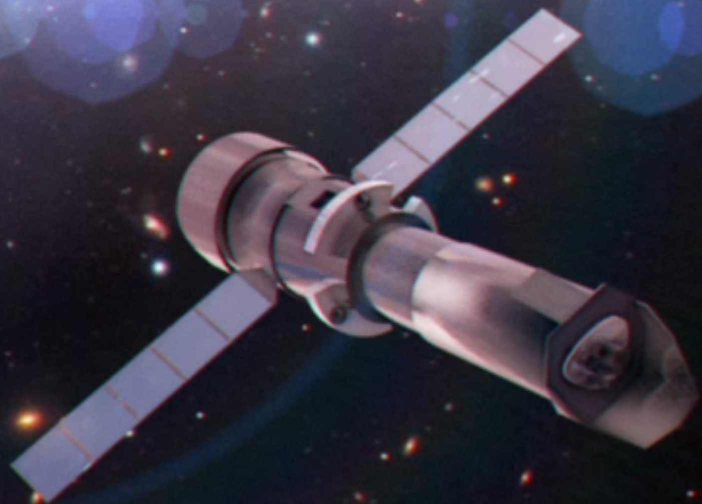
ATHENA

X-IFU

The Athena/X-IFU X-ray view of Hot and Energetic Universe: probing the Black Hole environment

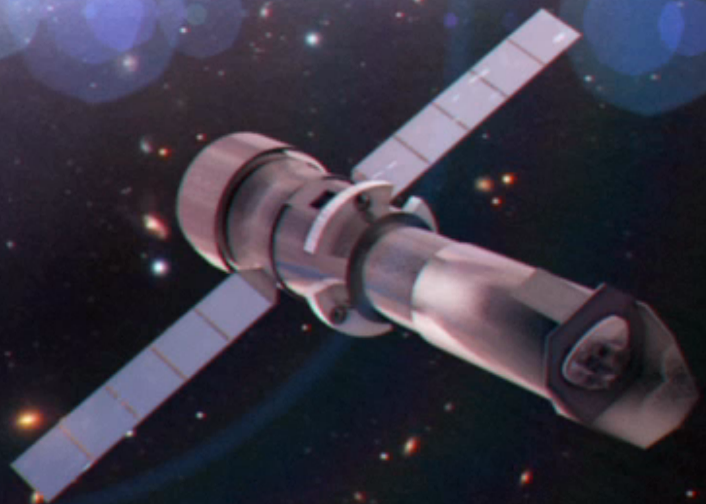


X. Barcons, IFCA (CSIC-UC) ES
D. Barret, IRAP FR
J.W. den Herder, SRON NL
L. Piro, INAF/IAPS IT
E. Pointecouteau, IRAP FR

ATHENA

The Athena X-ray view of Hot and Energetic Universe: probing the Black Hole environment

X. Barcons, IFCA (CSIC-UC) ES
D. Barret, IRAP FR
J.W. den Herder, SRON NL
L. Piro, INAF/IAPS IT
E. Pointecouteau, IRAP FR



Contents

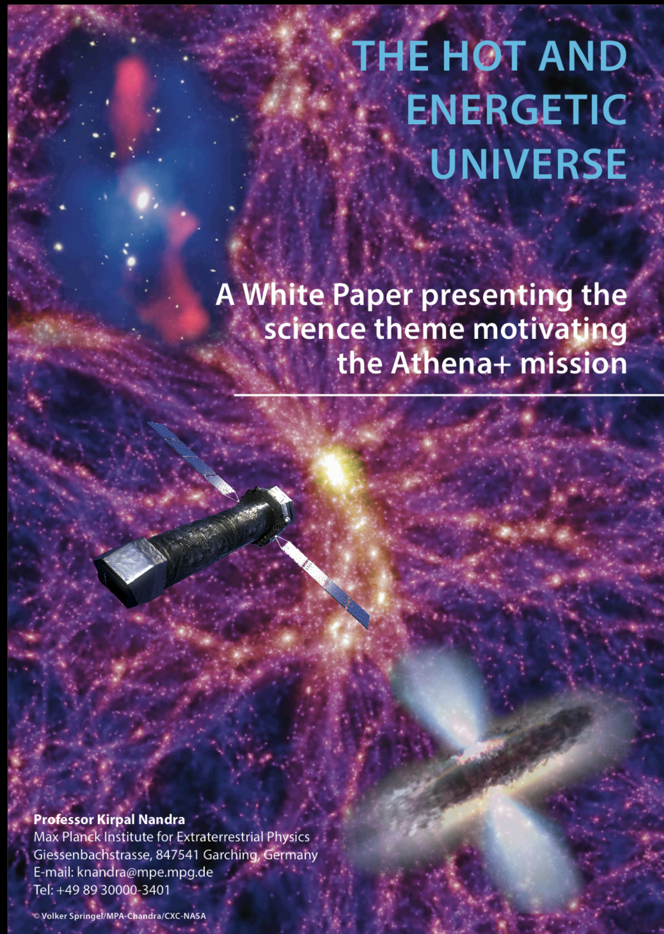
Athena (*Advanced Telescope for High Energy Astrophysics*) and the Hot and Energetic Universe

The X-IFU instrument on board Athena (see talk by J.W. den Herder)

The Athena X-ray view of Black Holes and their environment on all scales

The Hot and Energetic Universe

- **The Hot Universe:** How does the ordinary matter assemble into the large-scale structures that we see today?
  - >50% of the baryons today are in a hot (>10^6 K) phase
  - there are as many hot (> 10^7 K) baryons in clusters as in stars over the entire Universe
- **The Energetic Universe:** How do black holes grow and influence the Universe?
  - Building a SMBH releases 30 × the binding energy of a galaxy
  - 15% of the energy output in the Universe is in X-rays

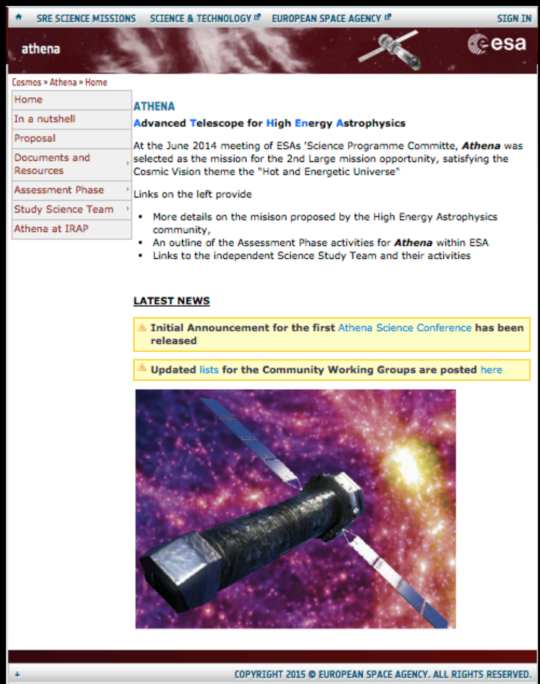


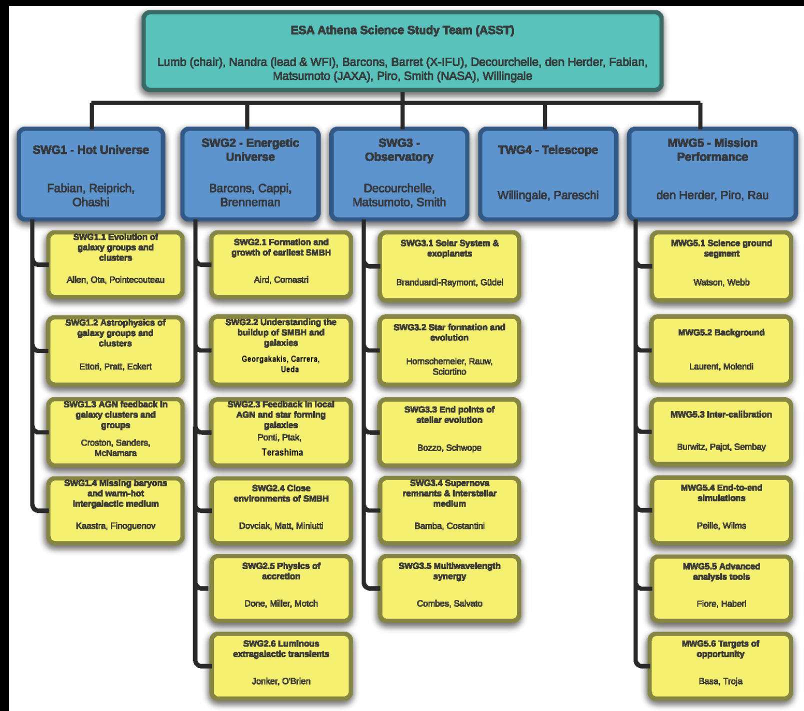
Nandra, Barret, Barcons, et al 2013, arXiv: 1306.2307

The Athena people

Athena Science Study Team:
D. Lumb (ESA), **K. Nandra (DE)**, D. Barret (FR), X. Barcons (ES), A. Decourchelle (FR), J.-W. den Herder (NL), A.C. Fabian (UK), H. Matsumoto (JP), L. Piro (IT), R. Smith (USA), R. Willingale (UK)

Athena Working Groups & Topical Panels
(~50 chairs and ~650 members)



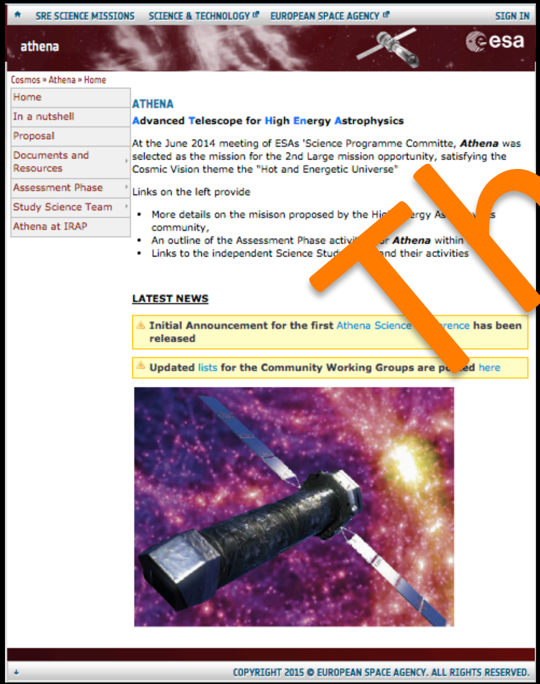


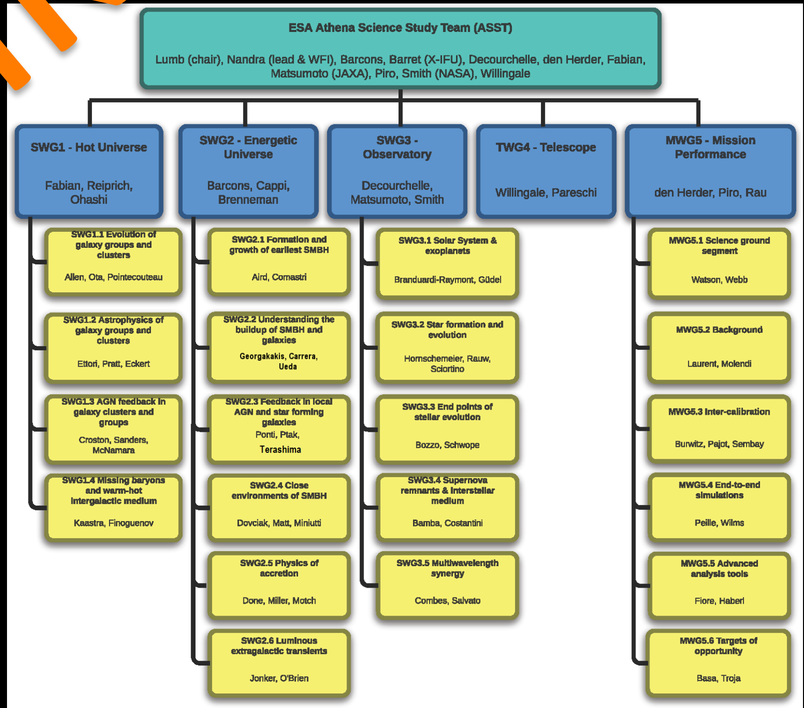
The Athena people

Athena Science Study Team:
D. Lumb (ESA), **K. Nandra (DE)**, D. Barret (FR), X. Barcons (ES), A. Decourchelle (FR), J.-W. den Herder (NL), A.C. Fabian (UK), H. Matsumoto (JP), L. Piro (IT), R. Smith (USA), R. Willingale (UK)

Athena Working Groups & Topical Panels
(~50 chairs and ~650 members)

Thank you!



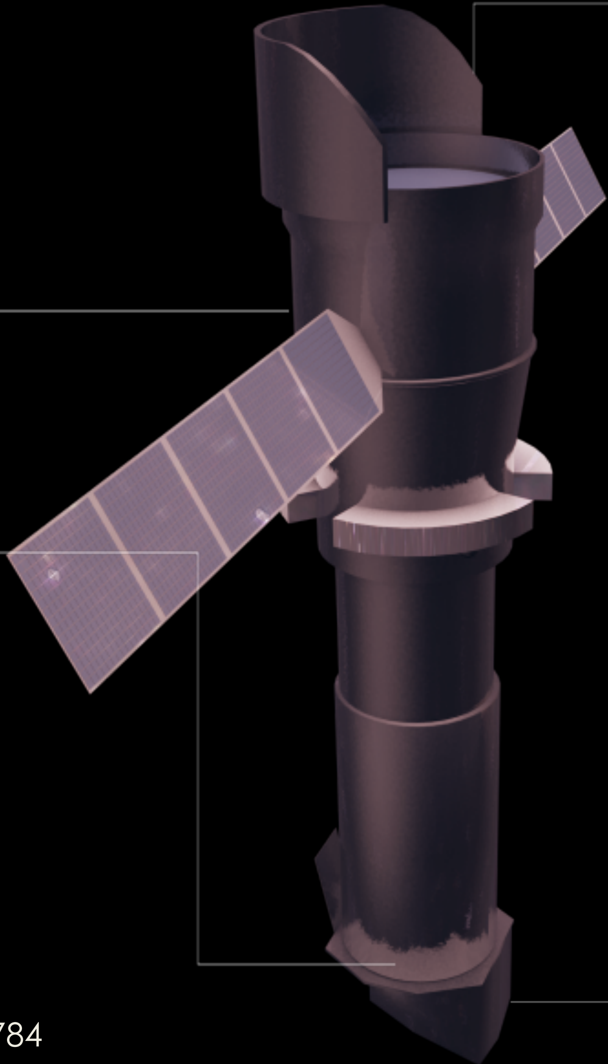


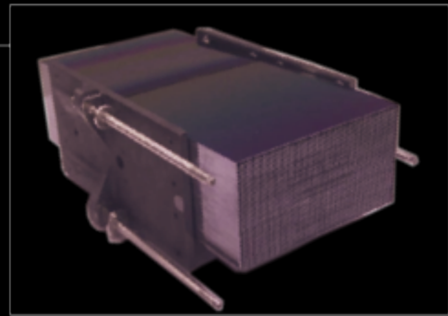
ATHENA

The Athena mission

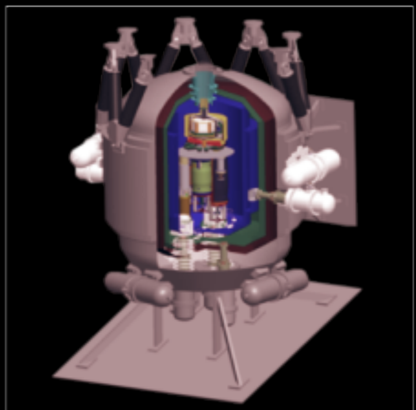
Willingale et al, 2013
arXiv1308.6785

L2 orbit Ariane V
Mass < 5100 kg
Power 2500 W
5+ year mission



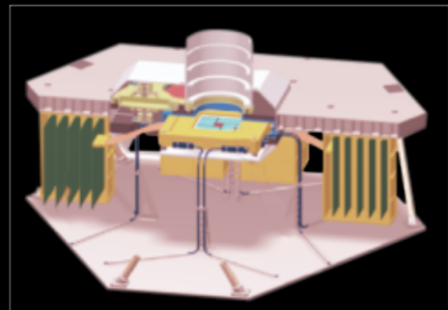


Silicon Pore Optics:
$2\ m^2$ at 1 keV
5 arcsec HEW
Focal length: 12 m
Sensitivity: $3\ 10^{-17}$ erg $cm^{-2}\ s^{-1}$



X-ray Integral Field Unit (X-IFU):
ΔE: 2.5 eV
Field of View: 5 arcmin
Operating temp: 50 mk

Barret et al., 2013 arXiv:1308.6784



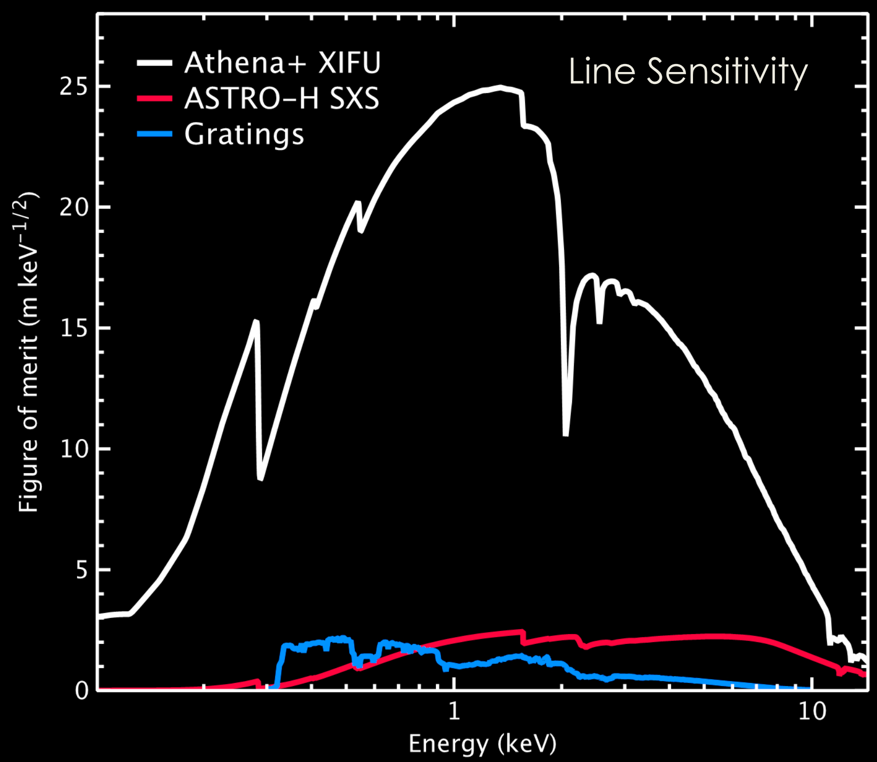
Wide Field Imager (WFI):
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

Rau et al. 2013 arXiv1307.1709

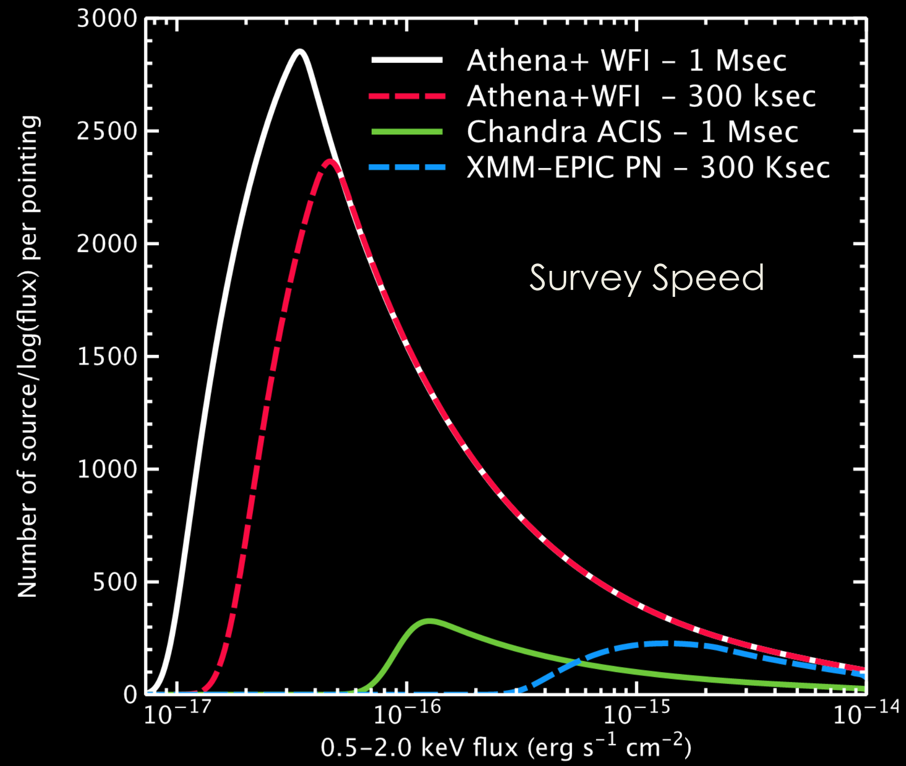
ATHENA

Athena: A Deep Universe X-ray Observatory

Athena has vastly improved capabilities compared to current or planned facilities, and will provide **transformational** science on virtually all areas of astrophysics



X-ray spectroscopy at the peak of the activity of the Universe

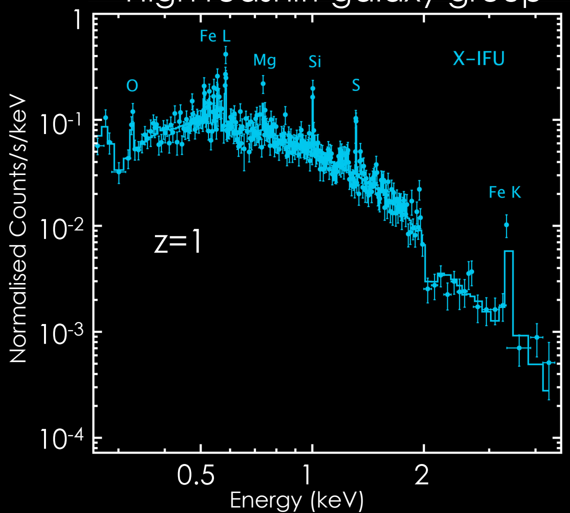


Deep survey capability into the dark ages and epoch of reionization

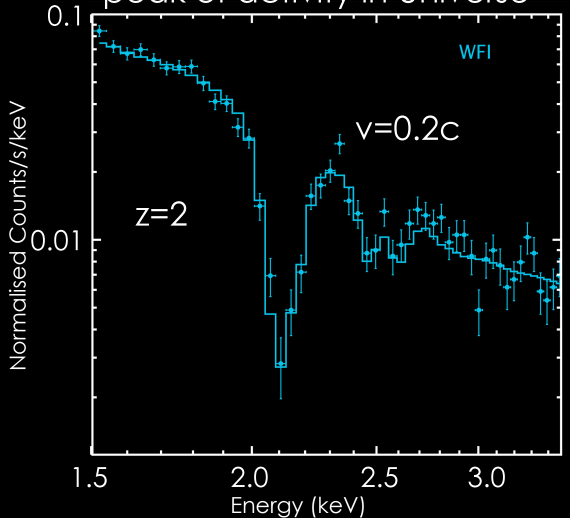
ATHENA

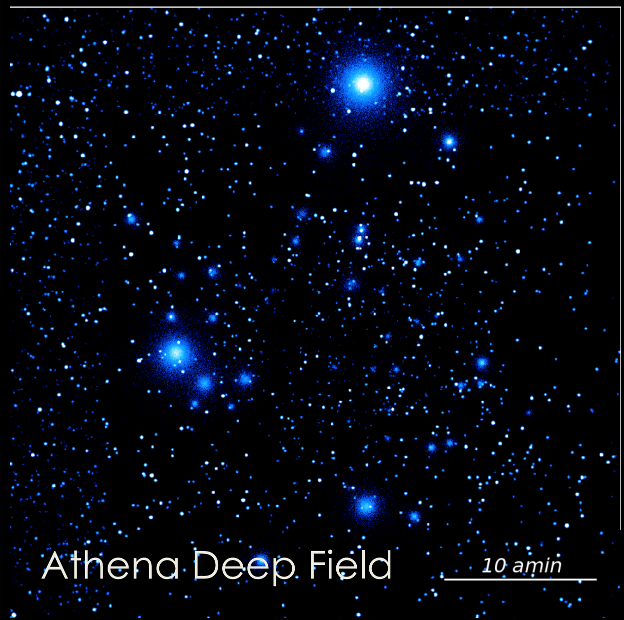
Athena: Exploring the Hot and Energetic Universe

High redshift galaxy group



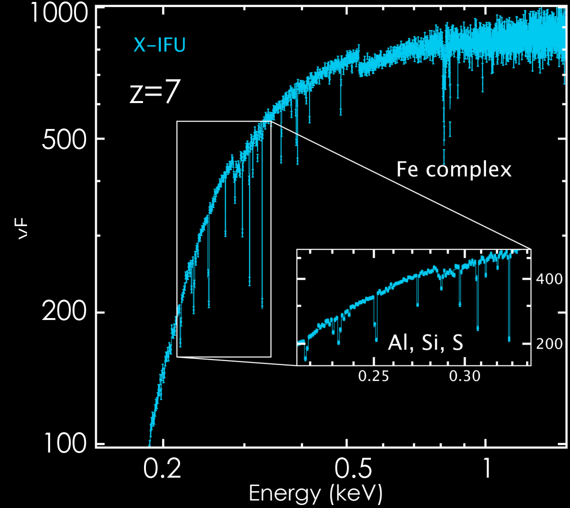
Black hole feedback at peak of activity in Universe



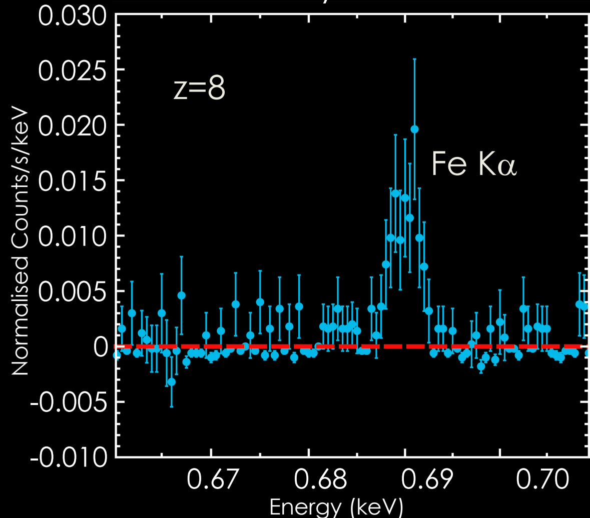


Nandra, Barret, Barcons, Fabian, den Herder, Piro, Watson et al. 2013 arXiv 1306.2307

Primordial stellar populations via GRB afterglow follow up



Obscured black hole in the early Universe



ATHENA

Athena mission milestones

- ESA SPC selected the Hot and Energetic Universe as the theme for L2 in Nov 2013
- ESA SPC selected the Athena mission in June 2014:
  - Design to cost 1 Bn€ + affordable payload + international partners (20%)
- The Athena Science Study Team was appointed by ESA in July 2014
- Phase 0 executed from August to December 2014, ESA/CDF study
  - CDF study showed Athena to be feasible
  - Programmatically would need significant international contribution or a 30% reduction in effective area
- Phase A1 (July 2015 – May 2016)
  - Study whether Athena is feasible, and determine mirror size
  - Mission Consolidation Review (MCR) in May 2016
- Phase A2 (mid 2016 - end 2017)
  - Complete assessment study on selected mission concept
- Phase B1 (early 2018 – mid 2019)
  - Systems Requirement Review (SRR) Q3 2019
- Mission adoption by ESA SPC expected by Feb 2020 if
  - SRR is successful, mission & payload are affordable
- Launch in 2028

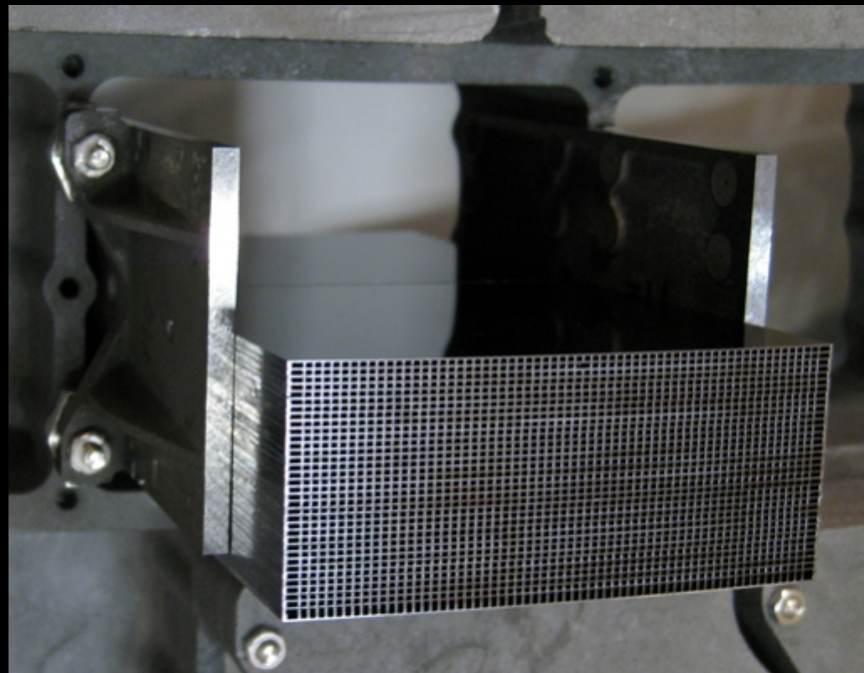
The Athena optics

Development of light-weight optics for X-ray astronomy

Grazing incidence optics, Wolter-I type (paraboloid-hyperboloid), largely with conical approximation

Substrate for reflecting surface is based on "commercial" Si wafers, but with small pores and short reflecting layers

Vigorous development programme at ESA and industry. Demonstration modules produced (TRL~4)



Willingale et al 2013 arXiv1308.6785

ATHENA

The Athena Wide Field Imager (WFI)

The most sensitive images of the X-ray Universe

Based on Si detectors, using Active Pixel Sensors based on DEPFETs.

Key performances;:

•120-150 eV spectral resolution,

•3'' pixel size (PSF oversampling)

•Field of view: 40'x40'

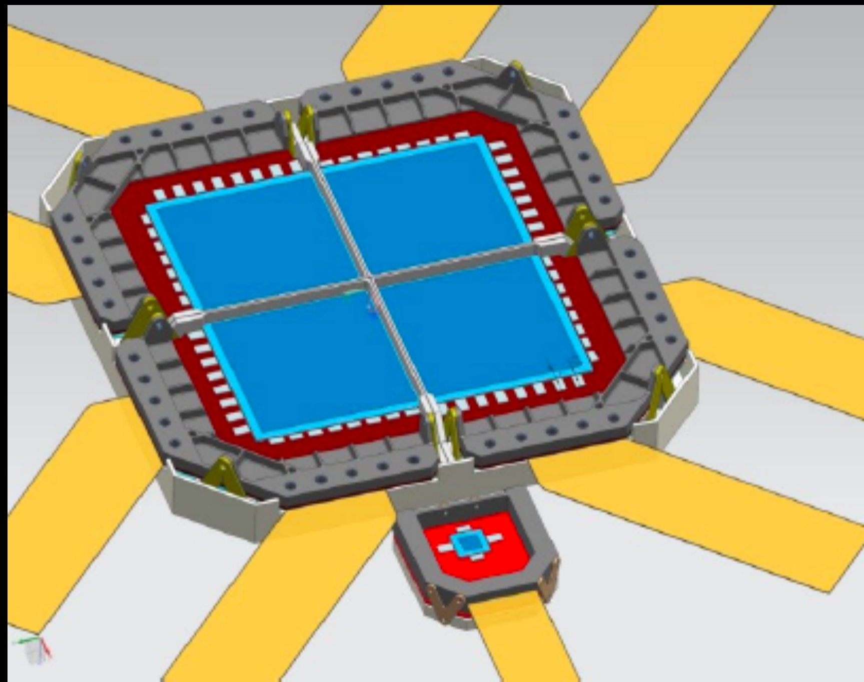
•Readout speed up to ~30 MHz

European consortium led by MPE (Germany), with participation of Austria, Denmark, France, Italy, Poland, UK and international partners (USA and Japan)

Optimized for:

• sensitive wide imaging at intermediate resolution spectroscopy

•Very bright sources



Rau et al 2013

Rau et al 2013, **arXiv1308.6785**

The Athena X-ray Integral Field Unit (X-IFU)

(see talk by J.W. den Herder)

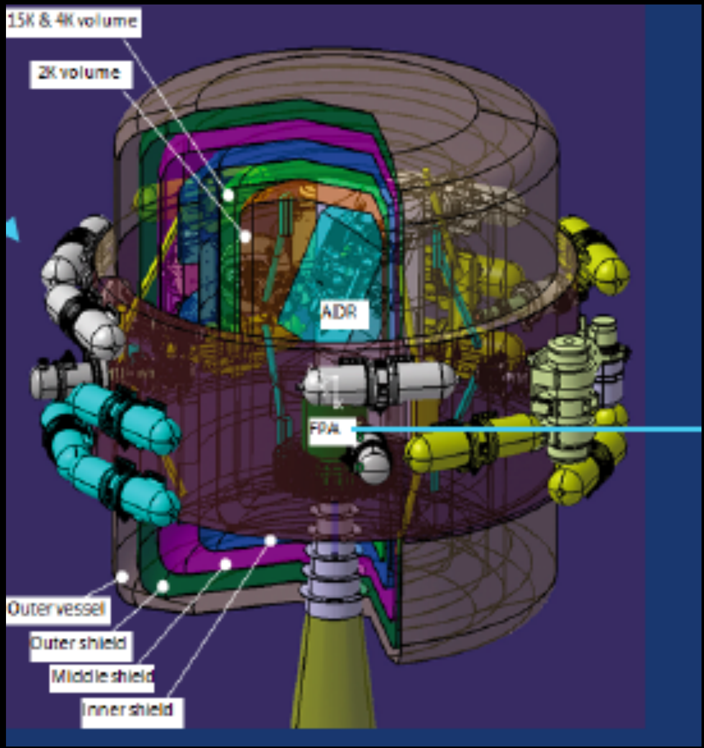
Cryogenic imaging spectrometer:

- based on Transition Edge Sensor
- operated at 50 mK
- multi-stage cooling chain
- active cryogenic background rejection subsystem

Consortium led by CNES/IRAP-F, with SRON-NL, INAF-IT and other partners in Belgium, Finland, Germany, Poland, Spain Switzerland and international partners (NASA and JAXA)

Optimised for:

- Spatially resolved X-ray spectroscopy
- High-resolution spectroscopy

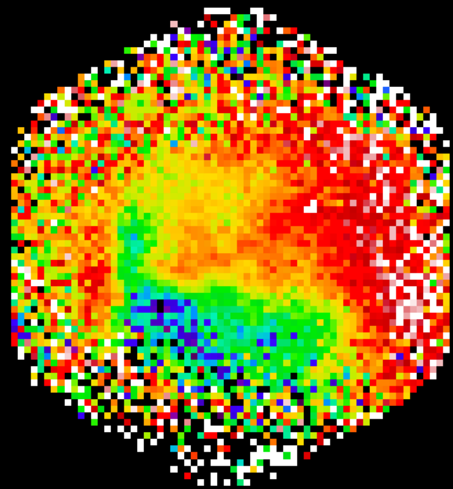


Barret, den Herder, Piro et al 2013, arXiv:1306.6784

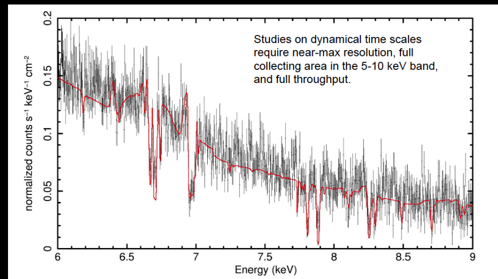
The Athena X-IFU science capabilities

The 3D view of the Hot and Energetic Universe

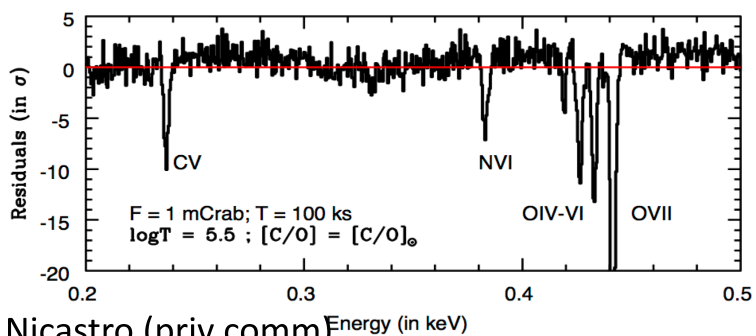
- 3D mapping of hot cosmic gas through spatially resolved spectroscopy
- Weak spectroscopic line detection (mostly absorption lines)
- Physical characterization of the HEU: plasma diagnostics (using multiplets), AGN reverberation and spins, BHXB reverberation, AGN outflows, stellar mass outflows, Solar Wind etc.



Peille et al (priv comm)



Miller et al (2015)



Nicastro (priv comm)

ATHENA

The Athena X-ray view of Black Holes

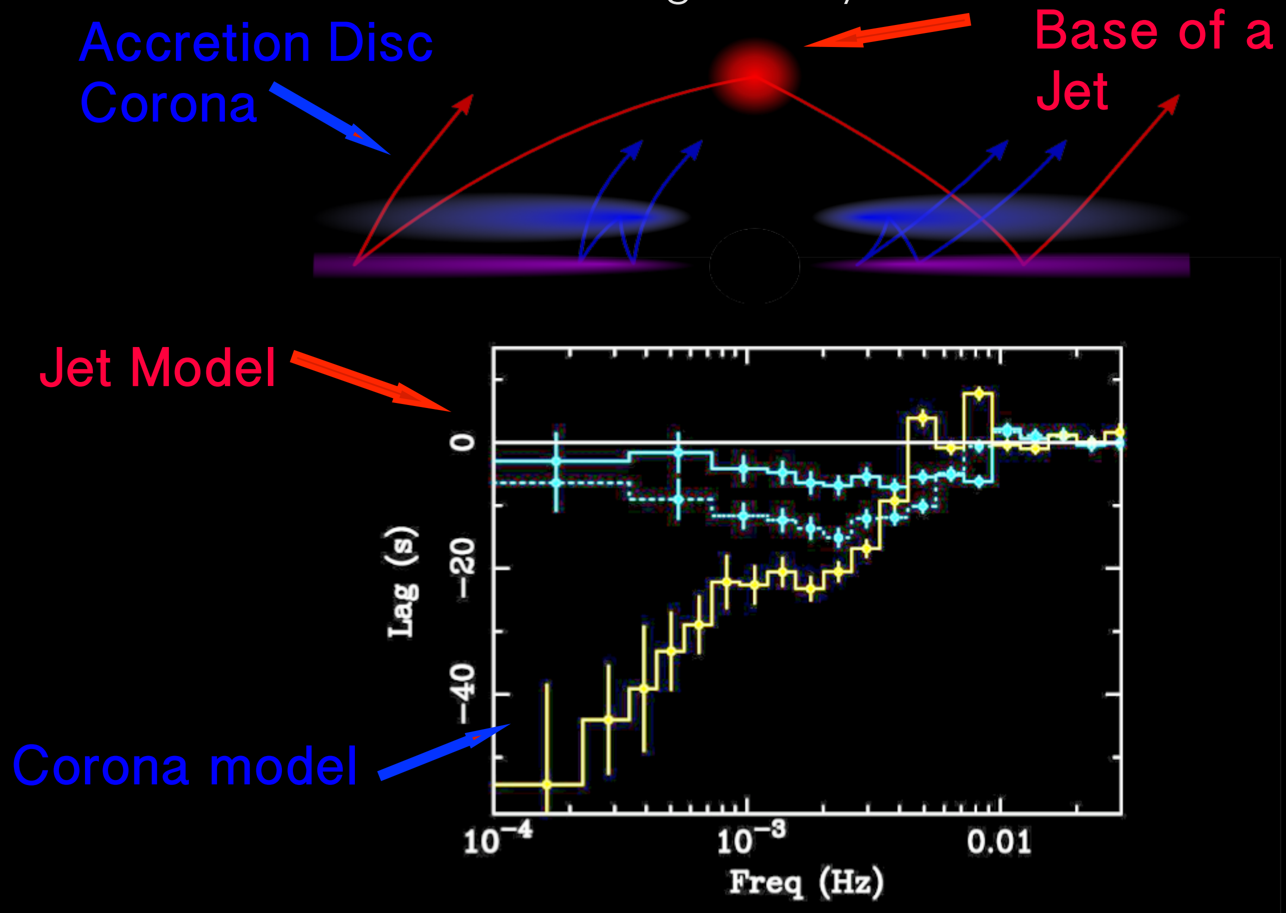
- The BH disk-jet connection
- Accretion and winds in BHBs
- Energetics of SMBH feedback:
- AGN winds and outflows
- Circum-nuclear matter
- Galactic & circum-galactic scales
- Cluster scales
- Early SMBH and their obscured growth
- SMBH spins: accretion vs mergers

MS0735.6+7421 (McNamara et al. 2005)

ATHENA

Mapping black holes near the event horizon

Reverberation mapping: disk-jet connection
& accretion flow geometry



Dovciak, Matt et al., 2013 arXiv1306.2331

Black Hole Binary winds

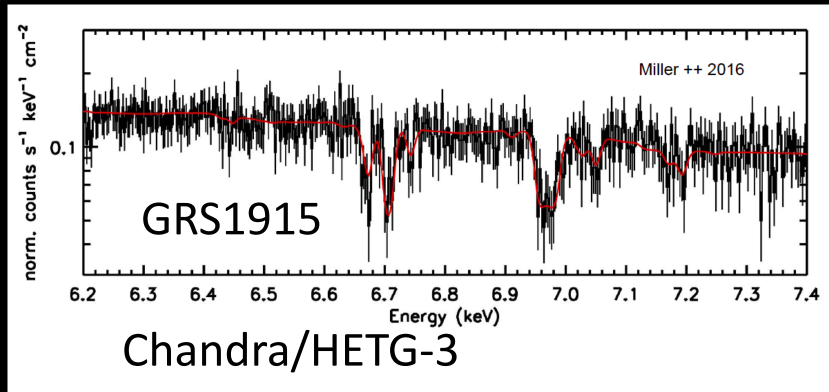
Connection between accretion disk & winds in BHBs

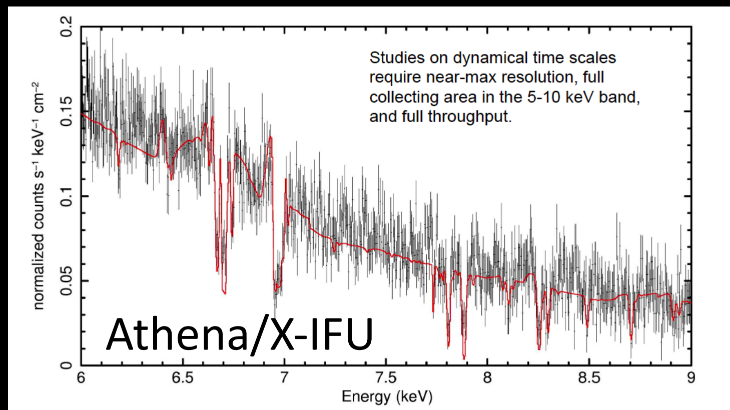
Winds connected to disk dynamical timescales ~100 sec

Expected/measured velocities in the range of 1000s of km/s

Present in bright soft states. Need to cope with:

- High count-rates
- High X-ray spectral resolution
- High throughput





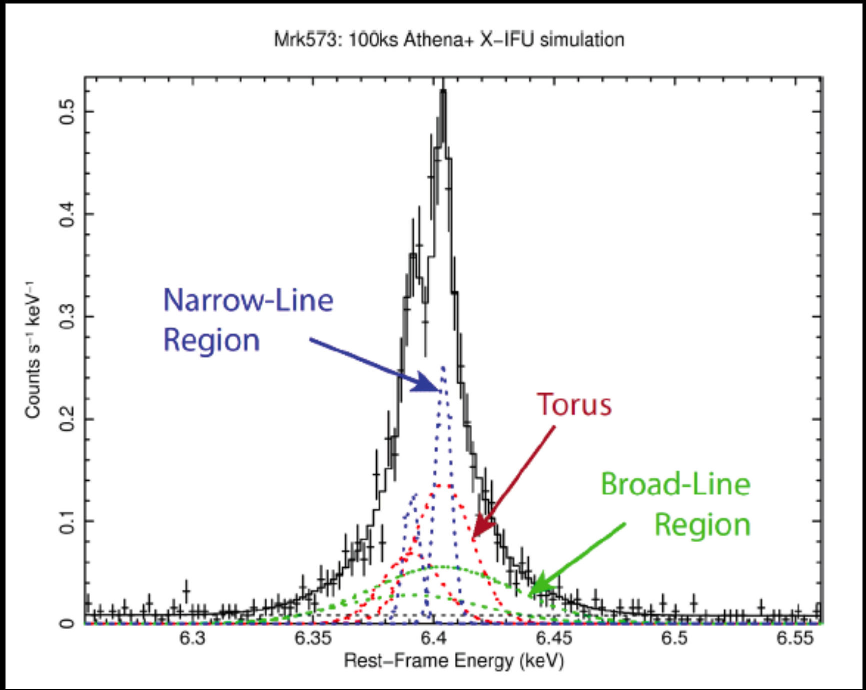
Miller et al (2015), MPE Athena meeting

Mapping AGN circum-nuclear matter

The sphere of influence of the SMBH

Origin of the narrow Fe line component

Contributions, velocities and turbulence from the BLR, NLR and Torus regions

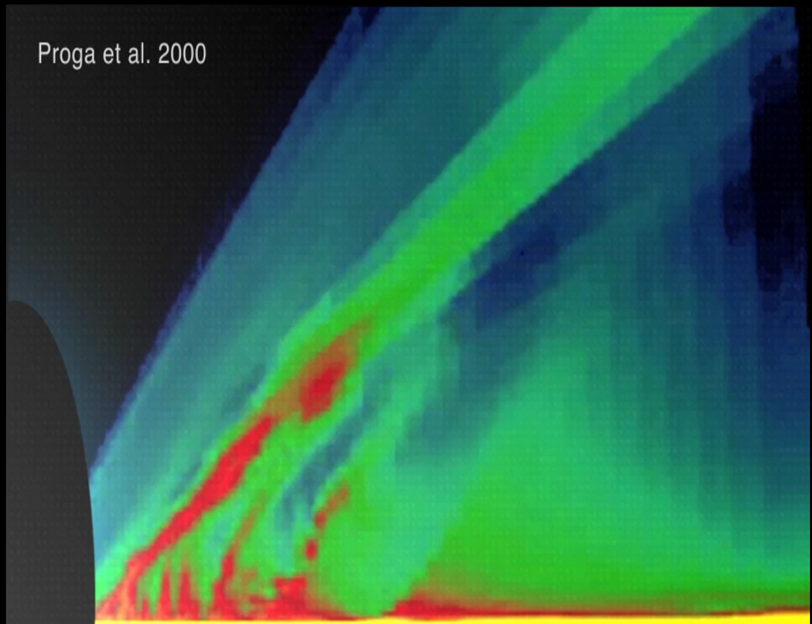


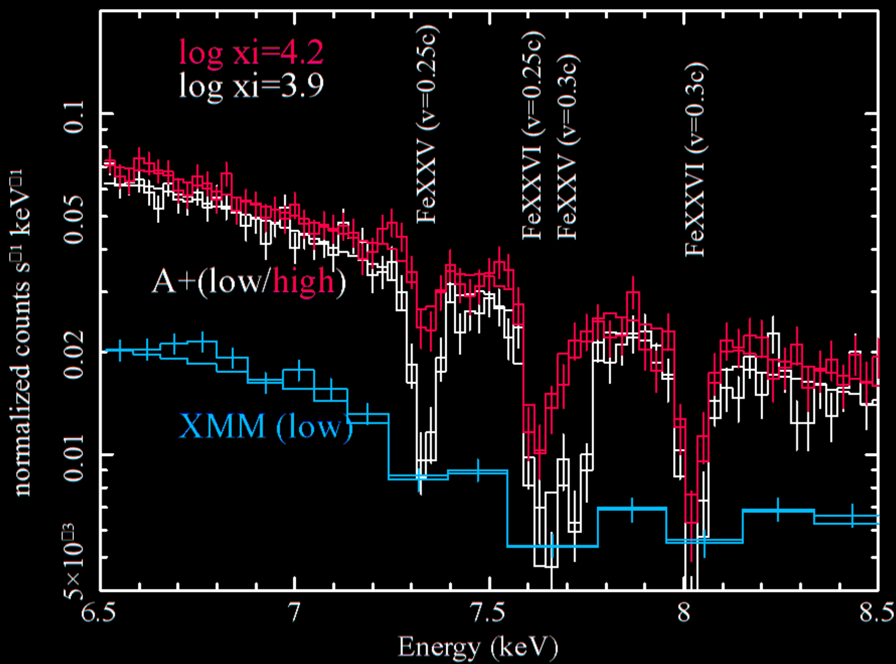
Credit: S. Bianchi

Dovciak, Matt et al., 2013 arXiv1306.2331

AGN winds and outflows

Measuring the mechanical energy of AGN winds & outflows
Disentangling their origin via time-resolved spectroscopy





(See talk by M. Cappi)

Cappi, Done et al., 2013 arXiv1306.2330
Dovciak, Matt et al., 2013 arXiv1306.2331

X-IFU

AGN feedback at z~2

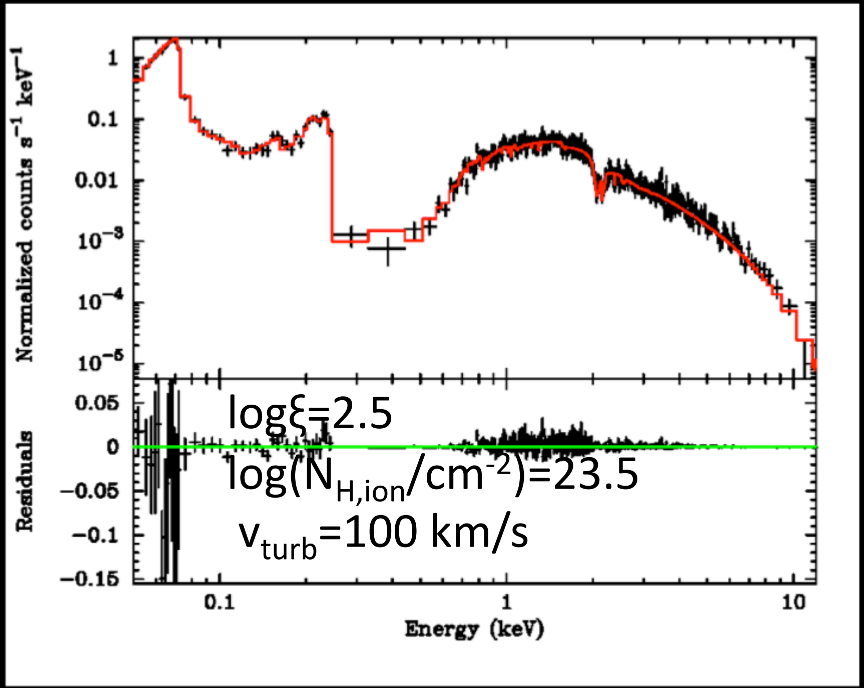
How does feedback operate at the peak of star formation and SMBH growth?

Quantify the incidence and energetics of Ultra-Fast outflows at z~1-4

•Can detect all large ($N_H > 10^{24}$ cm^{-2}) ionised and fast (>3000 km/s) absorbers for $L_X > 10^{44}$ erg/s and z<4 with WFI survey

•Slower and/or less massive outflows can also be measured with X-IFU. (But they can still carry a lot of energy $\sim N_H v_{out}^3$)

•Are molecular (& ionised gas) outflows at z~2 driven by AGN, starbursts or both?



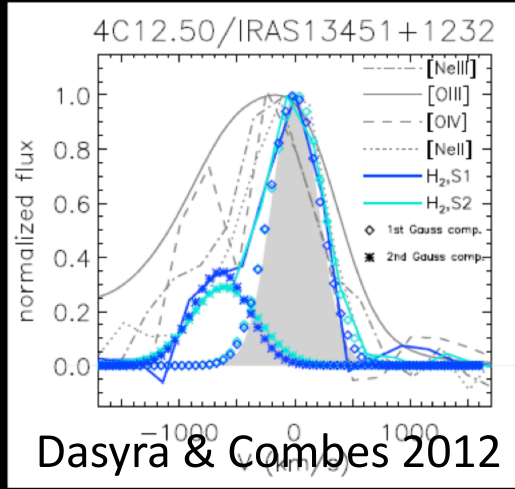
Georgakakis, Carrera et al., 2013 arXiv1306.2328

Energetics of AGN outflows

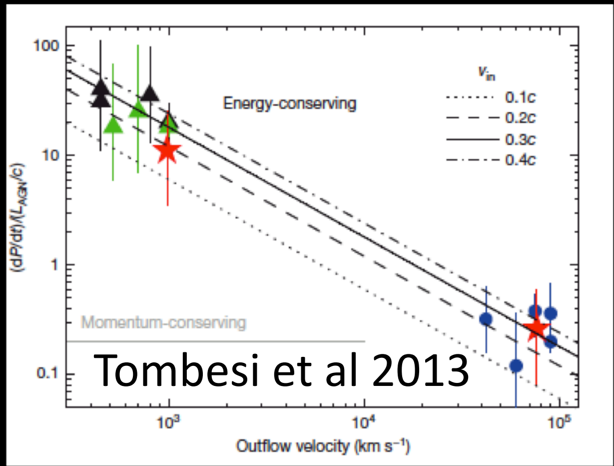
Molecular outflows are routinely found with IRAM-PdB, ALMA and Herschel, even at significant redshift.

AGN winds appear to power these molecular outflows in a couple of cases, assuming energy conservation.

Athena will be able to measure AGN disk wind energetics at z~2, where ALMA is already finding molecular outflows



Dasyra & Combes 2012



Tombesi et al 2013

ATHENA

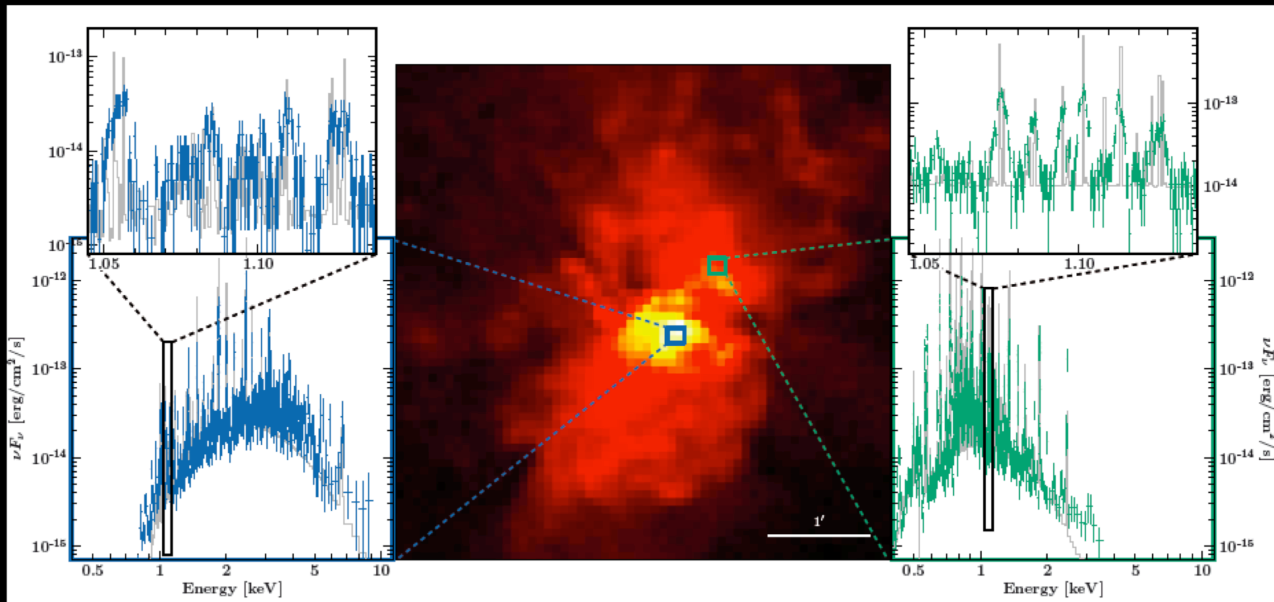
AGN winds on galactic scales

Interaction of AGN outflows with galactic & circum-galactic environment

Disentangling AGN contribution, thermal emission, shocked winds and possibly charge exchange.

Relative contributions from SMBH growth and Supernovae in ULIRGs.

The impact of AGN and Starburst winds on galactic scales



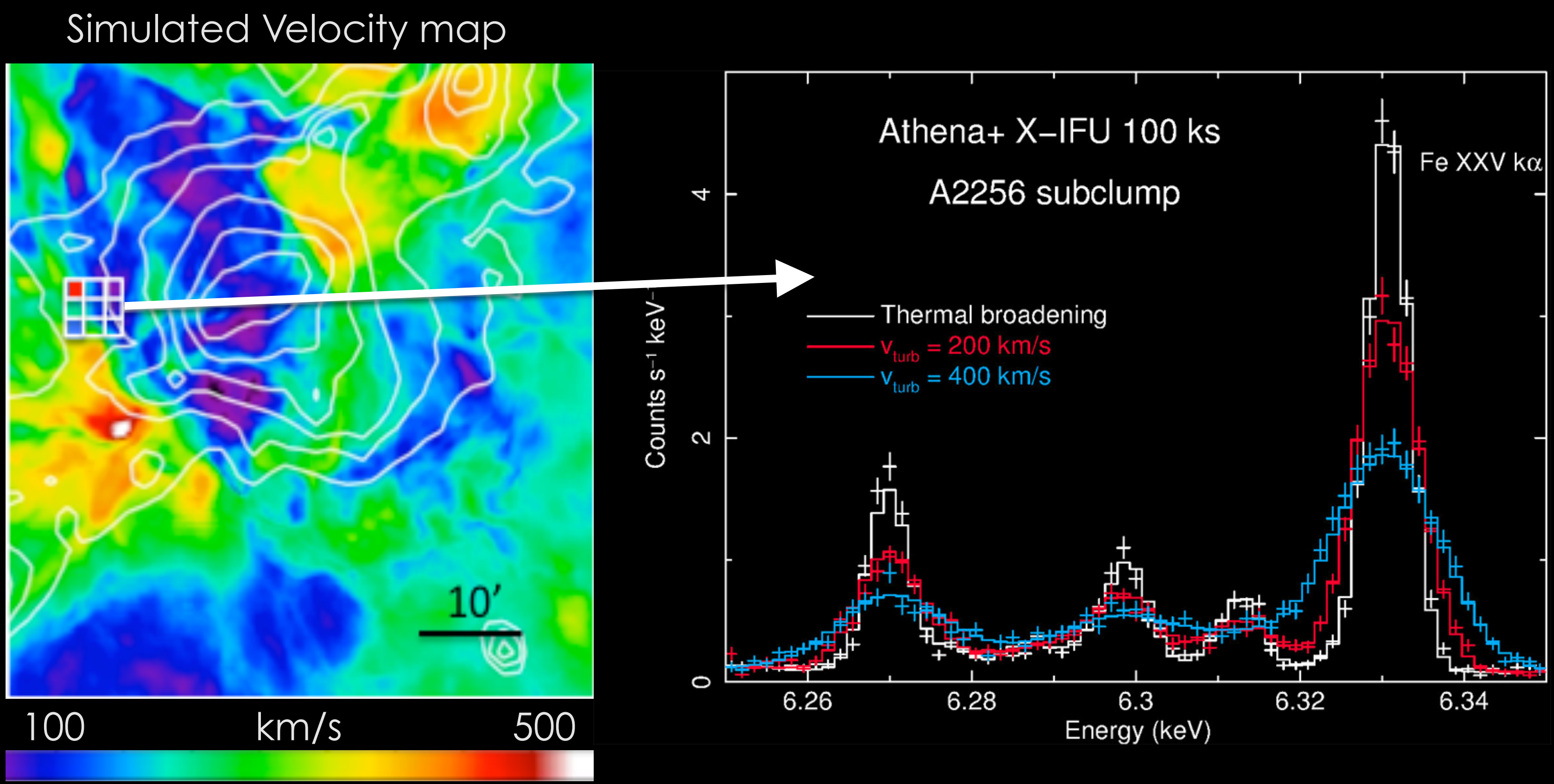
Ptak et al 2015 (in progress)

Cappi, Done et al., 2013 arXiv1306.2330

ATHENA

Measuring bulk velocities and turbulence on galaxy clusters

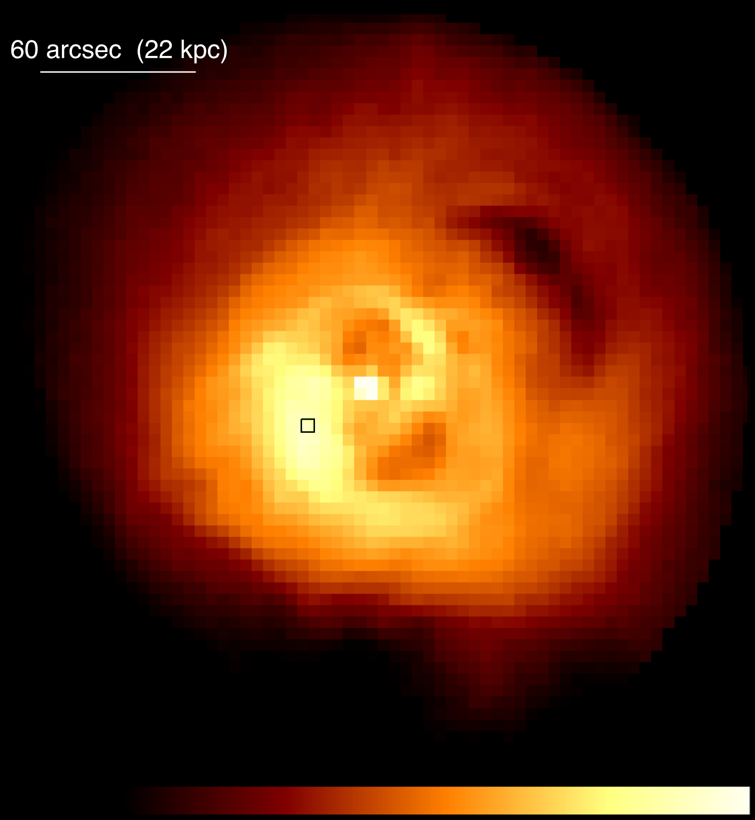
AGN feedback on cluster scales

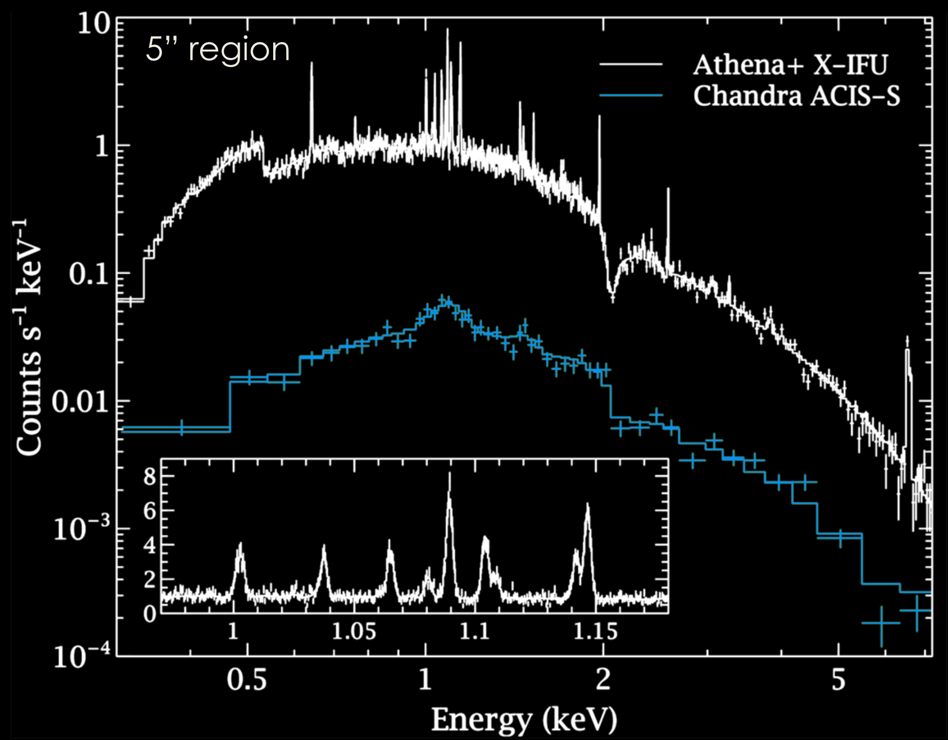


Ettori, Pratt, et al., 2013 arXiv1306.2322

Cosmic feedback: the impact on galaxy 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?





Croston, Sanders et al., 2013 arXiv1306.2323

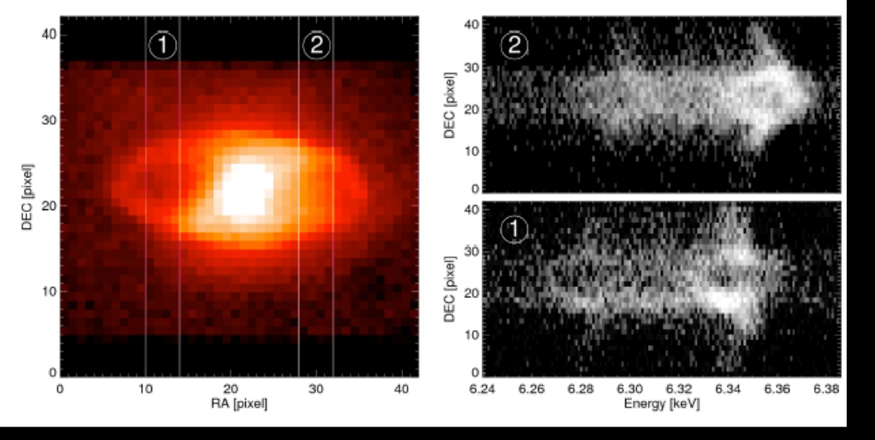
ATHENA

X-IFU

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.

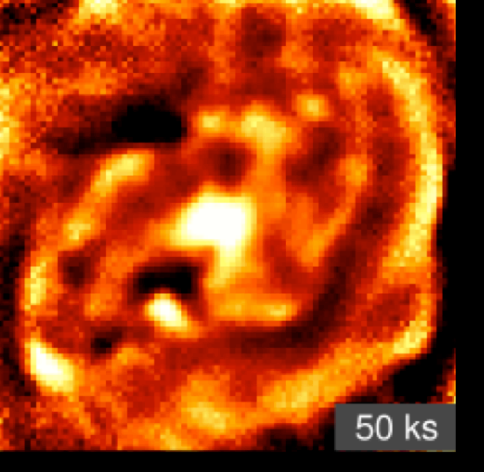


Simulations by S. Heinz

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

ATHENA

Early growth of SMBH

What were the seeds of SMBH at high-z?

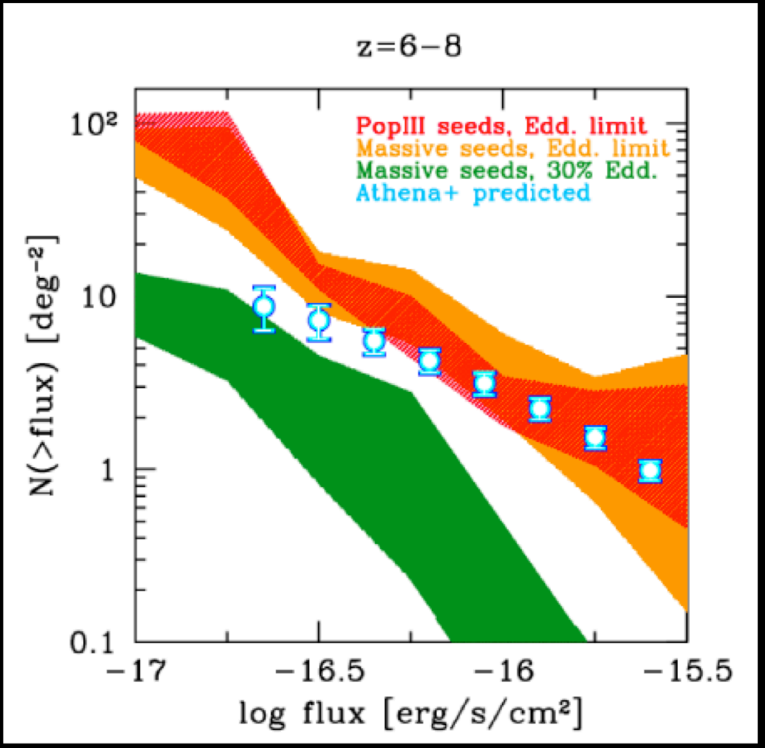
How did those SMBH grow?

High-z QSOs with large SMBH masses challenge our understanding of SMBH growth.

X-ray surveys can map the bulk of SMBH growth at high-z,

NIR/Optical surveys can easily find SMBH, but only very luminous ones

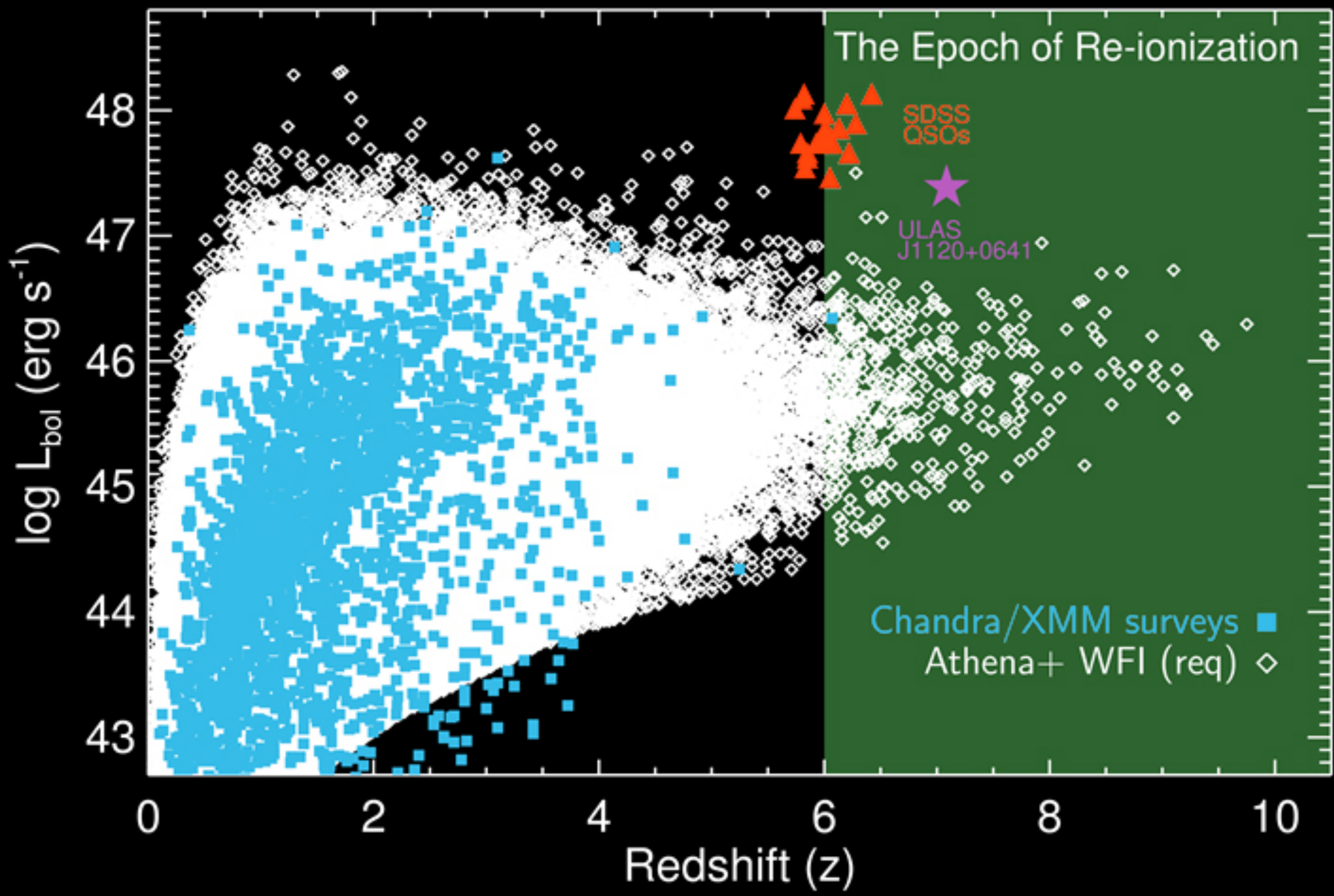
An Athena/WFI multi-tiered survey will find 100s of $L_X>10^{43}$ erg/s AGN at z>6 and 10s of $L_X>10^{44}$ erg/s AGN at z>8



Aird, Comastri et al. 2013 arXiv1306.2325

SMBH growth in the early Universe

What was the growth history of black holes in the epoch of reionization?



Aird, Comastri et al. 2013 arXiv1306.2325

ATHENA

Complete census of heavily obscured AGN

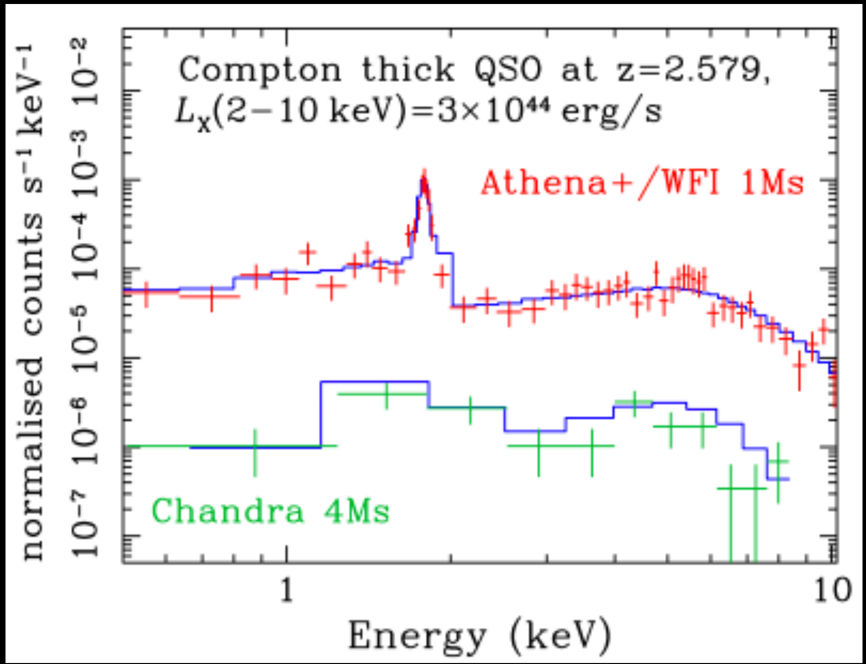
What is the relation between obscured growth of SMBH through cosmic history and how does it relate to galaxy formation?

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

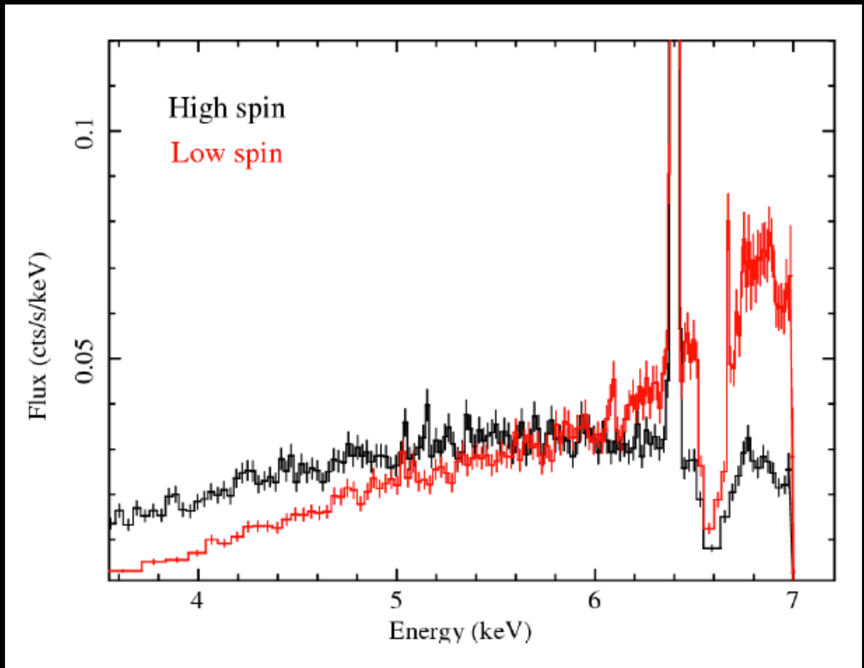
MIR observations can reliably uncover heavily obscured AGN, but only when the AGN is very powerful.

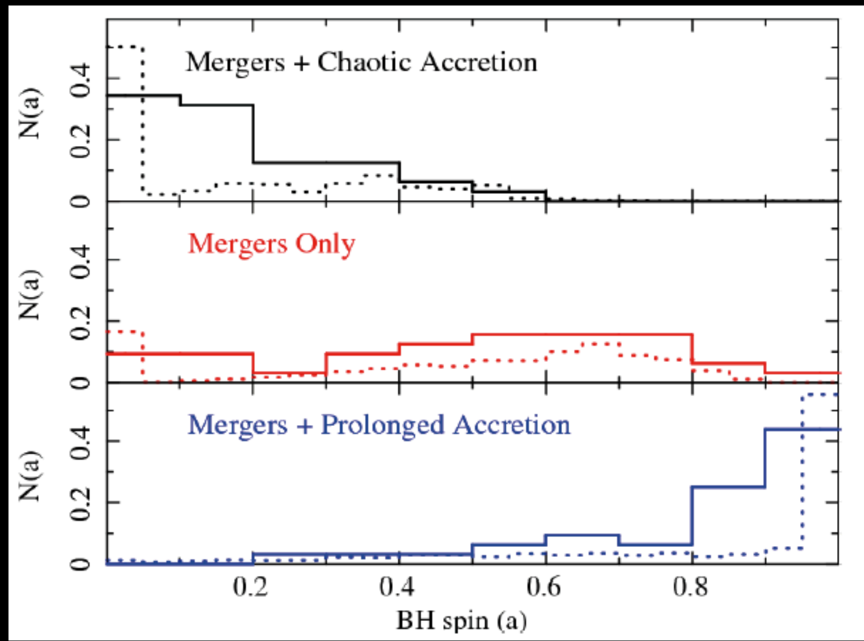


Georgakakis, Carrera et al. 2013 arXiv1306.2326

SMBH growth: mergers or accretion?

High spectral resolution instrumental to disentangle Broad and Narrow components & absorption lines





Simulations by G. Miniutti
Mind selection biases C. Reynolds et al

Dovciak, Matt et al., 2013 arXiv1306.2331

Outlook

Athena will be an essential tool to study Black Holes and their environment in the late 2020s

On all scales:

- A few Schwarzschild radii: disk-jet connection, accretion flow geometry, BHB and SMBH spins
- Accretion disk: energetics of winds and outflows
- pc-scale in SMBH: BLR, NLR and Torus
- Galaxy scale: interaction of winds
- Cluster scales: bulk motions, turbulence, radio-mode feedback
- Early SMBH growth and obscured evolution

Spatially resolved high-resolution X-ray spectroscopy with the Athena/X-IFU is key for most of these challenges