluster feedback via ripples.
  - Balance between AGN jet fuelling and cooling through gas temperature distribution.
  - Measure shock speeds of expanding radio lobes



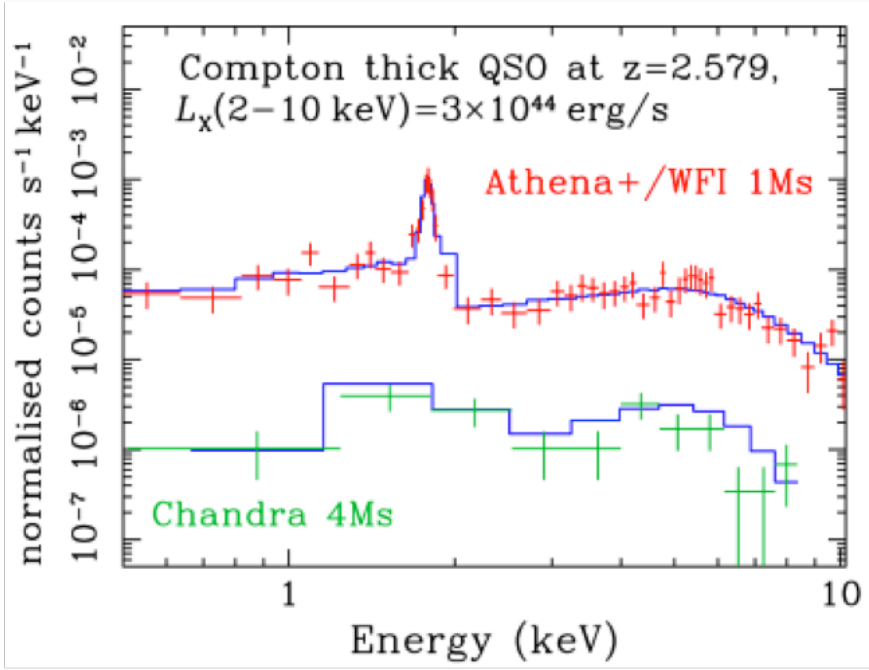
Croston, Sanders et al., 2013 arXiv1306.2323

Simulations by S. Heinz



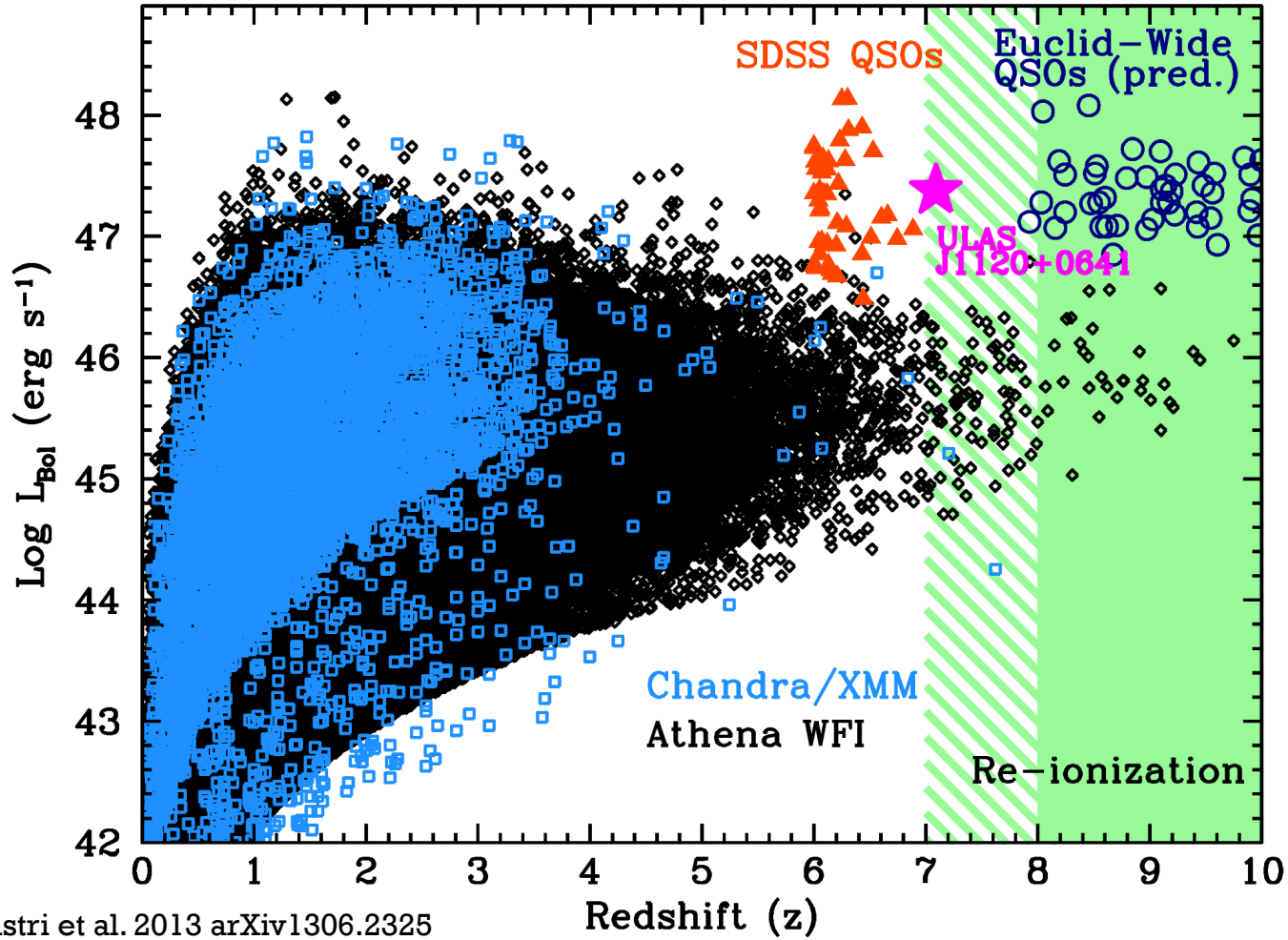
Obscured AGN census @ z~1-3

- What is the relation between obscured growth of SMBH through cosmic history and how does it relate to galaxy formation?
  - Most SMBH growth expected in heavily obscured (including Compton-Thick) environment.
  - Best X-ray signal of Compton-Thick AGN is the Fe emission line, EW ~0.5-1 keV.
  - Athena/WFI observations can uncover CT L* AGN @ z<3
    - MIR observations can reliably uncover heavily obscured AGN, but only when the AGN is very powerful.



Georgakakis, Carrera et al., 2013 arXiv1306.2328

The history of SMBH growth

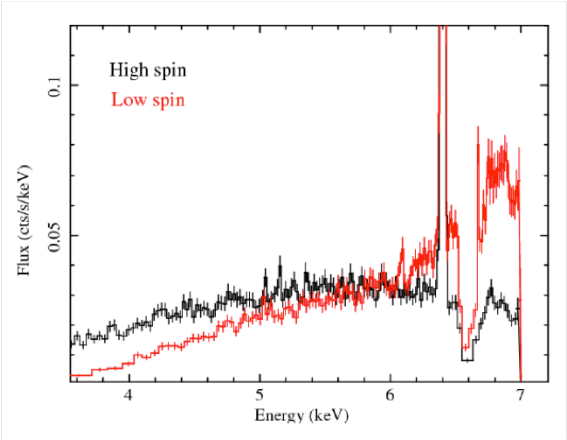


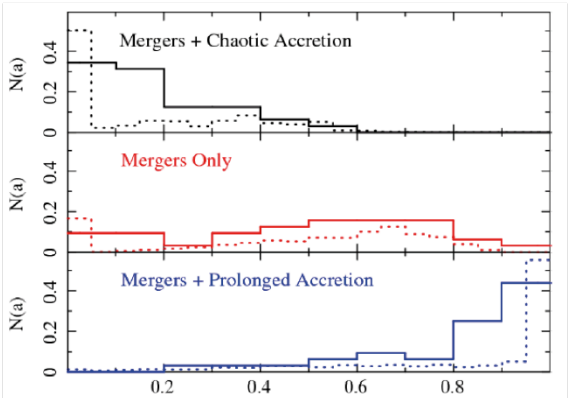
Comastri
Lanzuisi
Aird (2016)

Aird, Comastri et al. 2013 arXiv1306.2325

SMBH growth: accretion vs mergers

- SMBH spin distribution is highly sensitive to SMBH growth history:
  - Accretion spins up SMBH
  - Mergers & chaotic accretion spin down SMBH
- A SMBH spin survey with Athena will reveal dominant SMBH growth
  - Partly doable with XMM-Newton, but for removal narrow features
- Biases: Highly spinning SMBH are radiatively more efficient and therefore are overrepresented in flux-limited samples (Vasudevan et 2016)
  - Athena can obtain spins for fainter sources and correct for this effect





Dovciak, Matt et al 2013: arXiv 1306.2331
simulations by G. Miniutti

Athena Synergies with other facilities

- ESO-Athena Synergy exercise
  - Led by ESO-Athena Synergy Team: P. Padovani (chair), E. Hatziminaglou, M. Díaz-Trigo, S. Viti, S. Ettori, M. Salvato, F. Combes, P. Jonker
  - Leading to 2 Synergy White Papers ~March 2017: opt/NIR and sub/mm
  - AGN feature prominently:
    - High-z AGN (IFU)
    - Obscured AGN at z~3
    - Molecular vs disk winds
- SKA-Athena Synergy exercise starting, Synergy White Paper due by ~fall 2017
  - AGN, clusters & transients

Athena: Current status

- Phase A on-going, Jun 2015 to end 2017 (PRR)
  - System-level tradeoffs, spacecraft conceptual design
  - Development of the 2 instrument concepts by the consortia
  - Technology development activities (optics, cryo-coolers etc)
  - Contribution from external partners (NASA & JAXA)
- Mission Consolidation Review (MCR) Apr/May 2016 - > ΔPhaseA1
  - Mission concepts are sound
  - Instrument switching mechanism is through a Movable Mirror Assembly
  - Instrument resources challenging: all being addressed or already fixed.
  - Mass lift capacity of Ariane 64 uncertain, assumed conservatively those from Ariane 5 ECA (6.8 Tons).
    - Within this conservative allocation, tight margins
  - Consolidation of the Cost at Completion underway
  - **Mission concept to be carried over is that of the proposed mission, with 2 m^2 effective area at 1 keV**

Outlook

- Athena will be very powerful X-ray observatory, with key capacities to understand AGN
- It is an essential part of the observational landscape in the late 2020s, together with ALMA, E-ELT, SKA, CTA, etc.
- Good progress with Phase A, issues identified and being addressed

- Follow Athena on
  - Web: www.the-athena-x-ray-observatory.eu
  - Twitter: @athena2028
  - Facebook: The Athena X-ray Observatory
  - Athena Community Office email: aco@ifca.unican.es
    - Drop us a message if you want to receive the Newsletter