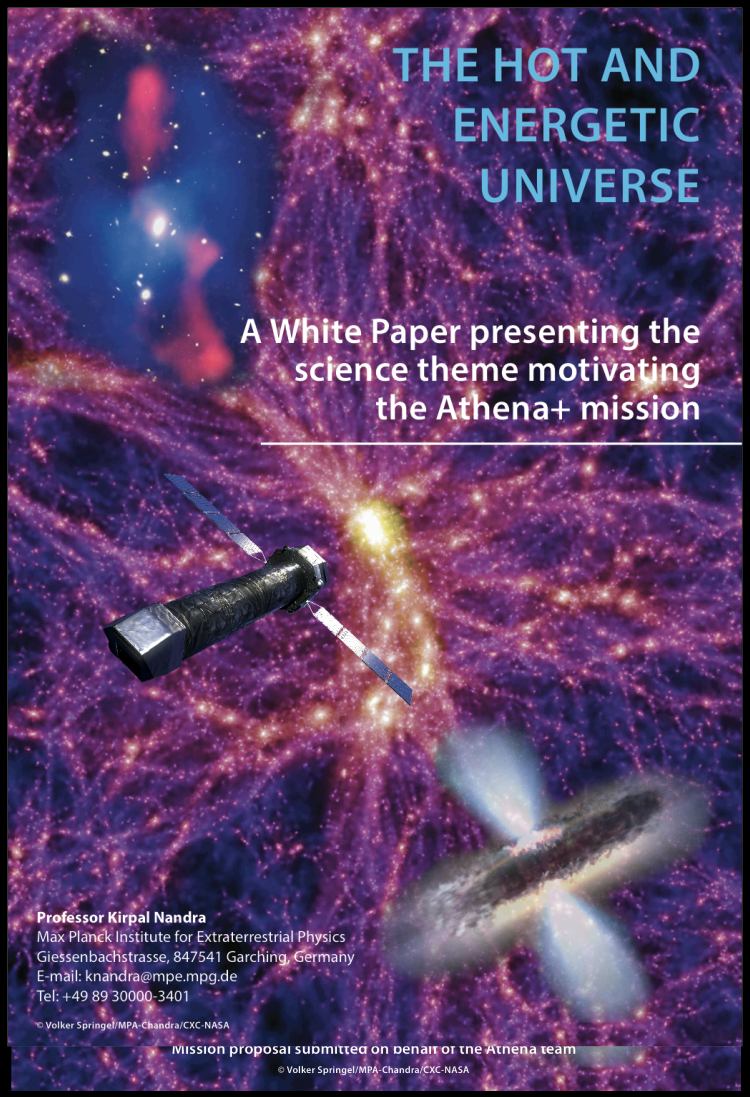
ATHENA

The Athena (just approved!) mission

A science theme approved by ESA for L2 slot (2028!) and which motivates the Athena mission (November 2013)

Massimo Cappi (IASF-Bologna)
On behalf of the Athena Coordination group and Working groups



- ***The Hot Universe:*** **How does the ordinary matter assemble into the large-scale structures that we see today?**

  [N.B: >50% of the baryons today are in a hot (>10^6 K) phase; and 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?**

  [N.B: Building a SMBH releases 30 × the binding energy of a galaxy; and 15% of the energy output in the Universe is in X-rays (mostly released via accretion)]

- ***The (proposed) Mission:*** **High-throughput X-ray Observatory (X-IFU + WFI)**

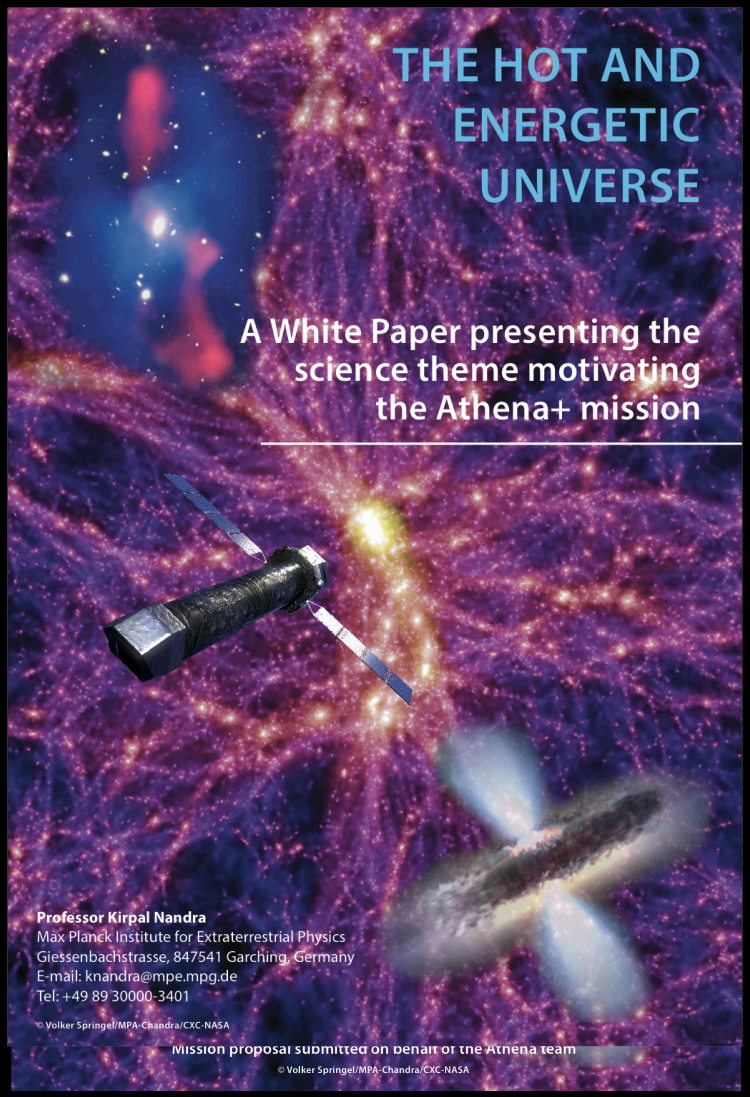
  A fantastic machine to address the Hot and Energetic Universe theme at both low-z (astrophysics) and high-z (cosmology/evolution)

ATHENA

The Athena (just approved!) mission

A mission proposal to ESA – Advanced Telescope for High-ENergy Astrophysics (June 2014)

Massimo Cappi (IASF-Bologna)
On behalf of the Athena Coordination group and Working groups



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ATHENA

The Athena (just approved!) mission

A mission proposal to ESA – Advanced Telescope for High-ENergy Astrophysics

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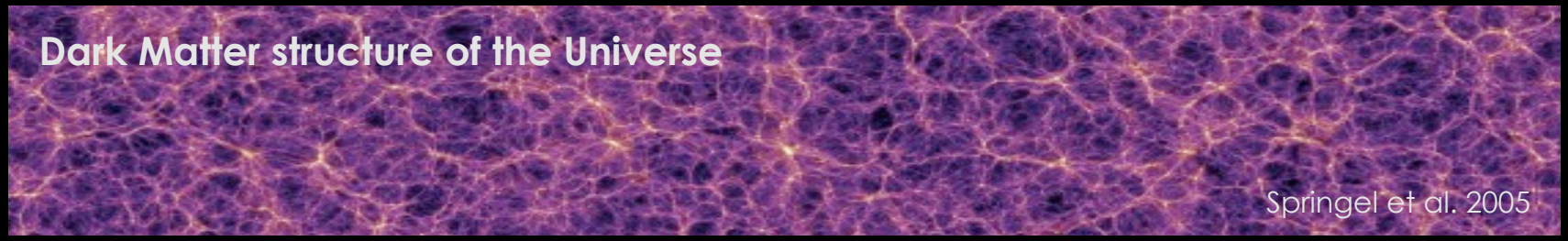
by ESA's SPC, June 2014

N.B: For Ass.&Def. studies!

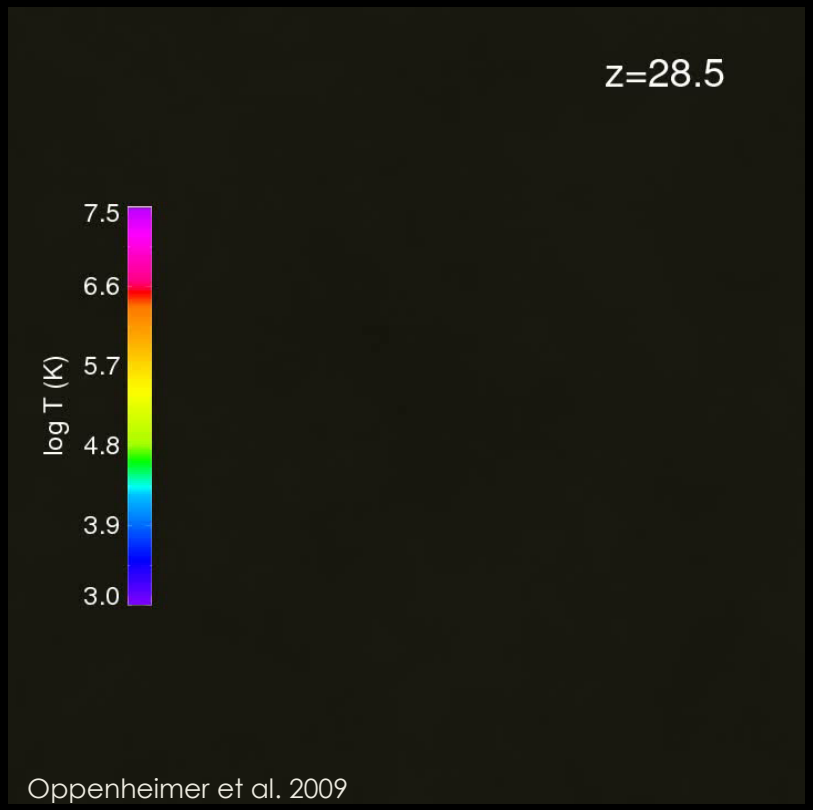
(key results from CDF and LFA meeting end of October…stay tuned!)

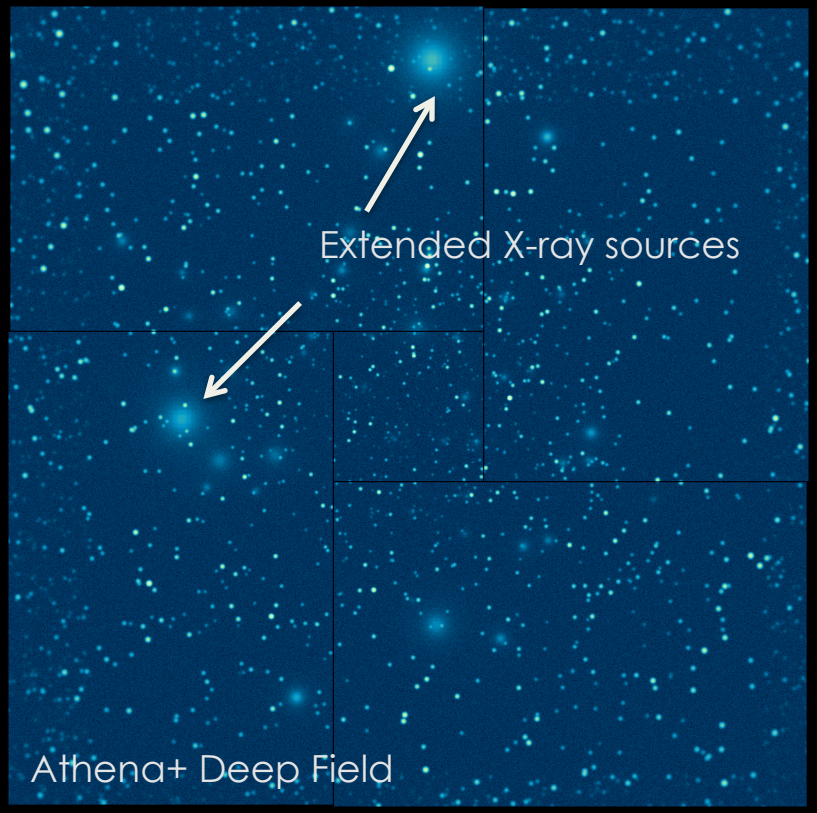
Why does the observable universe look the way it does?



Key questions for observational astrophysics in 2028

1. How does ordinary matter assemble into the large scale structures we see today?

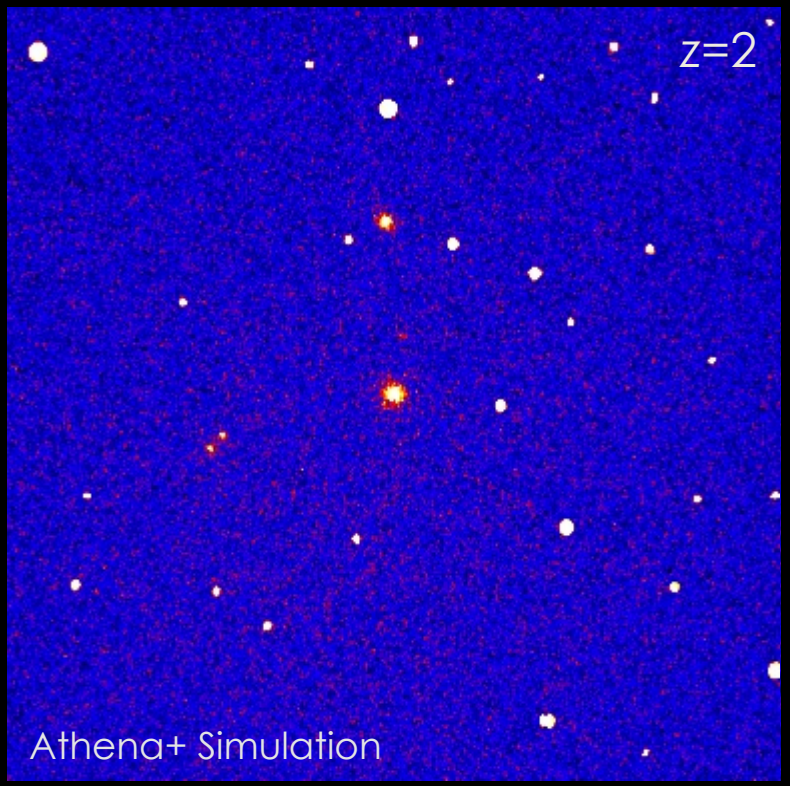




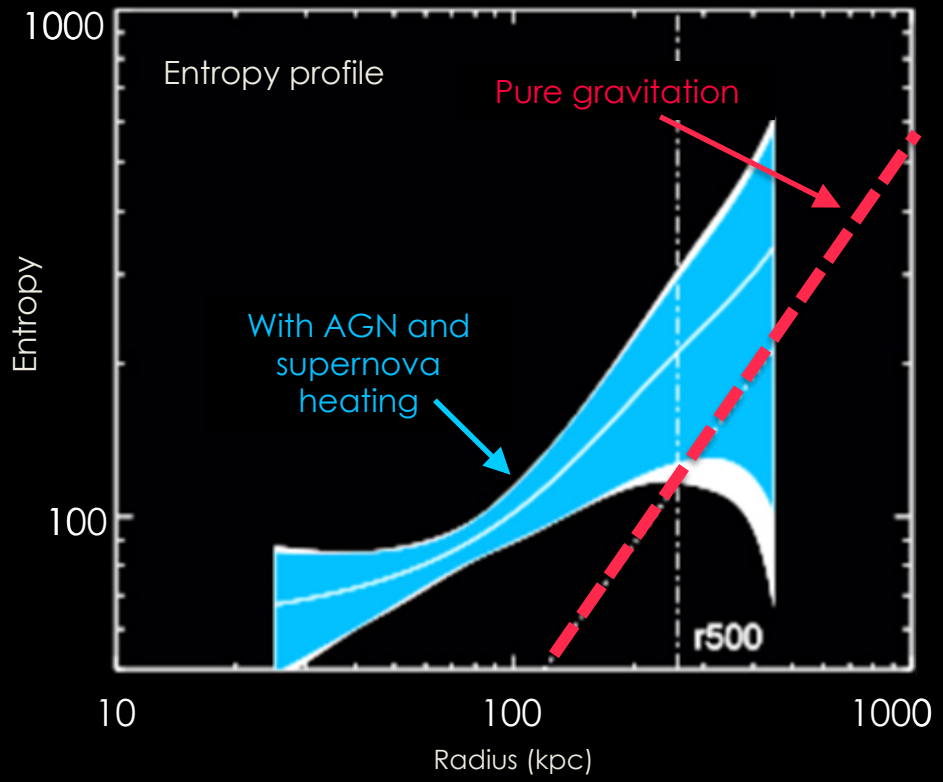
Pointecouteau, Reiprich et al., 2013 arXiv1306.2319

The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot intra-cluster medium generated?



Pointecouteau, Reiprich et al., 2013 arXiv1306.2319

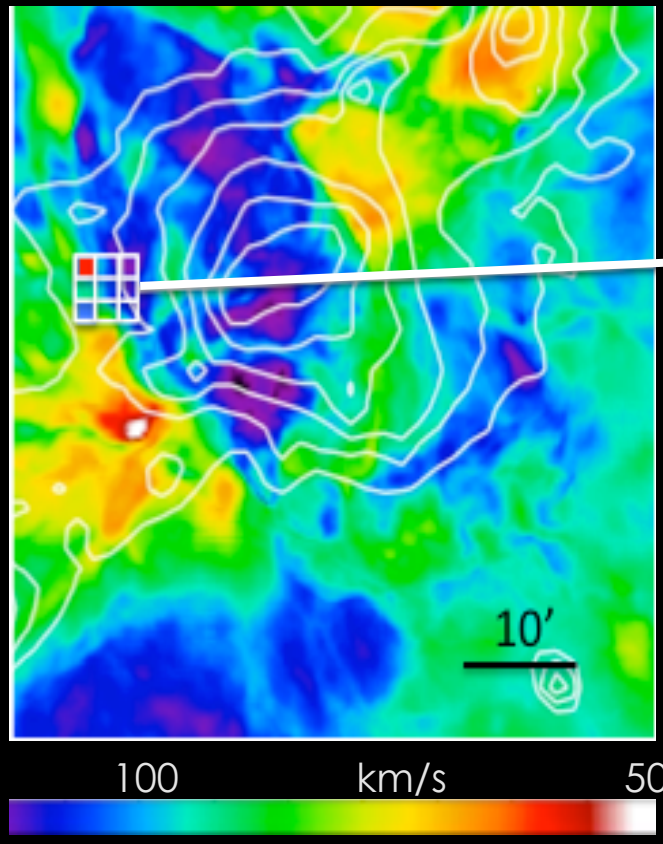


How does ordinary matter assemble into the large-scale structures that we see today?

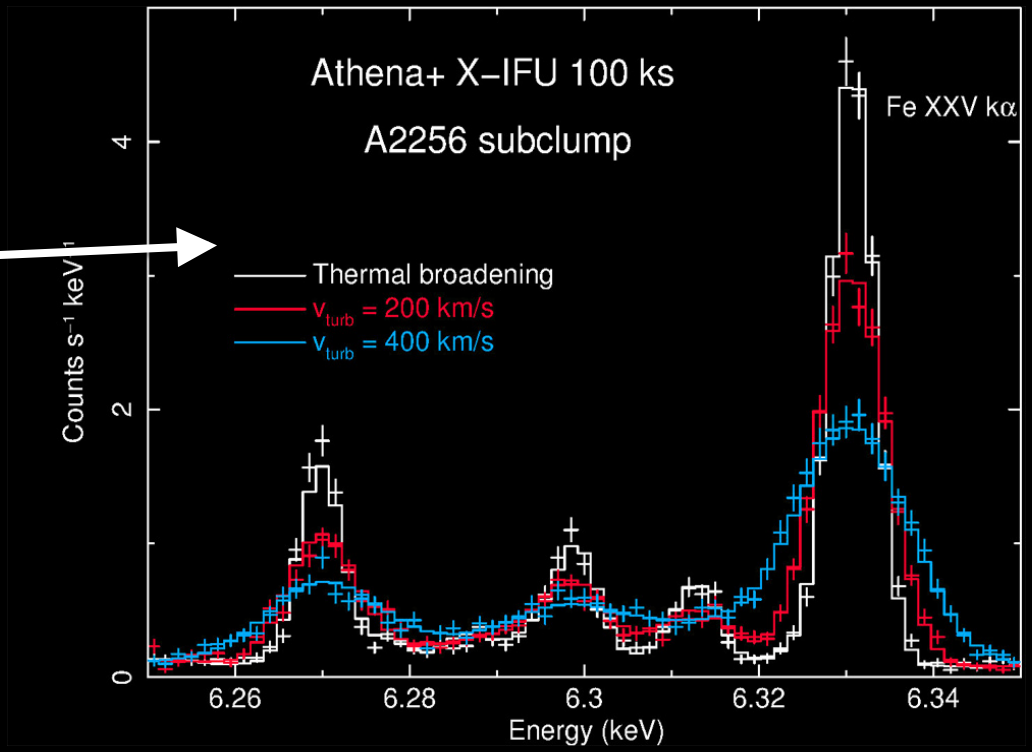
The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot intra-cluster medium generated?

Simulated Velocity map



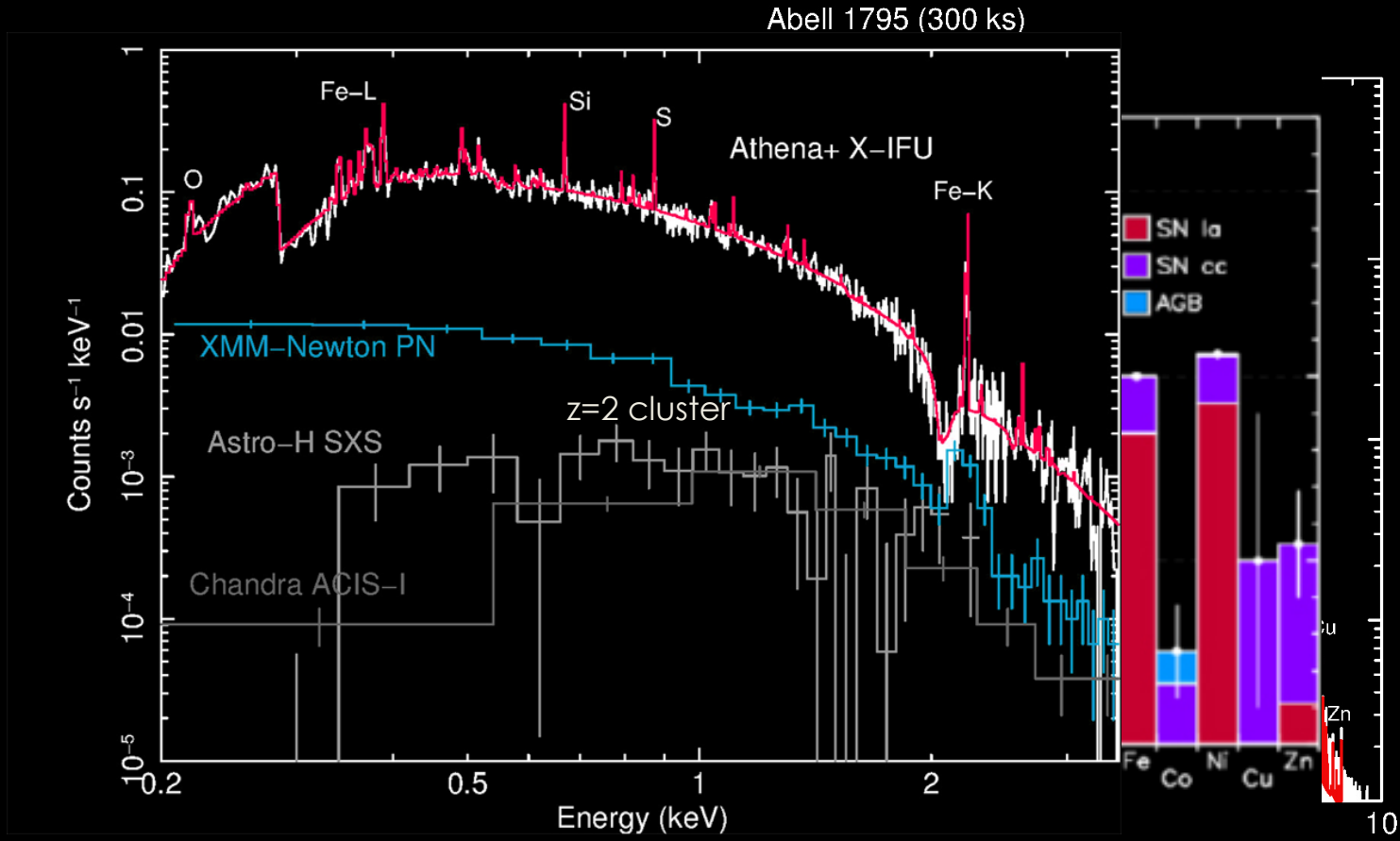
Ettori, Pratt, et al., 2013 arXiv1306.2322



How does ordinary matter assemble into the large-scale structures that we see today?

The chemical evolution of hot baryons

When and how were the largest baryon reservoirs in galaxy clusters chemically enriched?

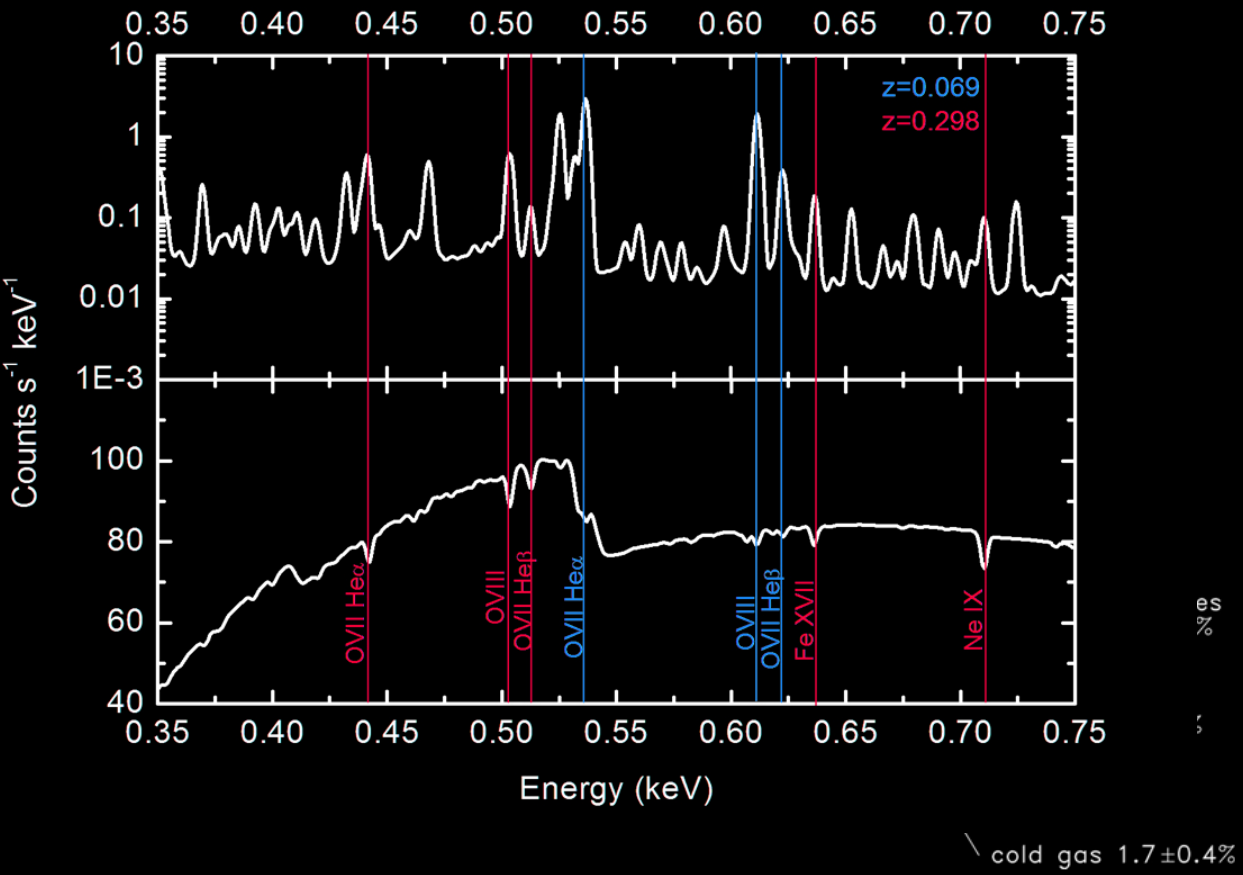


Ettori, Pratt, et al., 2013 arXiv1306.2322

How does ordinary matter assemble into the large-scale structures that we see today?

The Warm-Hot intergalactic medium (WHIM)

Where are the missing baryons in the local Universe? What is the underlying mechanism determining the distribution of the hot phase of the cosmic web?



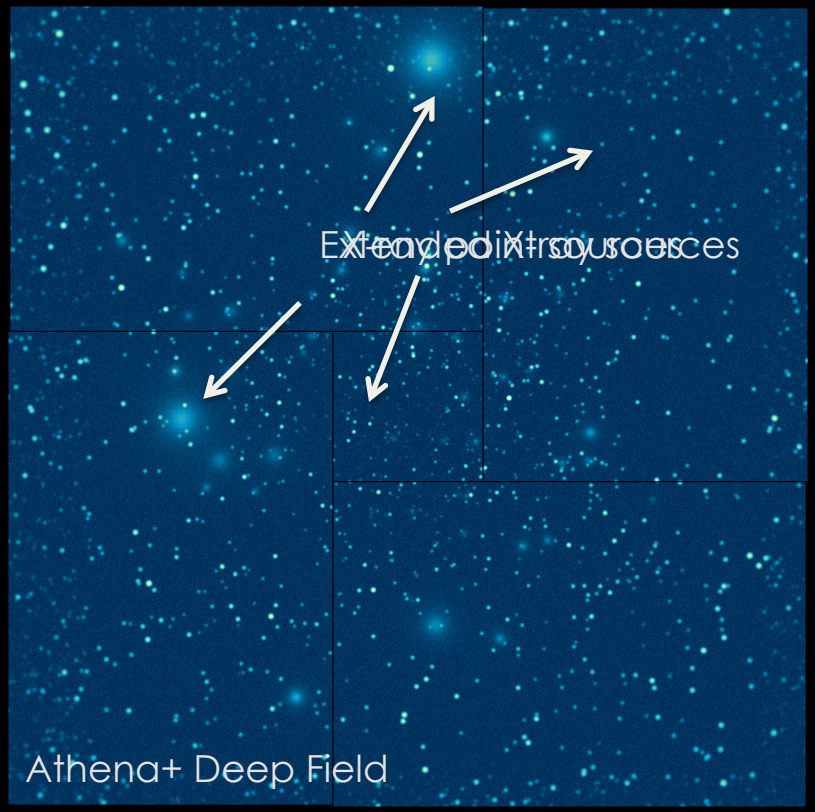
Kaastra, Finoguenov et al., 2013 arXiv1306.2324

How does ordinary matter assemble into the large-scale structures that we see today?

Key questions for observational astrophysics in 2028

1. How does ordinary matter assemble into the large scale structures we see today?

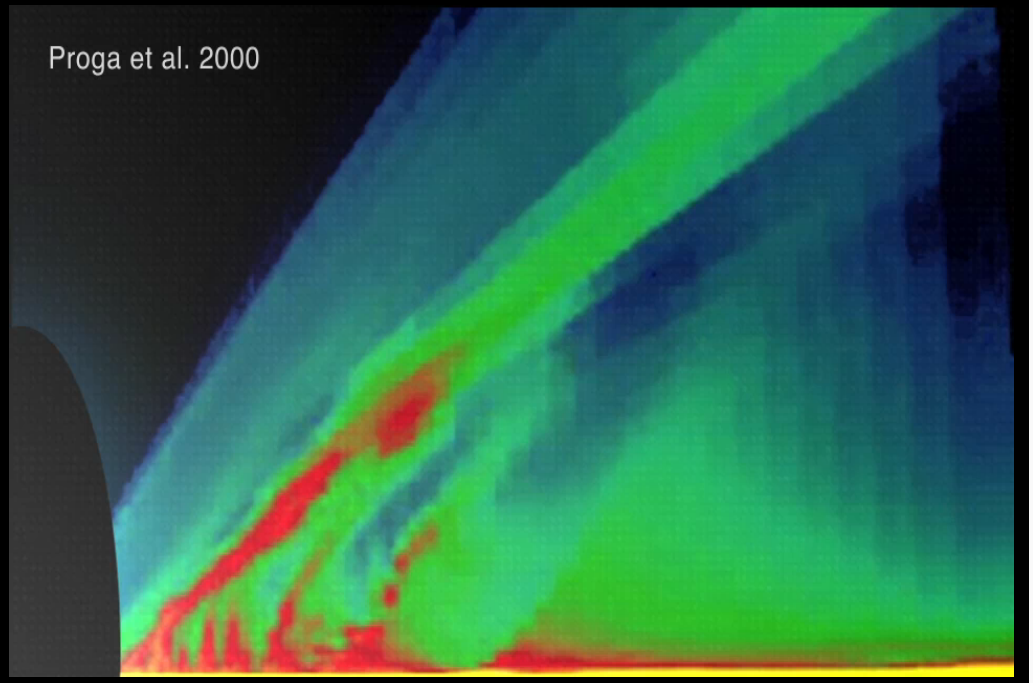
2. How do black holes grow and shape the Universe?

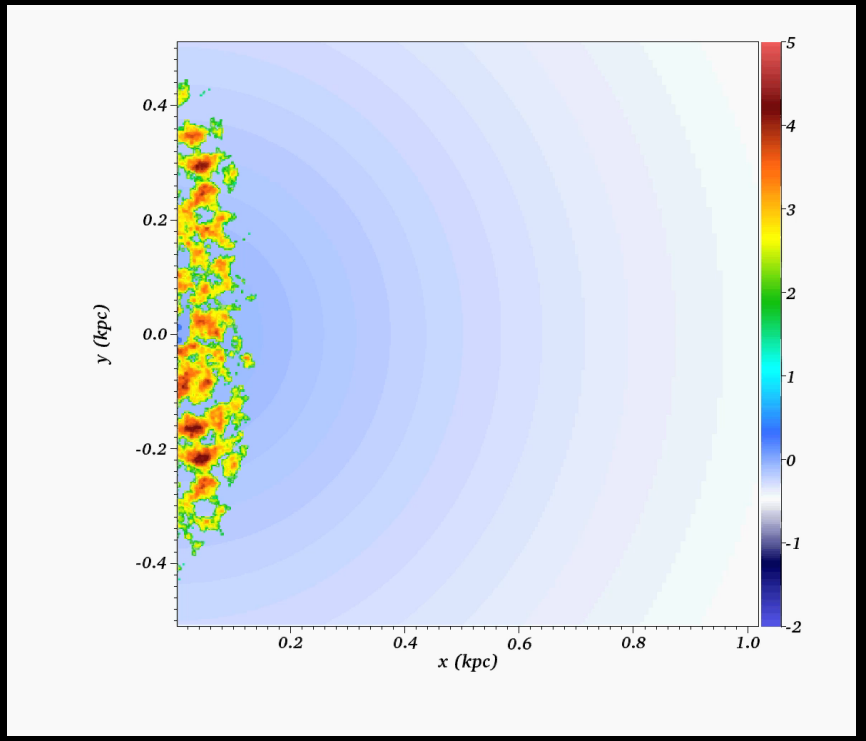


ATHENA

Cosmic feedback and the origin of black hole winds

How do black holes launch winds and outflows?
How much energy do they carry out to larger scales?

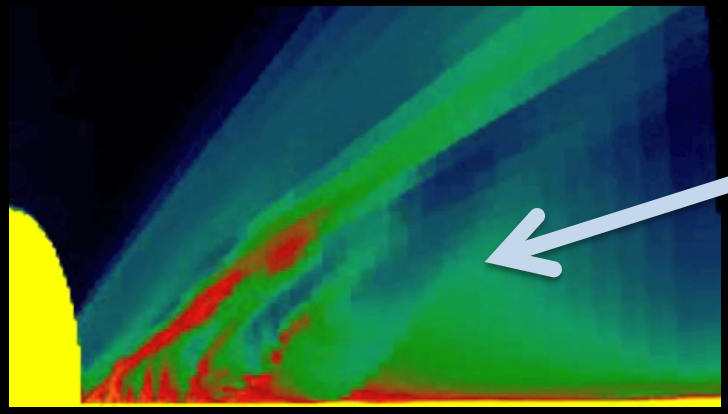


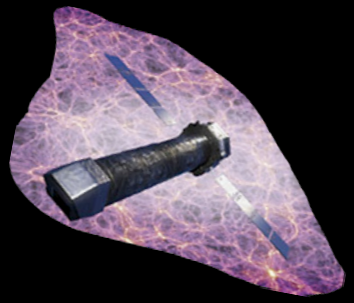


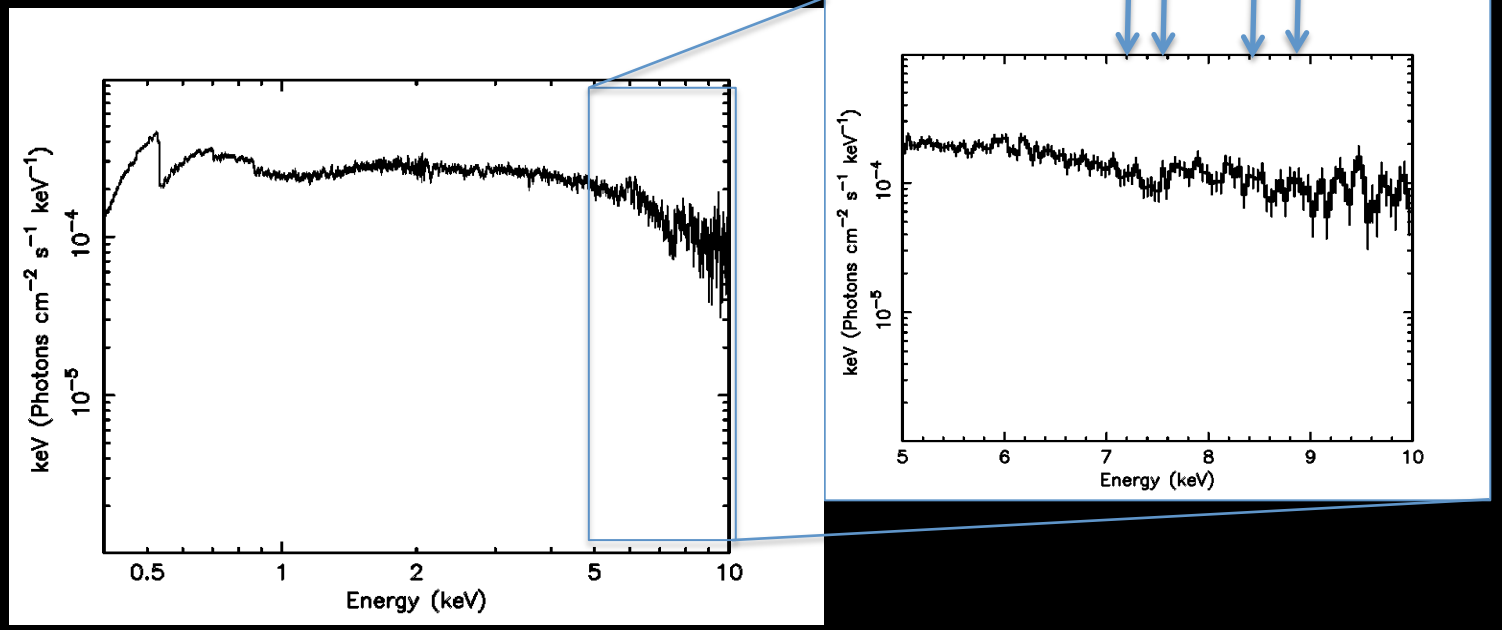
Cappi, Done et al., 2013 arXiv1306.2330
Dovciak, Matt et al., 2013 arXiv1306.2331

How do black holes grow and shape the Universe?

i) How do accretion disks around black holes launch winds/outflows, and how much energy do these carry?

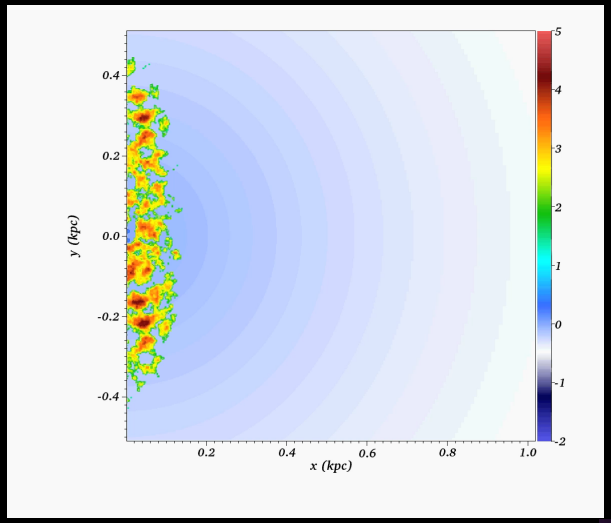


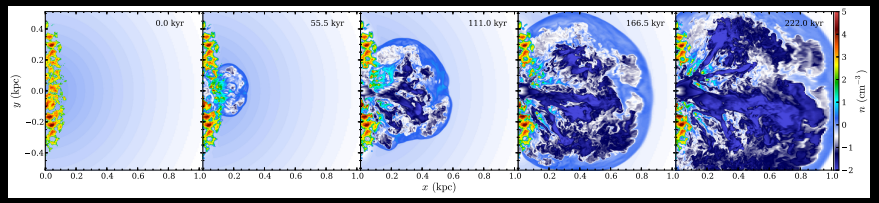




Only X-rays probe the highest energy outflows, need X-IFU with high effective area to probe fast outflows on the wind launching regions (few tens ks)

ii) How are the energy and metals accelerated in winds/outflows transferred and deposited into larger galactic scales?

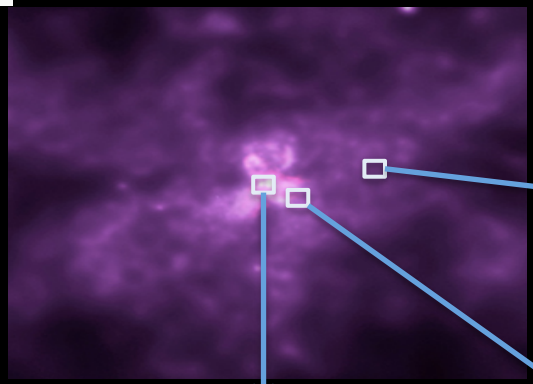


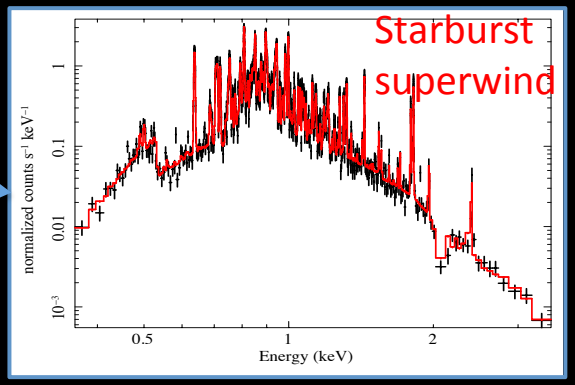


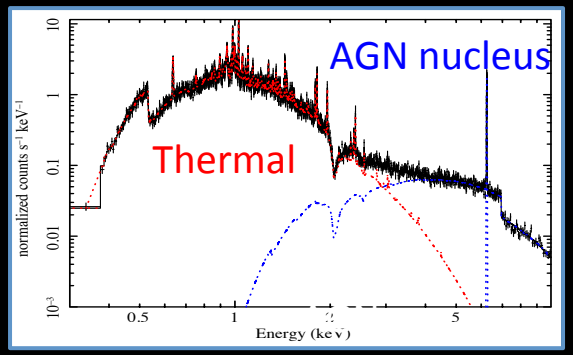
Wagner et al. 2013

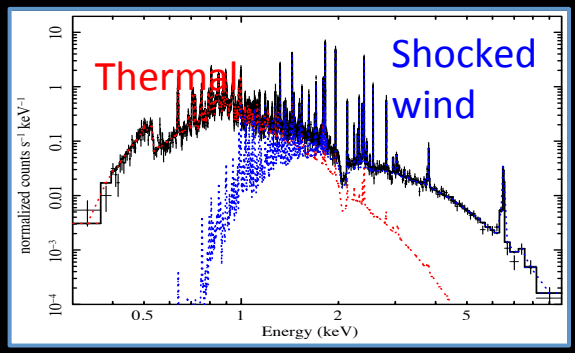
ULIRG NGC6240
(merging AGN+SB)

Unique capability
of X-IFU



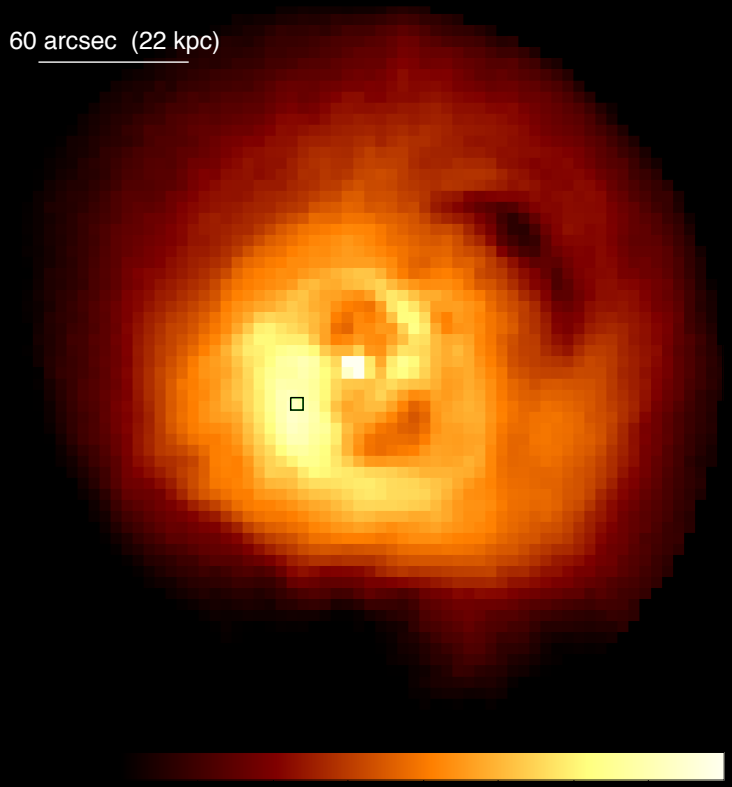


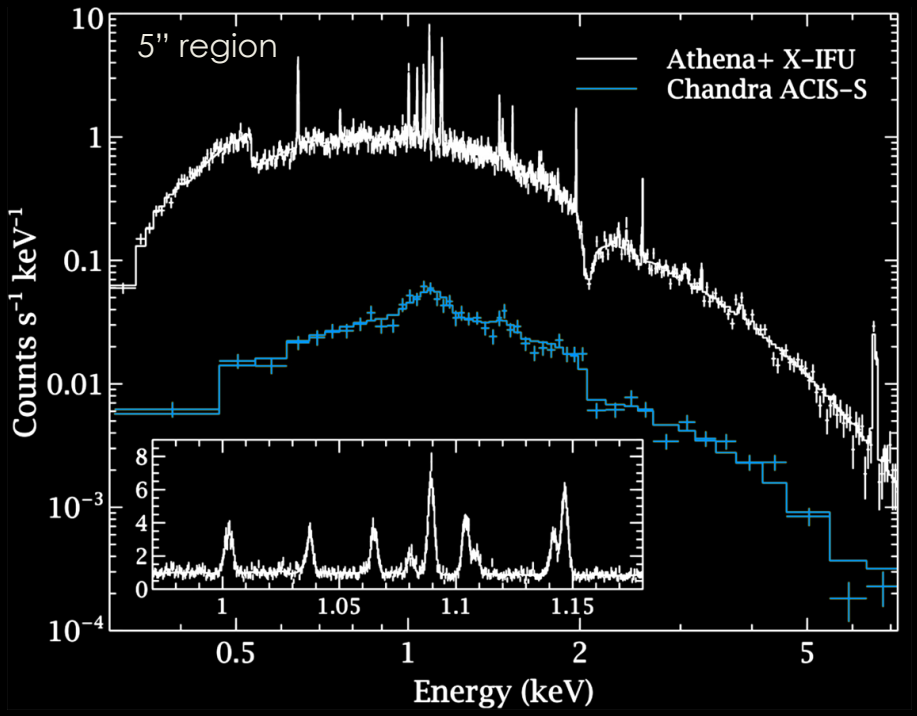




Cosmic feedback: the impact on galaxy cluster scales

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

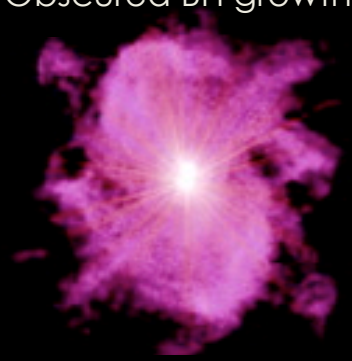
Cosmic feedback: black hole and galaxy co-evolution

How much black hole accretion occurs in the most obscured environments?
How does this relate to the evolution of the host galaxy?

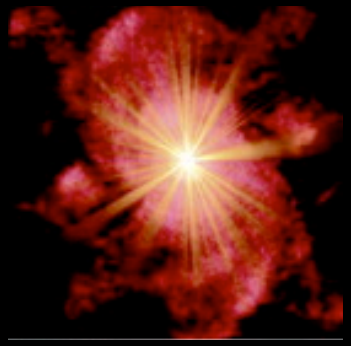
Disk instability

Ceverino et al. 2010

Obscured BH growth



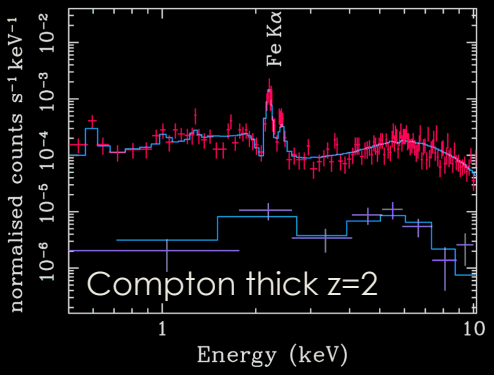
Feedback phase

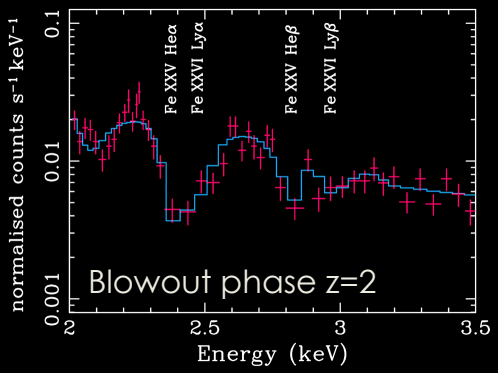


Quiescent remnant

Merger

Hopkins et al.2006



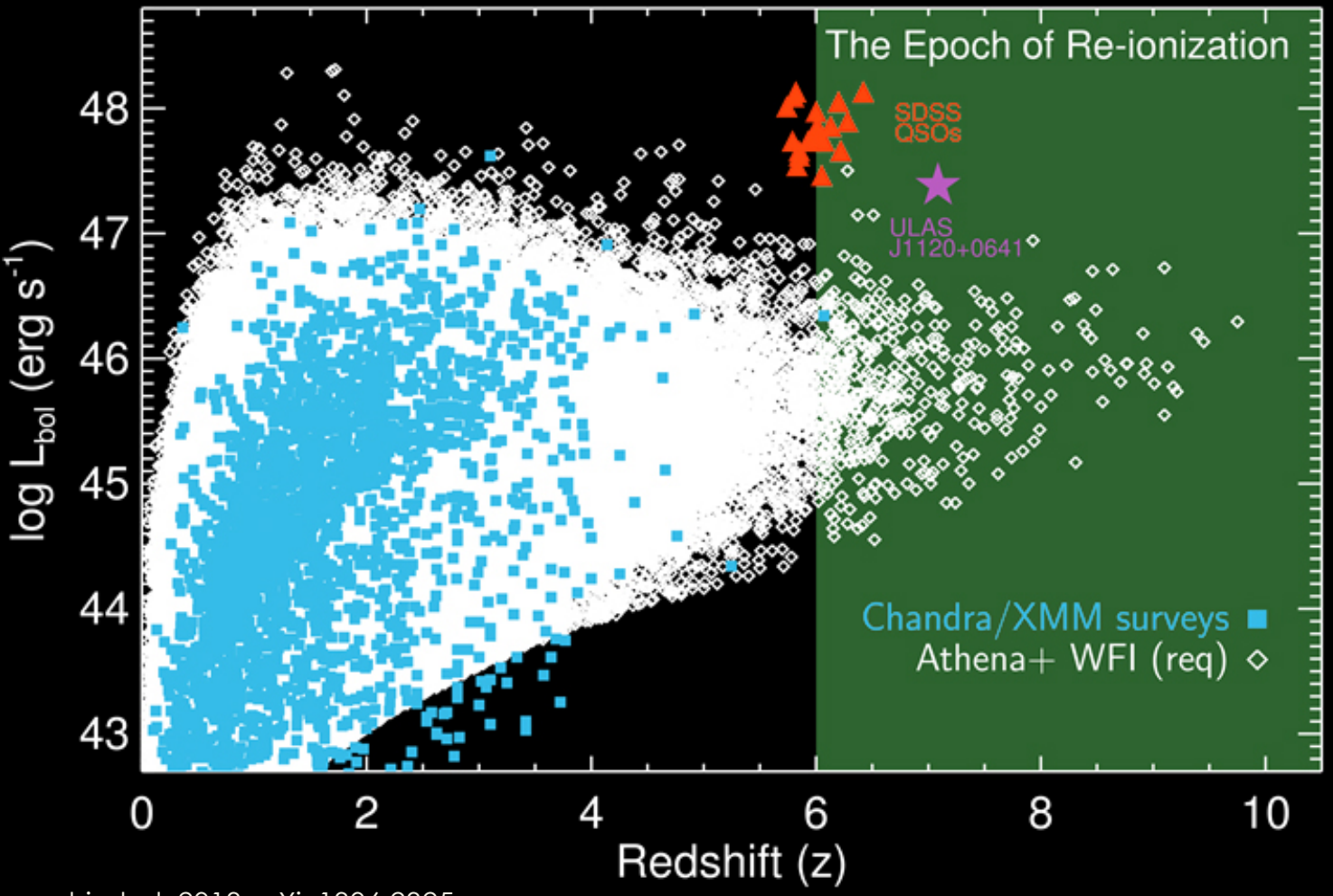


Georgakakis, Carrera et al., 2013 arXiv1306.2328

How do black holes grow and shape the Universe?

Black hole growth in the early Universe

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



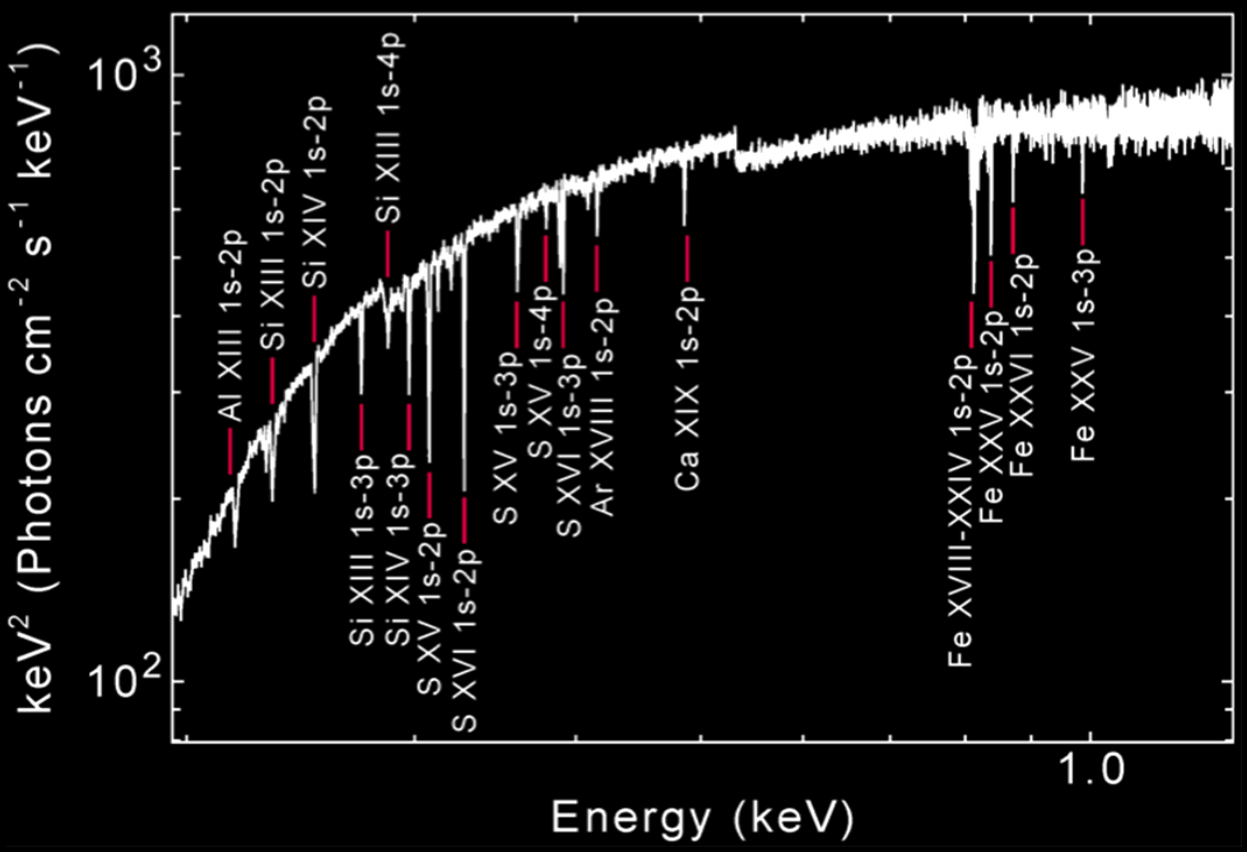
Aird, Comastri et al. 2013 arXiv1306.2325

ATHENA

The first stars and black holes

When did the first generation of stars explode to form the first seed black holes and disseminate the first metals in the Universe?

Gamma Ray Burst at z=7



Jonker, O'Brien et al., 2013 arXiv1306.2336

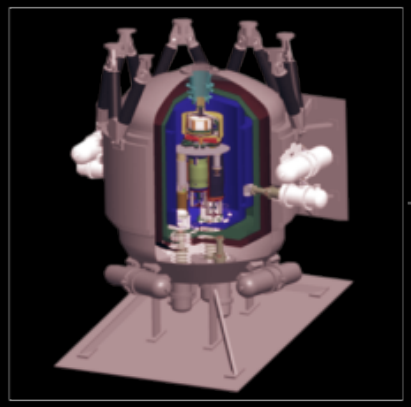
How do black holes grow and shape the Universe?

ATHENA

The Athena Observatory

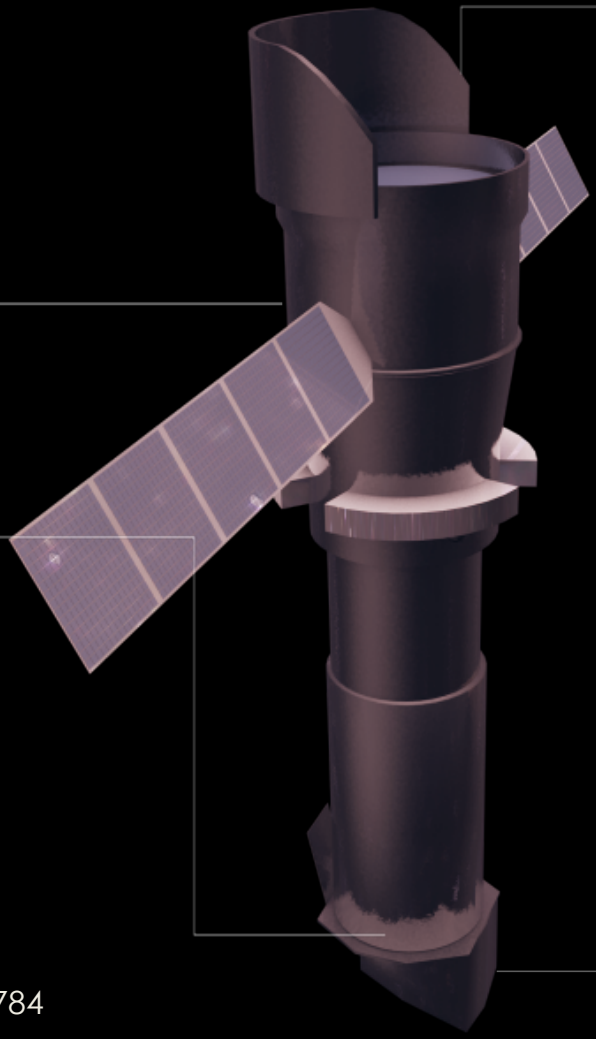
Willingale et al, 2013
arXiv1308.6785

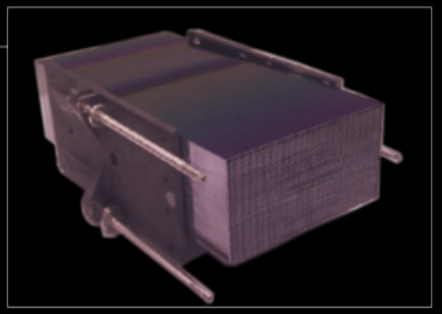
L2 orbit Ariane V
Mass < 5100 kg
Power 2500 W
5 year mission



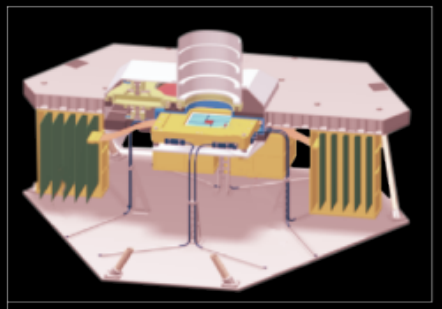
X-ray Integral Field Unit:
ΔE: 2.5 eV
Field of View: 5 arcmin
Operating temp: 50 mk

Barret et al., 2013 arXiv:1308.6784





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}

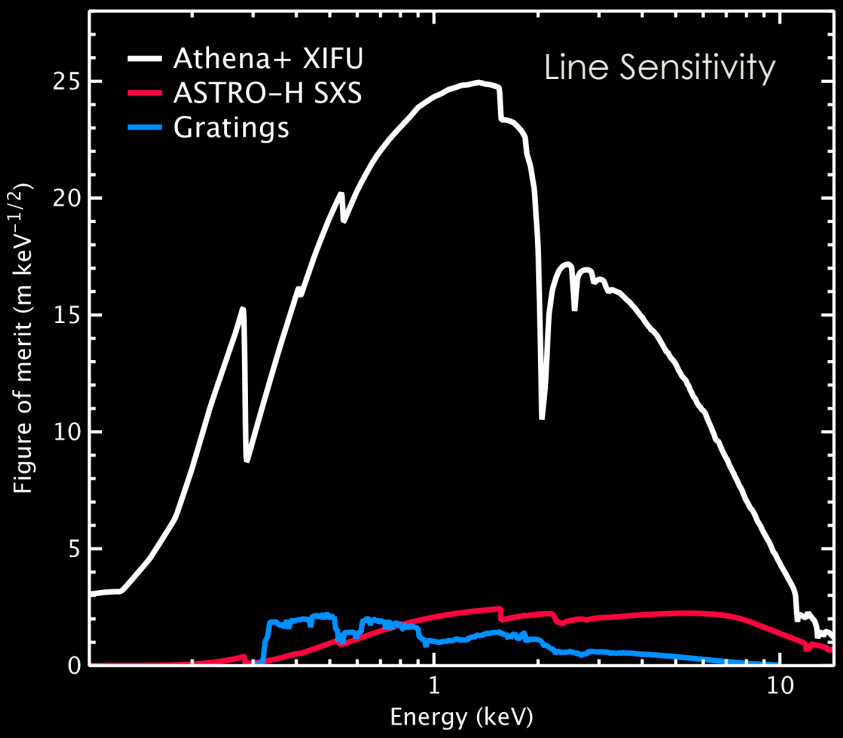


Wide Field Imager:
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

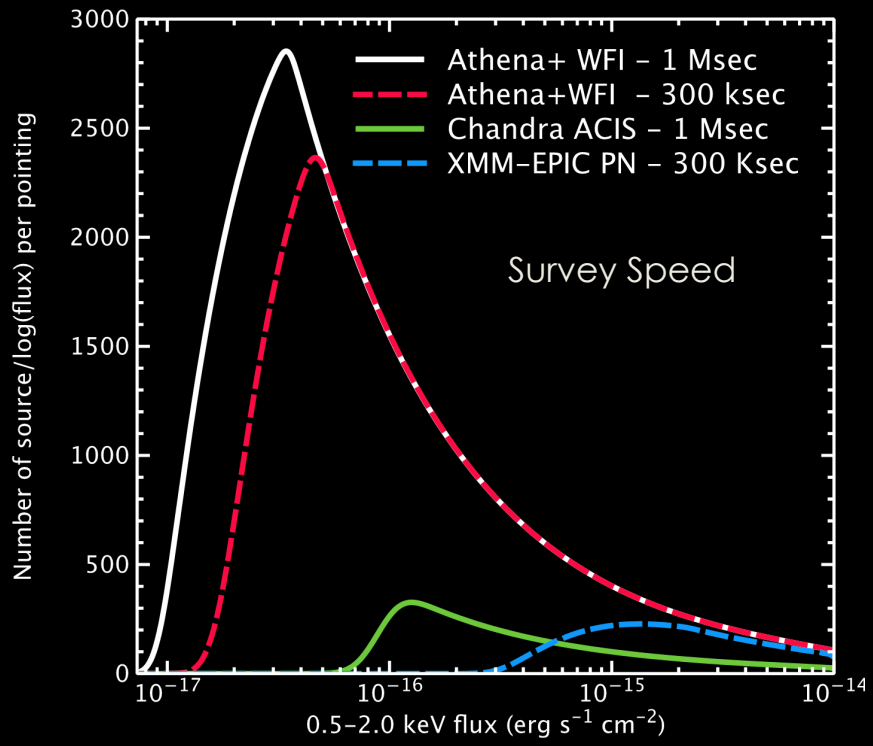
Rau et al. 2013 arXiv1307.1709

The first 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

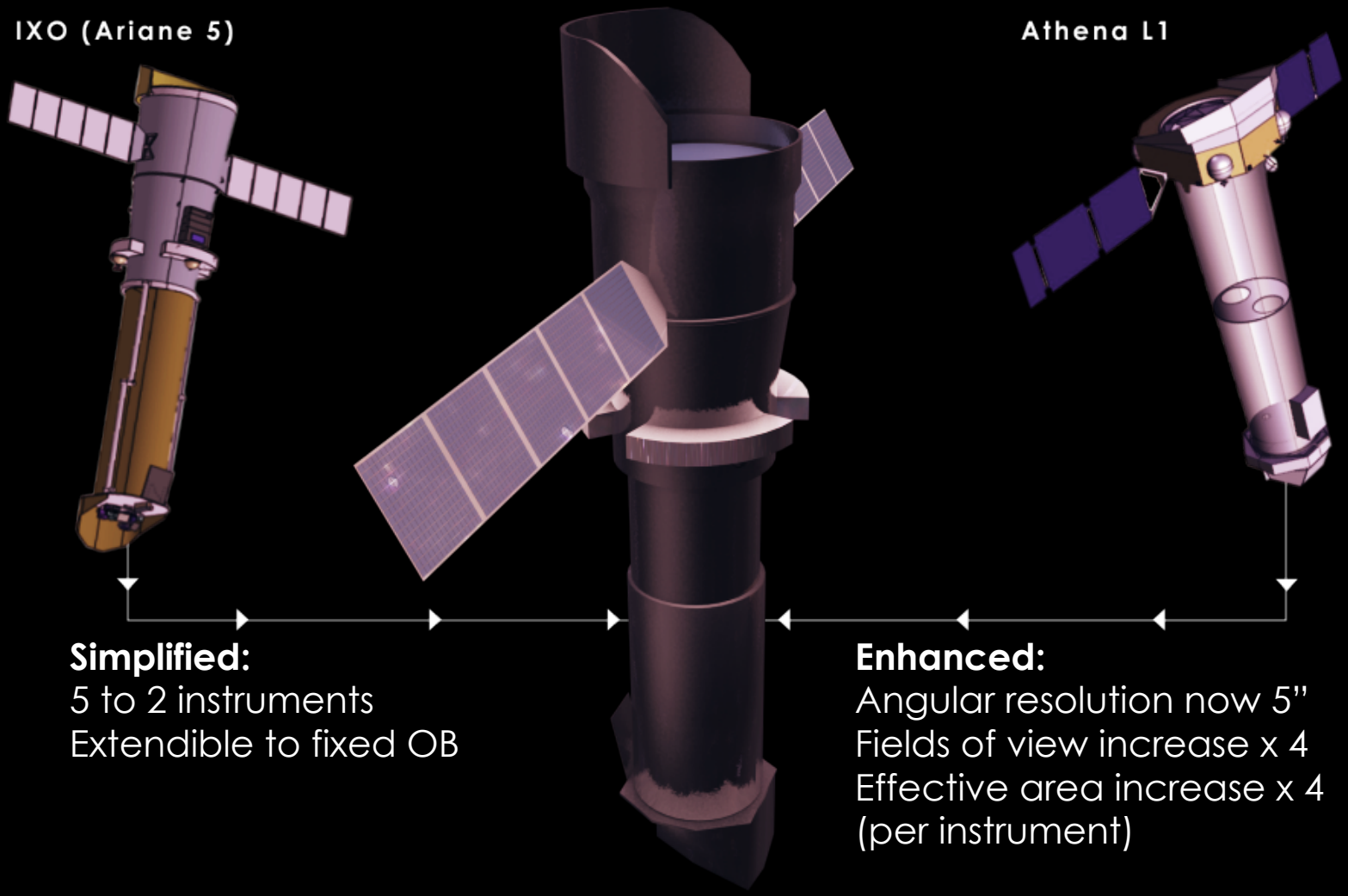


X-ray spectroscopy at the peak of the activity of the Universe



Deep survey capability into the dark ages and epoch of reionization

Technical Maturity



Simplified:
5 to 2 instruments
Extendible to fixed OB

Enhanced:
Angular resolution now 5”
Fields of view increase x 4
Effective area increase x 4
(per instrument)

ATHENA

Core of the mission proposal is:

4.2 SUMMARY OF MAIN SCIENCE REQUIREMENTS

Performance parameter	Requirement	Level 2 Science Goal
Effective area at 1 keV*	2 m²	SG1.1 Finding early groups; SG4.1 Census of warm-hot baryons; SG4.2 Physical properties of the WHIM; SG5.1 High z AGN population; SG5.2 Probing the first generation of stars; SG6.1 Complete census of AGN at the peak of activity of the Universe; SG6.2 Incidence of outflows in z=1-4 AGN; SG6.3 Mechanical energy of AGN outflows at z=1-4; SG6.4 Incidence of ultrafast outflows at z>1; SG8.1 AGN reverberation mapping
PSF HEW (at E<8 keV)	5" on axis 10" at 25' radius	SG1.1 Finding early groups; SG1.3 Non-gravitational heating processes; SG3.1 Jet energy dissipation in clusters; SG3.2 AGN ripples in clusters; SG3.4 Cumulative energy deposited by radio galaxies; SG5.1 High z AGN population; SG6.1 Complete census of AGN at the peak of activity of the Universe.
X-IFU spectral resolution	2.5 eV	SG1.2 Matter assembly in clusters; SG3.1 Jet energy dissipation on cluster scales; SG4.1 Census of warm-hot baryons; [SG3.3 X-ray cooling cores; SG4.2 Physical properties of the WHIM; SG5.2 Probing the first generation of stars, 3 eV]
WFI field of view	40' x 40'	SG1.1 Finding early groups; SG1.3 Non-gravitational heating processes; SG2.1 Metal production and dispersal; SG3.2 AGN ripples in clusters; SG3.4 Cumulative energy deposited by radio galaxies; SG5.1 High z AGN population; SG6.1 Complete census of AGN at the peak of activity of the Universe.
X-IFU total optical blocking filter attenuation	Factor 10^{12} at 1200 Å	SG4.1 Census of warm-hot baryons; SG7.1 AGN winds and outflows; SG7.2 Interaction of Winds with their environment
WFI count rate capability at 80% throughput	1 Crab[2]	SG8.3 Measuring spins in GBH; SG8.4 reverberation mapping of X-ray binaries
Charged particle background	<5 x 10^{-3}	SG1.2 Matter assembly in clusters; SG1.3 Non-gravitational
TOO reaction time	< 4 hours	SG4.1 Census of warm-hot baryons; SG5.2 Probing the first generation of stars

Table 4.1: Key parameters and requirements for the *Athena* prime science goals. Those are achievable within a 5 year mission lifetime with a conservative 75% observing efficiency (see section 5.3).

Athena: a powerful observatory

Planets

(interaction of solar wind with planet environment and comets)

Exoplanets

Stellar physics

Supernovae

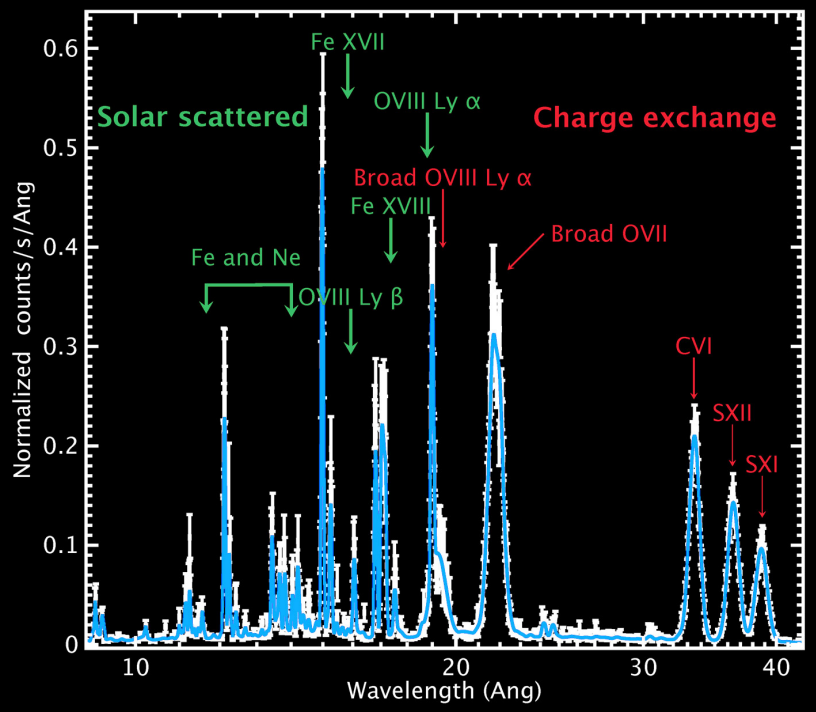
(explosion mechanism, heavy element production)

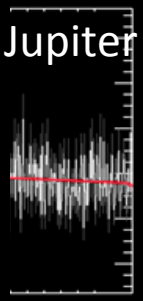
Stellar endpoints

(physics of outflows and winds in X-ray binaries)

Sgr A*

Interstellar dust and medium





Branduardi-Raymont, Sciortino, et al., 2013 arXiv 1306.2332; Sciortino, Rauw et al., 2013 arXiv1306.2333; Motch, Wilms, et al., 2013 arXiv1306.2334; Decourchelle, Costantini et al., 2013 arXiv1306.2335

Athena science in context

Athena+ is a crucial part of the suite of large observatories needed to reach the science objectives of astronomy in the coming decades

People involved (as of today)

(only EU for now, but NASA and JAXA may also join)

The Athena+ Co-ordination Group: Xavier Barcons (ES), Didier Barret (FR), Andy Fabian (UK), Jan-Willem den Herder (NL), Kirpal Nandra (DE), Luigi Piro (IT), Mike Watson (UK)

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THE END...NO, THE BEGINNING!

Thank you very much
for your attention