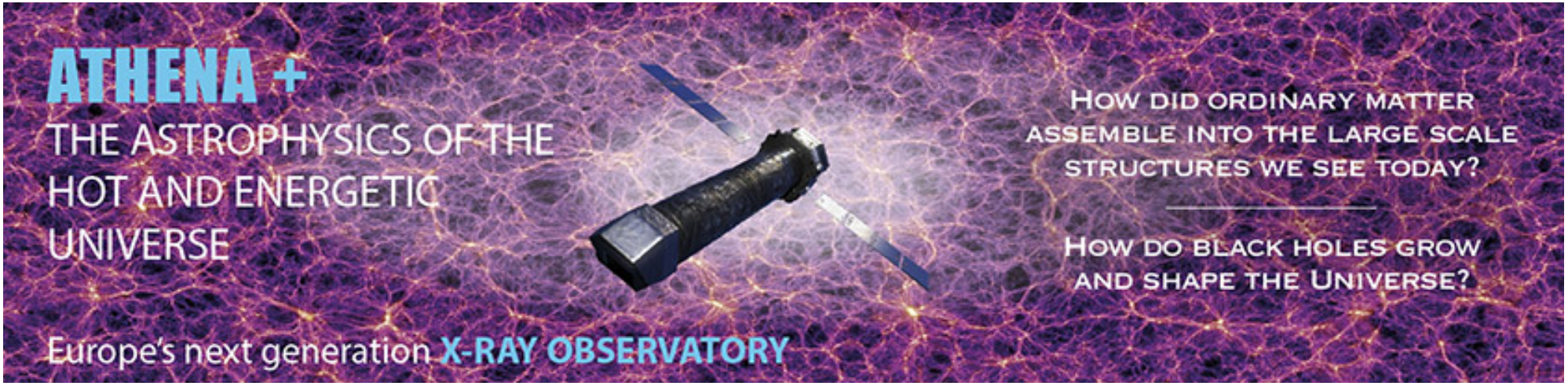


A theme proposed to ESA for L2/L3

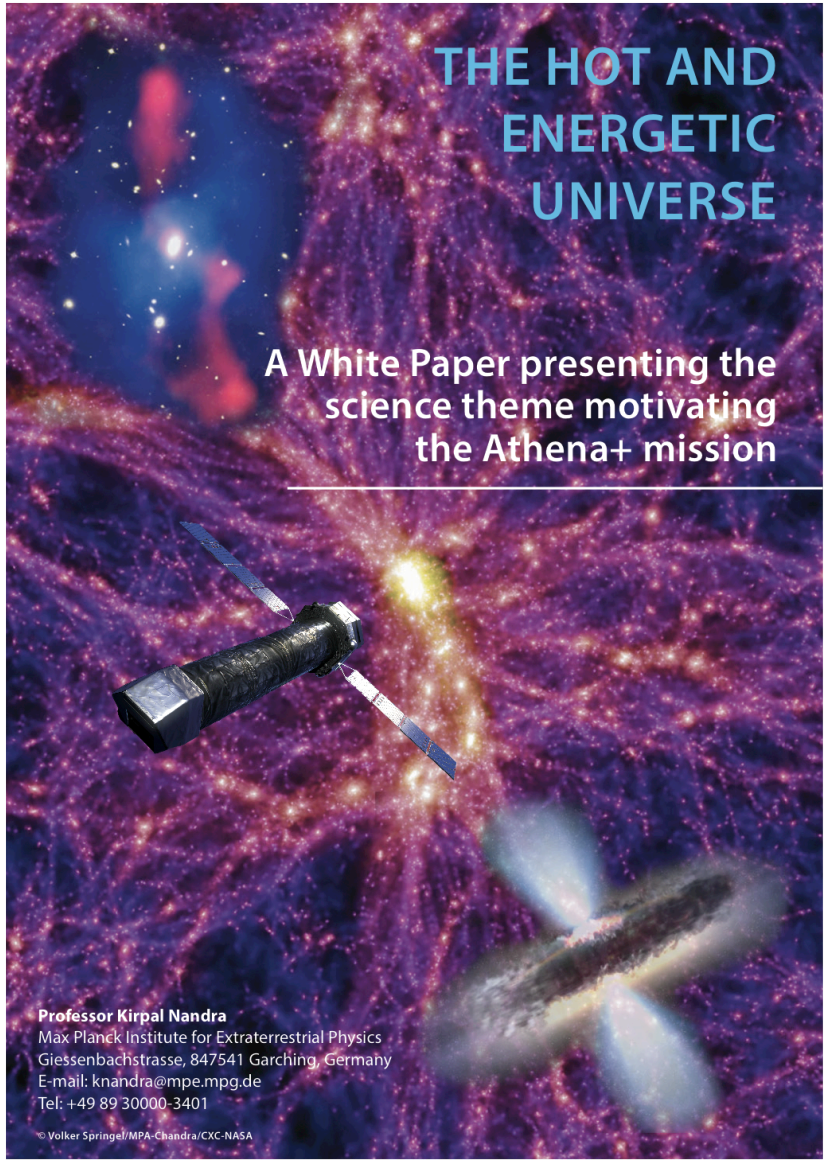
www.the-athena-x-ray-observatory.eu

Xavier Barcons
Instituto de Física de Cantabria (CSIC-UC)

On behalf of The Athena+ Co-ordination Group, the Athena+ Working Groups and Supporters

The Hot and Energetic Universe

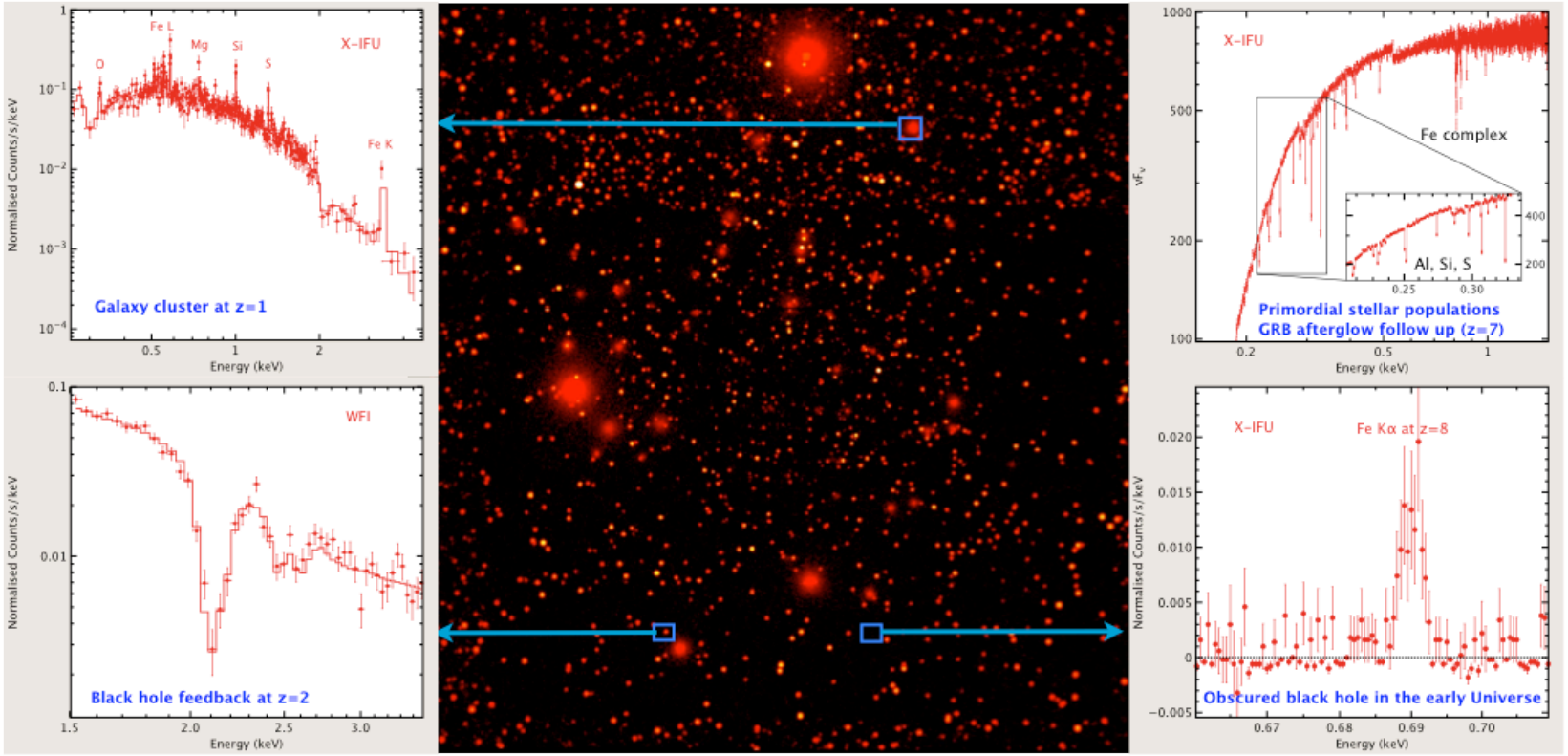
- **The Hot Universe:** How does the ordinary matter assemble into the large-scale structures that we see today?
  - >50% of the baryons today are in a hot (>10^6 K) phase
  - there are as many hot (> 10^7 K) baryons in clusters as in stars over the entire Universe
- **The Energetic Universe:** How do 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



Athena+ observations in a nutshell

Cluster at z=1

GRB afterglow at z=7



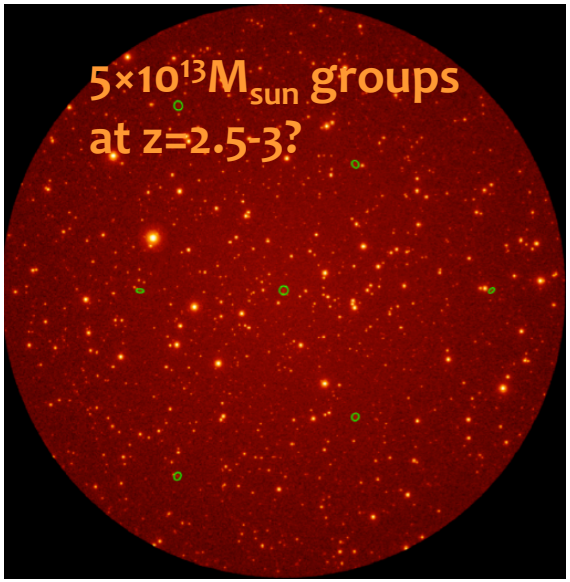
QSO feedback z=2

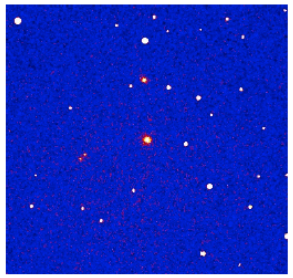
Early AGN at z=9

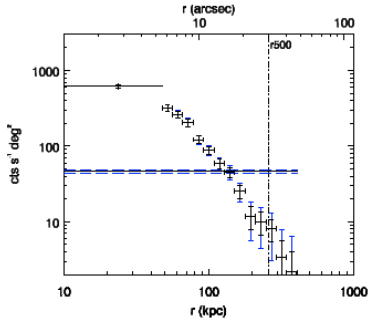
How does ordinary matter assemble into the large-scale structures that we see today? (I)

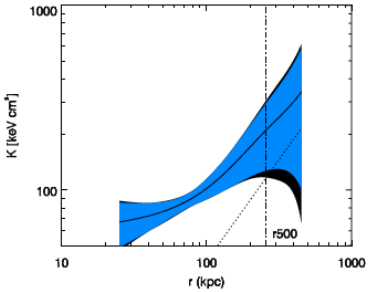
The formation and evolution of groups and clusters of galaxies

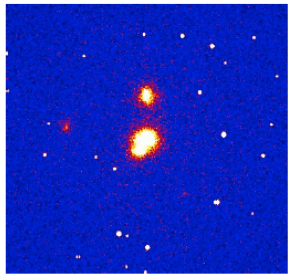
Understand how baryons accrete and evolve in the largest dark matter potential wells of groups and clusters. Determine how and when the energy contained in the hot intra-cluster medium was generated.

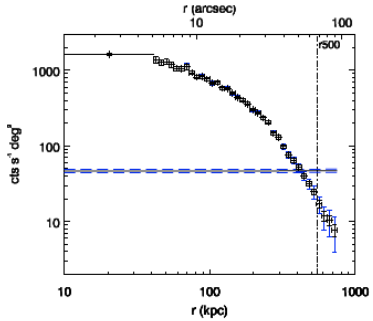


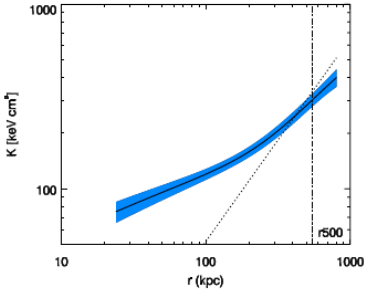


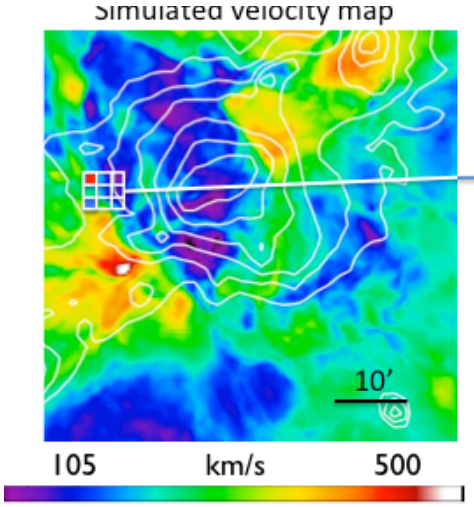


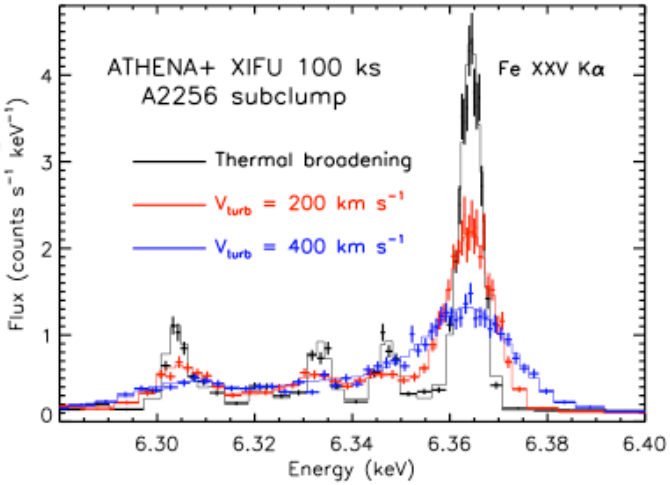








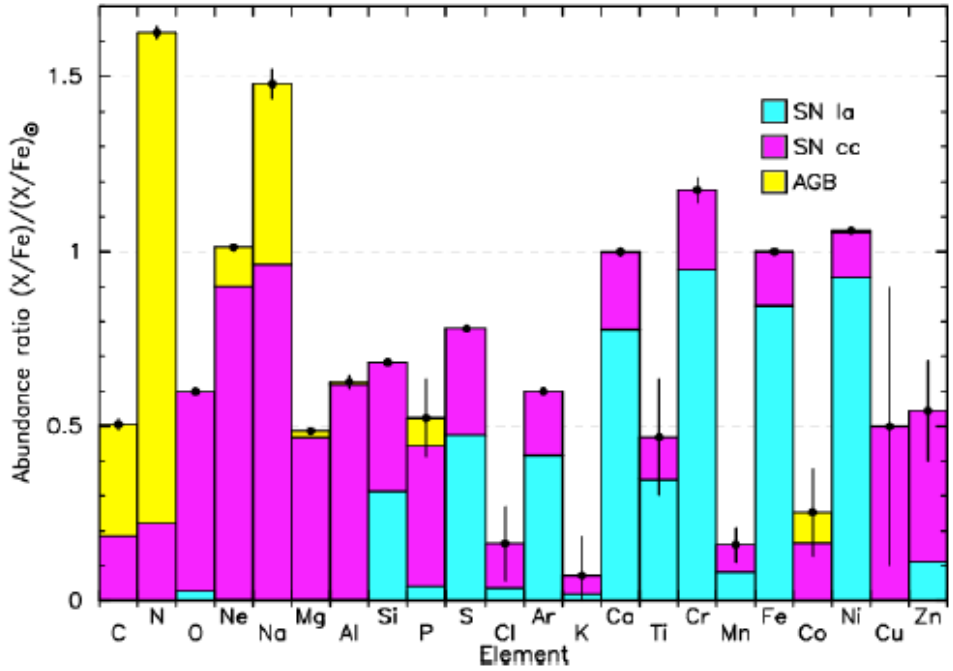


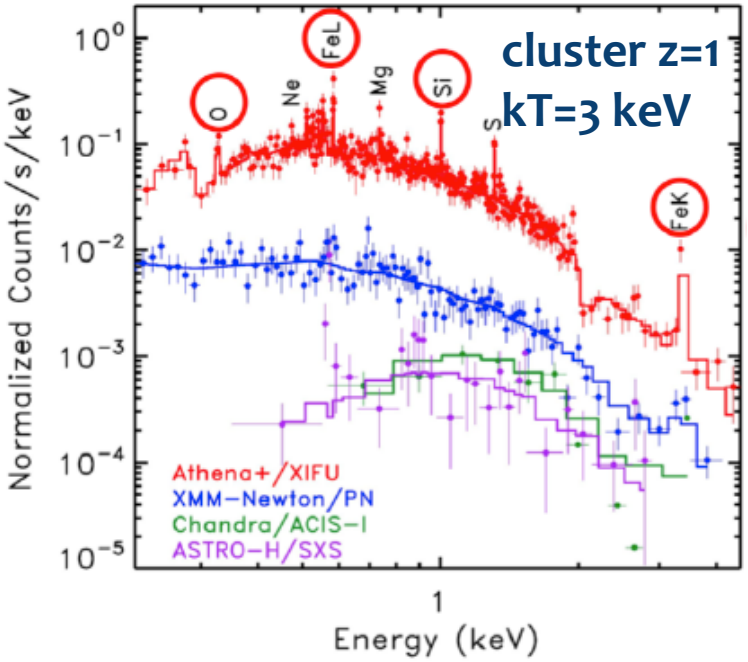


How does ordinary matter assemble into the large-scale structures that we see today? (II)

- **The chemical evolution of hot baryons**

Determine when the largest baryon reservoirs in galaxy clusters were chemically enriched. Infer the relative contributions of supernova types, and the initial stellar mass function in proto-clusters. Identify the locations in clusters where most of the metals are generated, and determine how they are dispersed.

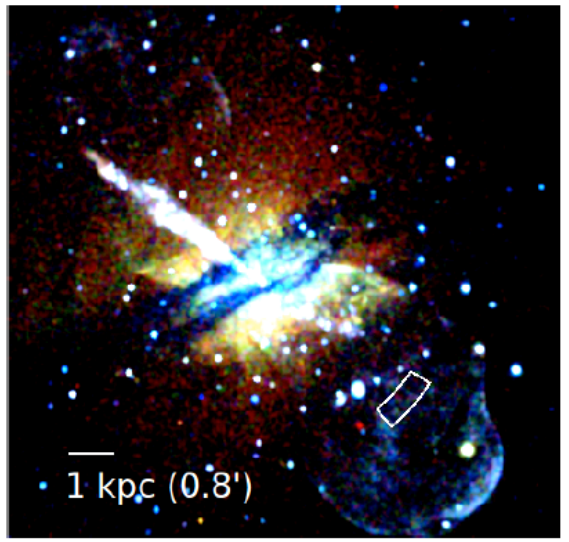


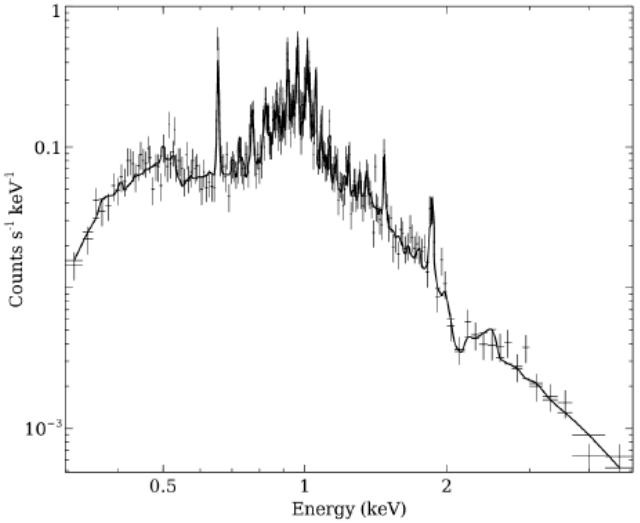


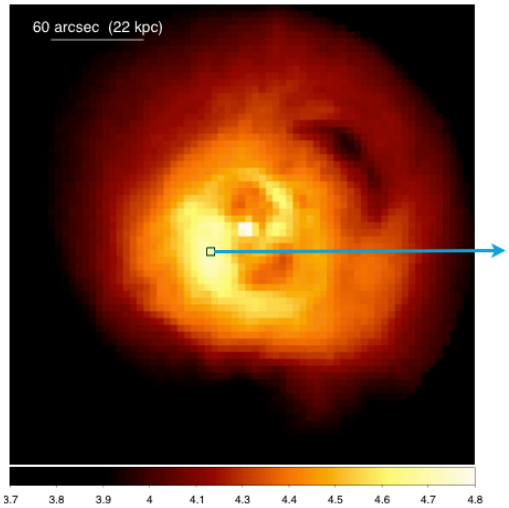
How does ordinary matter assemble into the large-scale structures that we see today? (III)

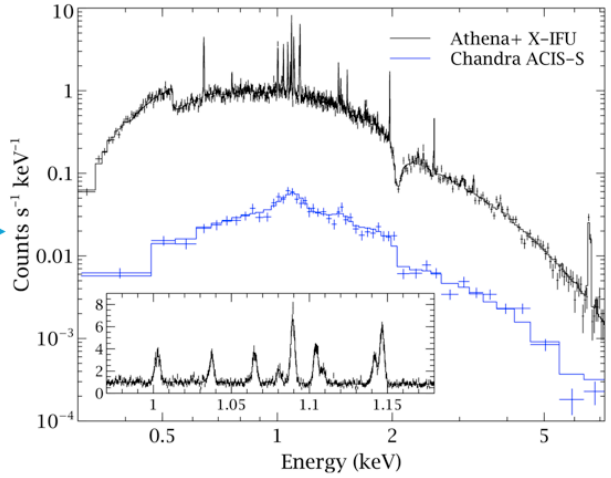
AGN feedback in clusters of galaxies

- Understand how jets from active galactic nuclei dissipate their mechanical energy in the intracluster medium, and how this affects the hot gas distribution.
- Determine whether jets from powerful radio-loud AGN are the dominant non-gravitational process affecting the evolution of hot gas in galaxy groups and clusters.
- Establish how AGN feedback regulates gas cooling in groups and clusters and AGN fuelling





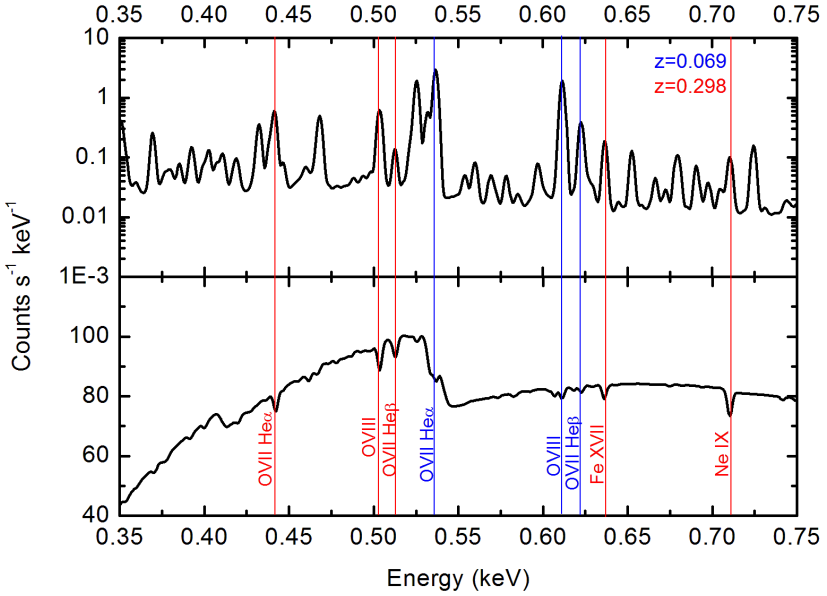


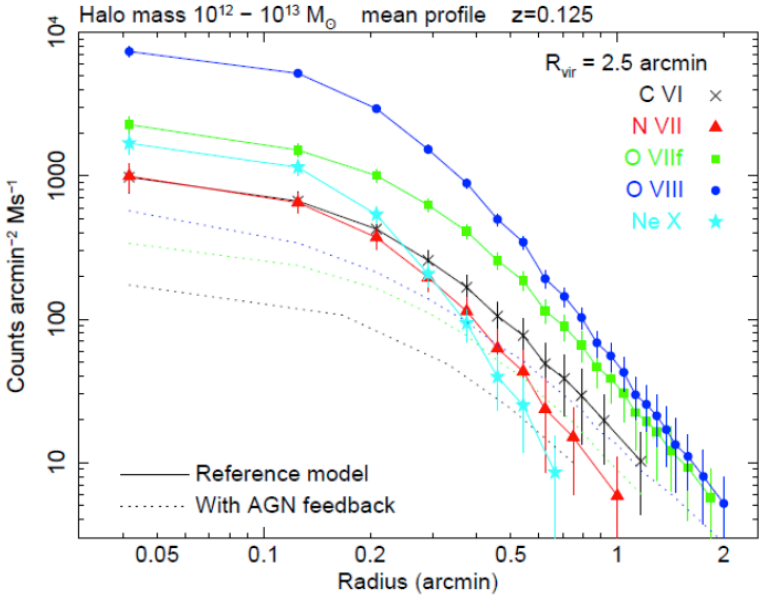


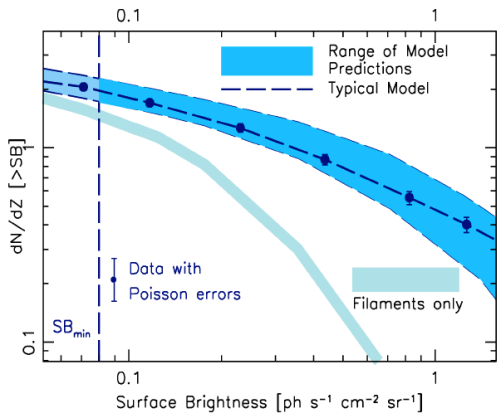
How does ordinary matter assemble into the large-scale structures that we see today? (IV)

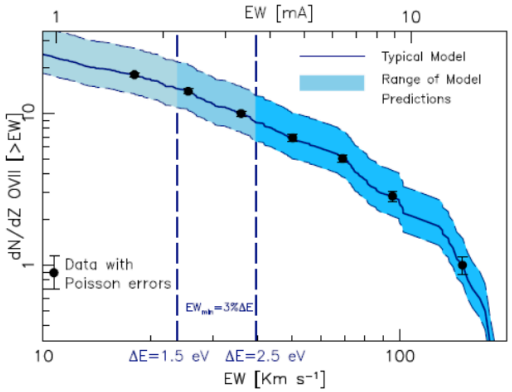
The missing baryons and the Warm-Hot Intergalactic Medium

Find the missing <50% baryons at z<2 and reveal the underlying mechanisms driving the distribution of this gas on various scales, from galaxies to galaxy clusters, as well as metal circulation and feedback processes.





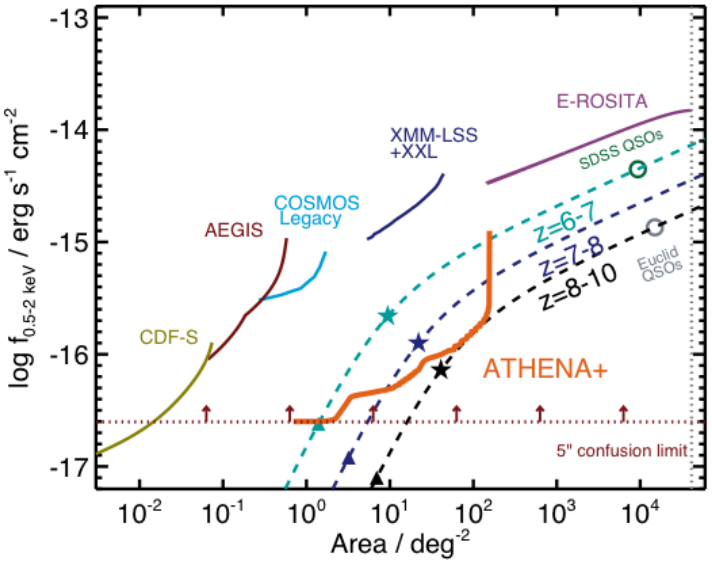


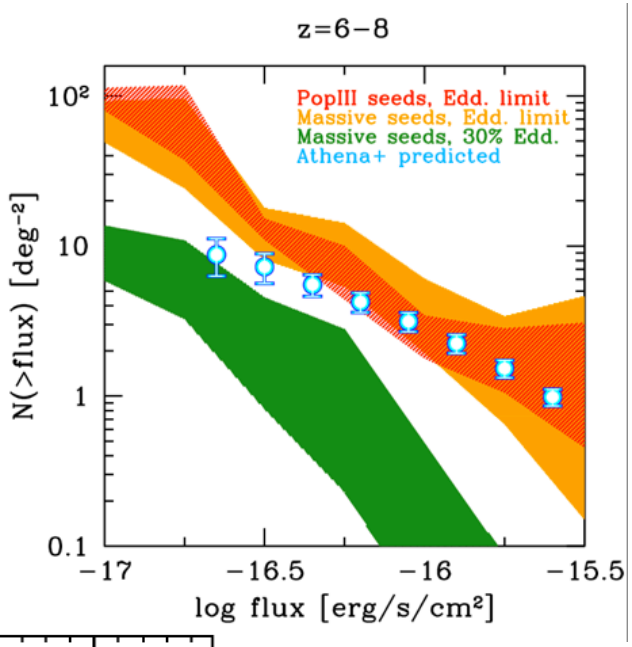


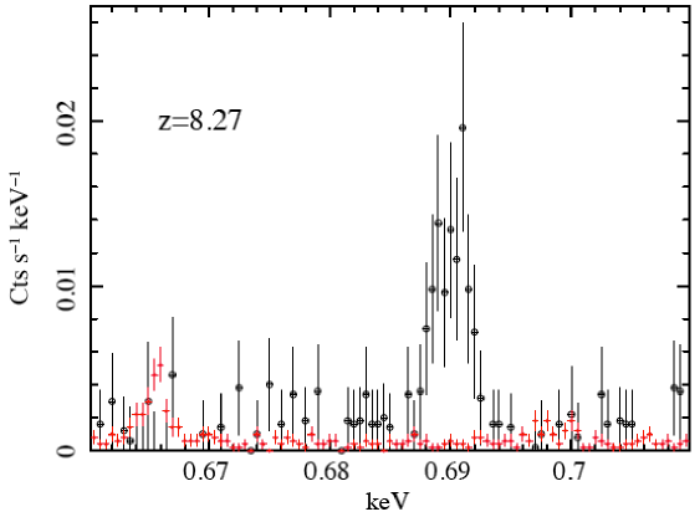
How do black holes grow and influence the Universe? (I)

• How do early supermassive black holes form, evolve and affect the distant Universe?

- Determine the nature of the seeds of high redshift (z>6) SMBH, which processes dominated their early growth, and the influence of accreting SMBH on the formation of galaxies in the early Universe.
- Trace 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 in the Universe.



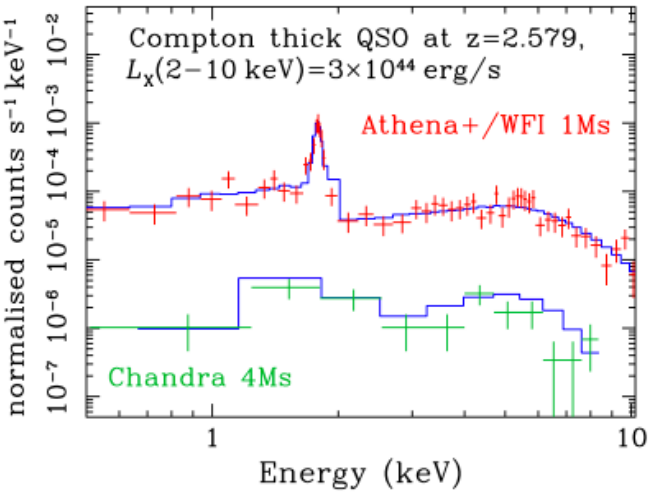


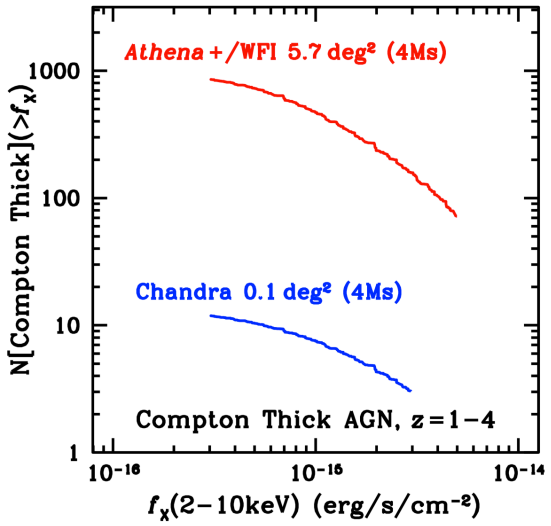


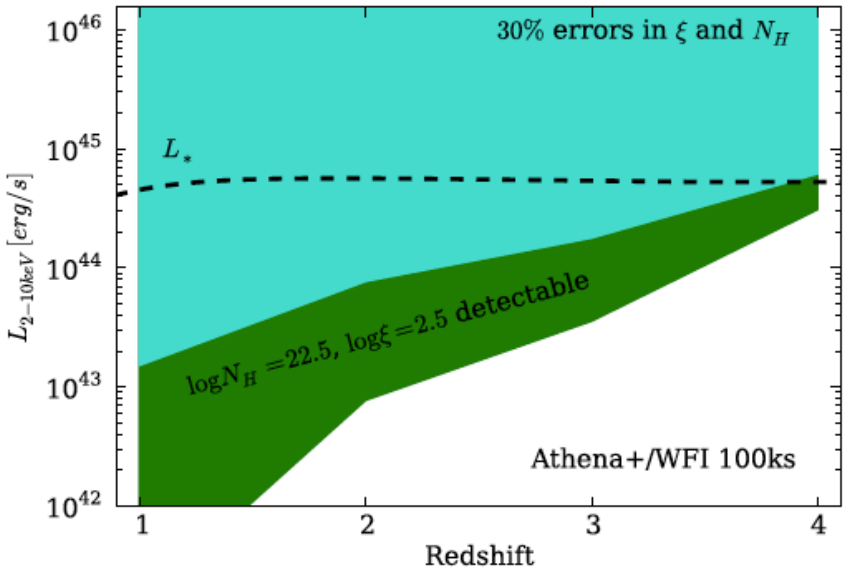
How do black holes grow and influence the Universe? (II)

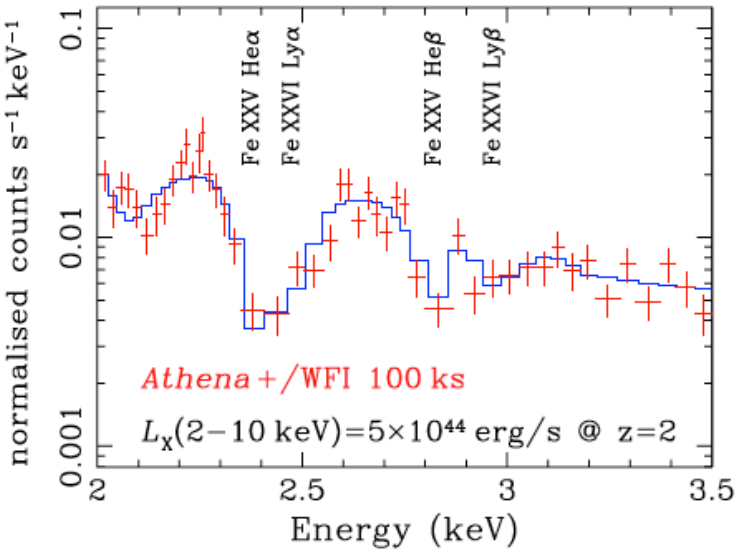
- What is the role of (obscured) black hole growth in the evolution of galaxies?

•Find the physical conditions under which SMBH grew at the epoch when most of the accretion and star formation in the Universe occurred (z~1-4).





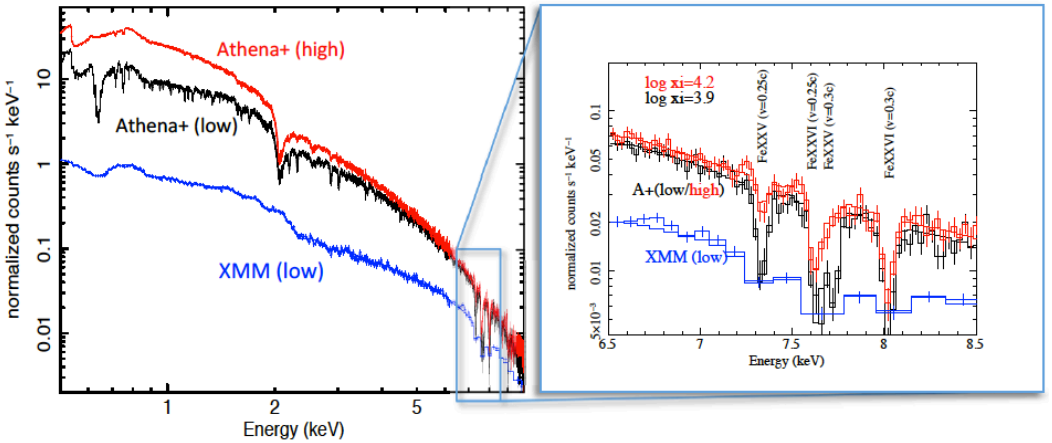


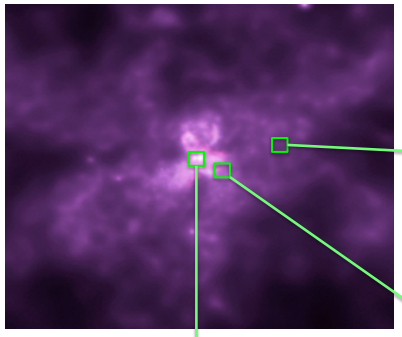


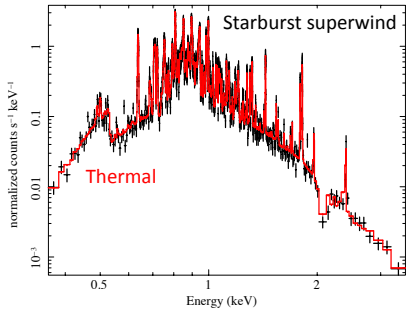
How do black holes grow and influence the Universe? (III)

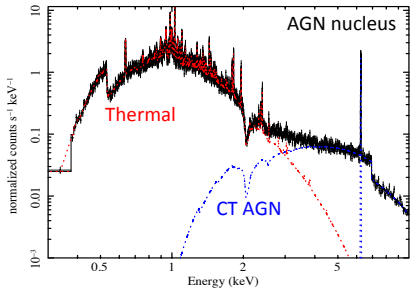
How do accretion powered outflows affect larger scales via feedback?

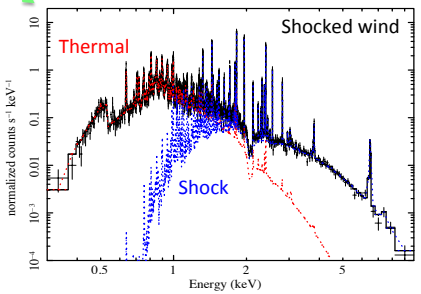
- Understand how accretion disks around black holes launch winds and outflows and determine how much energy these carry.
- Understand the significance of AGN outflows in determining the build-up of galaxies at the epoch when most stars in present day galaxies formed.
- Understand how the energy and metals are accelerated in galactic winds and outflows and are deposited in the circum-galactic medium. Determine whether the baryons and metals missing in galaxies since z~3 reside in such extended hot envelopes.





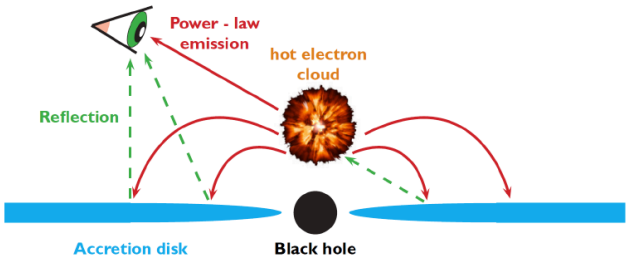


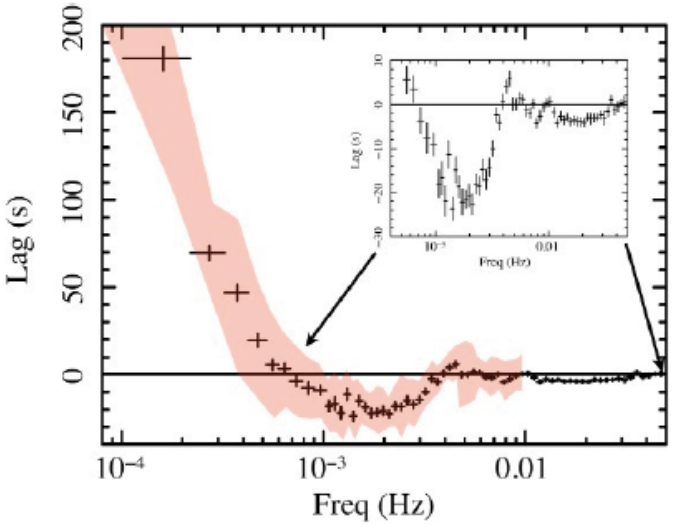


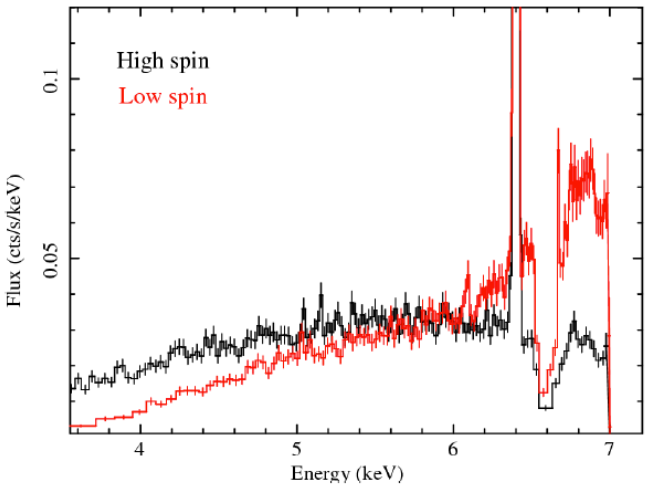


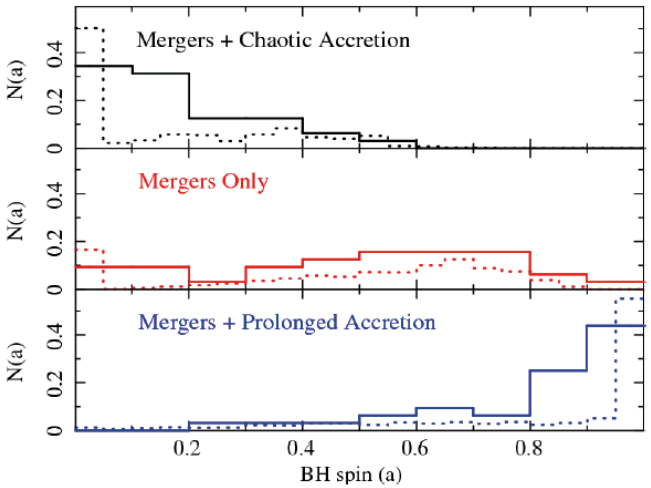
How do black holes grow and influence the Universe? (IV)

- How do accretion and ejection processes operate in the near environment of black holes?
  - Determine the relationship between tl accretion disk around black holes and its hot electron plasma. Understand the interplay of the disk/corona system with matter ejected in the form of winds and outflows.
  - Infer whether accretion or mergers drive the growth of SMBH across cosmic time.



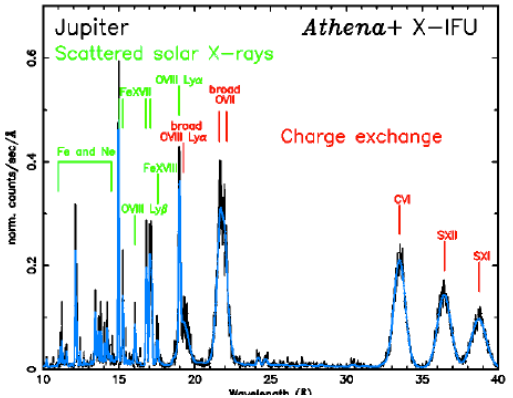


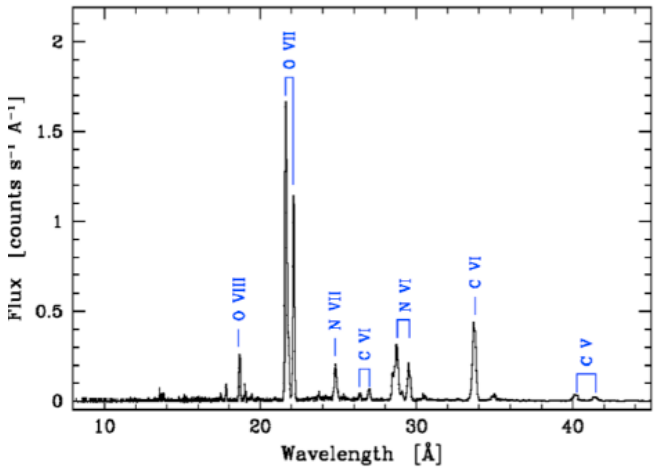


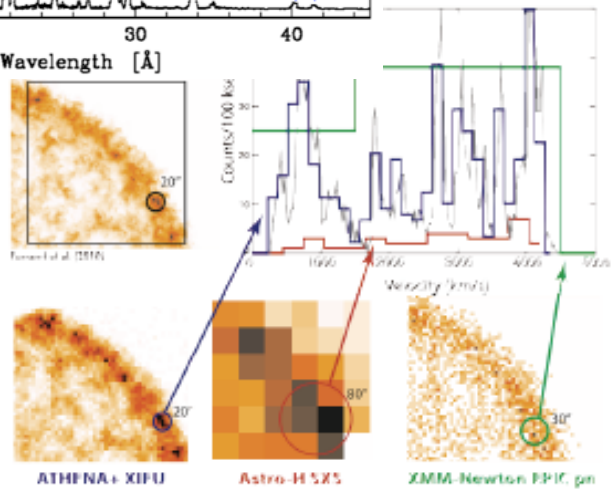


(Some) other astrophysical questions requiring an X-ray observatory

- Interaction of the Solar Wind with planetary exospheres and comets
- Magnetic interplay between exo-planets and their stars
- Assess mass loss rates in massive stars and their role in galaxy feedback
- Influence of X-ray irradiation on protoplanetary disks around low-mass stars
- Physics of core collapse Supernovae, asymmetry, heavy element dispersion
- Effects of mass-loss disk winds on X-ray binary stars
- Measure mass and radius of neutron stars in quiescent and distant objects
- Measure the echo of past activity in the Galactic Centre SMBH Sgr A*
- Chemical composition of the dust grains in the Interstellar medium
- Map the hot Interstellar gas in our own and other galaxies







Athena+ Science Requirements

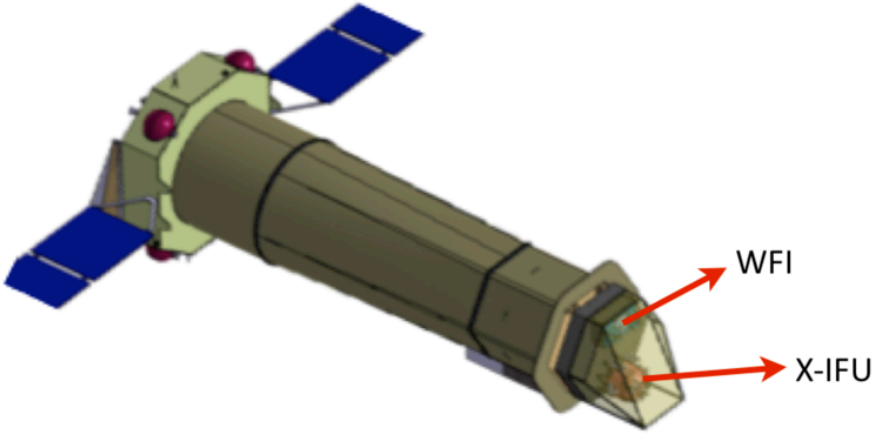
Parameter	Requirements	Enabling technology/comments
Effective area	2 m^2 @ 1 keV (goal 2.5 m^2) 0.25 m^2 @ 6 keV (goal 0.3 m^2)	Silicon Pore Optics developed by ESA. Single telescope: 3 m outer diameter, 12 m fixed focal length
Angular Resolution	5" (goal 3") on-axis 10" at 25' radius	Detailed analysis of error budget confirms that a performance of 5" HEW is feasible.
Energy range	0.3-12 keV	Grazing incidence optics & detectors
Instrument field of view (diameter)	*Wide-Field Imager:* (**WFI**): 40' (goal 50')	Large area DEPFET Active Pixel Sensors
	X-ray Integral Field Unit: (**X-IFU**): 5' (goal 7')	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)	*Inner array (10" x 10") optimized for higher resolution at low energy (50 micron pixels).*
Count Rate capability	> 1 Crab1 (**WFI**)	Central chip for high count rates without pile-up and with micro-second time resolution
	10 mCrab, point source (**X-IFU**) 1 Crab (30% throughput)	Filters and beam diffuser enable higher count rate capability with reduced spectral resolution
TOO response	4 hours (goal 2 hours) for 50% of time	Slew times <2 hours feasible; total response time dependent on ground system issues

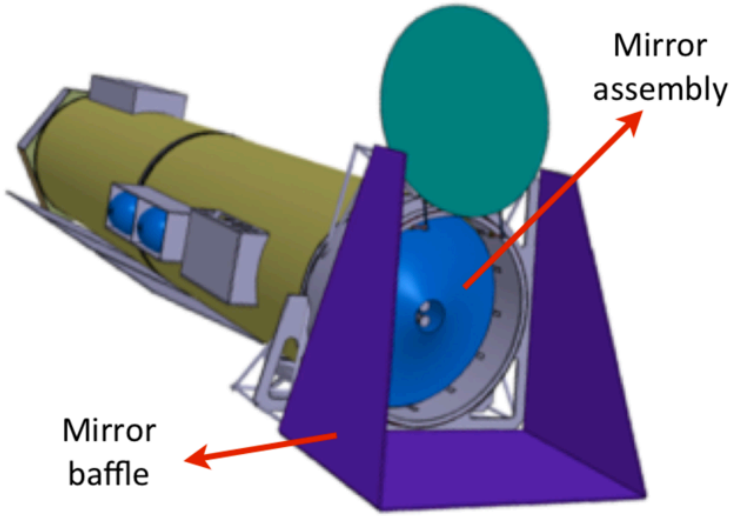
Notional Athena+ Mission Profile

Ariane V launch to L2, 5yr nominal mission

Single telescope with fixed 12m focal length
using ESA Silicon Pore Optics

5″ (3″) resolution





Two focal plane instruments, on a rotating turntable: X-IFU and WFI

Extremely robust concept, smooth evolution from Athena

The Athena+ focal plane instruments

X-IFU (X-ray Integral Field Unit)

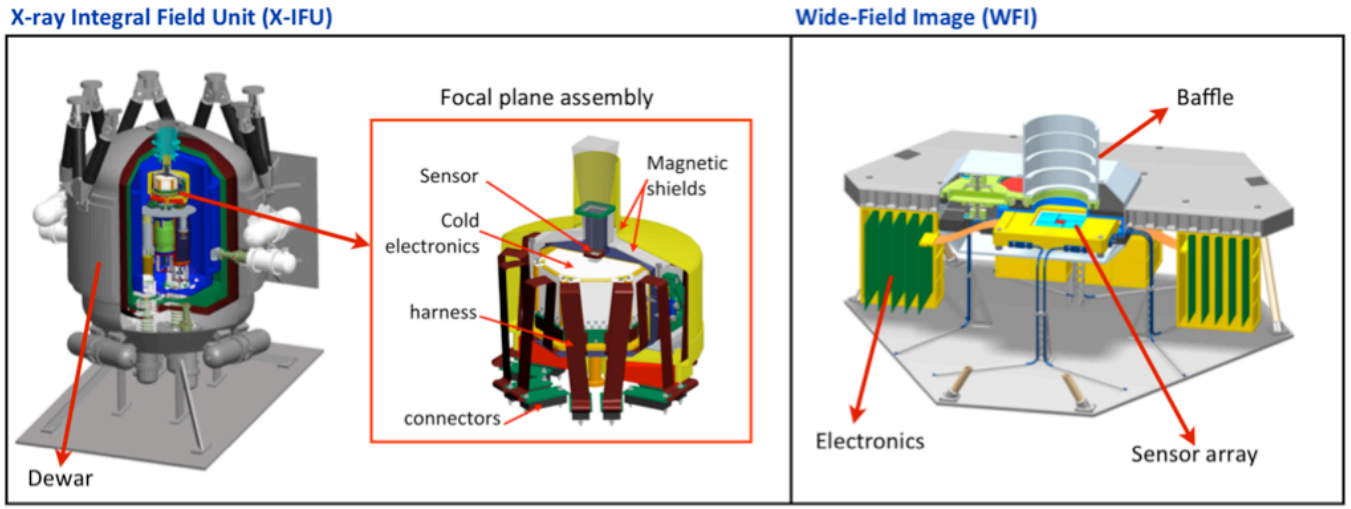
TES calorimeter
Cooled to 50 mK

High spectral resolution spatially resolved spectroscopy over limited FoV

WFI (Wide Field Imager)

Si-based DEPFET

Low spectral resolution, spatially resolved spectroscopy on wide FoV and high count-rate capability



Athena+ White Paper and Supporting Papers

The Hot and Energetic Universe: A White Paper presenting the science theme motivating the Athena+ mission, Nandra, Barret, Barcons, et al., 2013arXiv1306.2307N

The Hot and Energetic Universe: The evolution of galaxy groups and clusters, Pointecouteau, Reiprich, Adami, et al., 2013arXiv1306.2319P

The Hot and Energetic Universe: The astrophysics of galaxy groups and clusters, Ettori, Pratt, de Plaa, et al., 2013arXiv1306.2322

The Hot and Energetic Universe: AGN feedback in galaxy clusters and groups, Croston, Sanders, Heinz, et al., 2013arXiv1306.2323

The Hot and Energetic Universe: The missing baryons and the warm-hot intergalactic medium, Kaastra, Finoguenov, Nicastro, et al., 2013arXiv1306.2324

The Hot and Energetic Universe: The formation and growth of the earliest supermassive black holes, Aird, Comastri, Brusa, et al., 2013arXiv1306.2325

The Hot and Energetic Universe: Understanding the build-up of supermassive black holes and galaxies at the heyday of the Universe, Georgakakis, Carrera, Lanzuisi, et al., 2013arXiv1306.2328

The Hot and Energetic Universe: Astrophysics of feedback in local AGN, Cappi, Done, Behar, et al., 2013arXiv1306.2330

The Hot and Energetic Universe: The close environments of supermassive black holes, Dovciak, Matt, Bianchi, et al., 2013arXiv1306.2331

The Hot and Energetic Universe: Solar system and exoplanets, Branduardi-Raymont, Sciortino, Dennerl, et al., 2013arXiv1306.2332

The Hot and Energetic Universe: Star formation and evolution, Sciortino, Rauw, Audard, et al., 2013arXiv1306.2333

The Hot and Energetic Universe: End points of stellar evolution, Motch, Wilms, Barret, et al., 2013arXiv1306.2334

The Hot and Energetic Universe: The astrophysics of supernova remnants and the interstellar medium, Decourchelle, Costantini, Badenes, et al., 2013arXiv1306.2335

The Hot and Energetic Universe: Luminous extragalactic transients, Jonker, O'Brien, Amati, et al., 2013arXiv1306.2336J

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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)

The Athena+ Working Groups[1]**:** Christophe Adami (FR), **James Aird (UK),** Jose Manuel Afonso (PT), Dave Alexander (UK), Costanza Argiroffi (IT), Lorenzo Amati (IT), Monique Arnaud (FR), Jean-Luc Atteia (FR), Marc Audard (CH), Carles Badenes (US), Jean Ballet (FR), Lucia Ballo (IT), Aya Bamba (JP), Anil Bhardwaj (IN), Elia Stefano Battistelli (IT), Werner Becker (DE), Michaël De Becker (BE), Ehud Behar (IL), Stefano Bianchi (IT), Veronica Biffi (IT), Laura Bîrzan (NL), Fabrizio Bocchino (IT), Slavko Bogdanov (US), Laurence Boirin (FR), Thomas Boller (DE), Stefano Borgani (IT), Katharina Borm (DE), Nicolas Bouché (FR), Hervé Bourdin (IT), Richard Bower (UK), Valentina Braito (IT), Enzo Branchini (IT), **Graziella Branduardi-Raymont (UK),** Joel Bregman (USA), Laura Brenneman (USA), Murray Brightman (DE), Marcus Brüggen (DE), Johannes Buchner (DE), Esra Bulbul (USA), Marcella Brusa (IT), Michal Bursa (CZ), Alessandro Caccianiga (IT), Ed Cackett (USA), Sergio Campana (IT), Nico Cappelluti (IT), **Massimo Cappi (IT), Francisco Carrera (ES),** Maite Ceballos (ES), Finn Christensen (DK), You-Hua Chu (US), Eugene Churazov (DE), Nicolas Clerc (DE), Stephane Corbel (FR), Amalia Corral (GR), **Andrea Comastri (IT), Elisa Costantini (NL), Judith Croston (UK),** Mauro Dadina (IT), Antonino D'Ai (IT), **Anne Decourchelle (FR),** Roberto Della Ceca (IT), Konrad Dennerl (DE), Klaus Dolag (DE), **Chris Done (UK), Michal Dovciak (CZ),** Jeremy Drake (US), Dominique Eckert (S), Alastair Edge (UK), **Stefano Ettori (IT),** Yuichiro Ezoe (JP), Eric Feigelson (US), Rob Fender (UK), Chiara Feruglio (FR), **Alexis Finoguenov (FI),** Fabrizio Fiore (IT), Massimiliano Galeazzi (IT), Sarah Gallagher (CA), Poshak Gandi (UK), Massimo Gaspari (IT), Fabio Gastaldello (IT), **Antonis Georgakakis (DE),** Ioannis Georgantopoulos (GR), Marat Gilfanov (DE), Myriam Gitti (IT), Randy Gladstone (USA), Rene Goosmann (FR), Eric Gosset (BE), Nicolas Grosso (FR), Manuel Guedel (AT), Martin Guerrero (ES), Frank Haberl (DE), Martin Hardcastle (UK), Sebastian Heinz (US), Almudena Alonso Herrero (ES), Anthony Hervé (FR), Mats Holmstrom (SE), Kazushi Iwasawa (ES), **Peter Jonker (NL), Jelle Kaastra (NL),** Erin Kara (UK), Vladimir Karas (CZ), Joel Kastner (US), Andrew King (UK), Daria Kosenko (FR), Dimita Koutroumpa (FR), Ralph Kraft (US), Ingo Kreykenbohm (D), Rosine Lallement (FR), J. Lee (US), Marianne Lemoine-Goumard (FR), Andrew Lobban (UK), Giuseppe Lodato (IT), Lorenzo Lovisari (DE), Simone Lotti (IT), Ian McCharthy (UK), Brian McNamara (CA), Antonio Maggio (IT), Roberto Maiolino (UK), Barbara De Marco (DE), Domitilla de Martino (I), Silvia Mateos (ES), **Giorgio Matt (IT),** Ben Maughan (UK), Pasquale Mazzotta (IT), Mariano Mendez (NL), Andrea Merloni (DE), Giuseppina Micela (IT), Marco Miceli (IT), Robert Mignani (IT), Jon Miller (US), Giovanni Miniutti (ES), Silvano Molendi (IT), Rodolfo Montez (ES), Alberto Moretti (IT), **Christian Motch (FR),** Yaël Nazé (BE), Jukka Nevalainen (FI), Fabrizio Nicastro (IT), Paul Nulsen (US), Takaya Ohashi (JP), **Paul O'Brien (UK),** Julian Osborne (UK), Lida Oskinova (DE), Florian Pacaud (DE), Frederik Paerels (US), Mat Page (UK), Iossif Papadakis (GR), Giovanni Pareschi (IT), Robert Petre (US), Pierre-Olivier Petrucci (FR), Enrico Piconcelli (IT), Ignazio Pillitteri (IT), C. Pinto (UK), Jelle de Plaa (NL), **Etienne Pointecouteau (FR),** Trevor Ponman (UK), Gabriele Ponti (DE), Delphine Porquet (FR), Ken Pounds (UK), **Gabriel Pratt (FR),** Peter Predehl (DE), Daniel Proga (US), Dimitrios Psaltis (US), David Rafferty (NL), Miriam Ramos-Ceja (DE), Piero Ranalli (IT), Elena Rasia (US), Arne Rau (DE), **Gregor Rauw (BE),** Nanda Rea (IT), Andy Read (UK), James Reeves (UK), **Thomas Reiprich (DE),** Matthieu Renaud (FR), Chris Reynolds (US), Guido Risaliti (IT), Jerome Rodriguez (FR), Paola Rodriguez Hidalgo (CA), Mauro Roncarelli

[1] Bold face denotes Working Group chairs. The list of the 14 Athena+ Working Groups, together with the full list of the 1000+ Athena+ supporters is available at: http://www.the-athena-x-ray-observatory.eu

- **Athena+ Coordination Group:** Nandra, Barret, Barcons, den Herder, Fabian, Piro, Watson
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Summary

- The *Hot and Energetic Universe* addresses most important questions affecting astronomy at large
- Athena+ mission concept very robust, strong heritage from Athena (and IXO and XEUS). Technological developments assessed by ESA's X-TASAT.
- Detailed and precise study of what can be done and how with Athena+
- Athena+ is an *observatory*, all corners of astronomy will benefit enormously

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