

The Hot and Energetic Universe with Athena: Science and programmatics

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On behalf of the Athena Consortium

Outline

- **Science (The Hot and Energetic Universe)**
- **Mission&Instruments**
- **International Context**
- **National Context**
- **National Contribution**
- **Schedule and programmatics**

ATHENA
THE **ADVANCED**
TELESCOPE FOR HIGH
ENERGY ASTROPHYSICS

A mission addressing
The Hot and Energetic Universe
science theme



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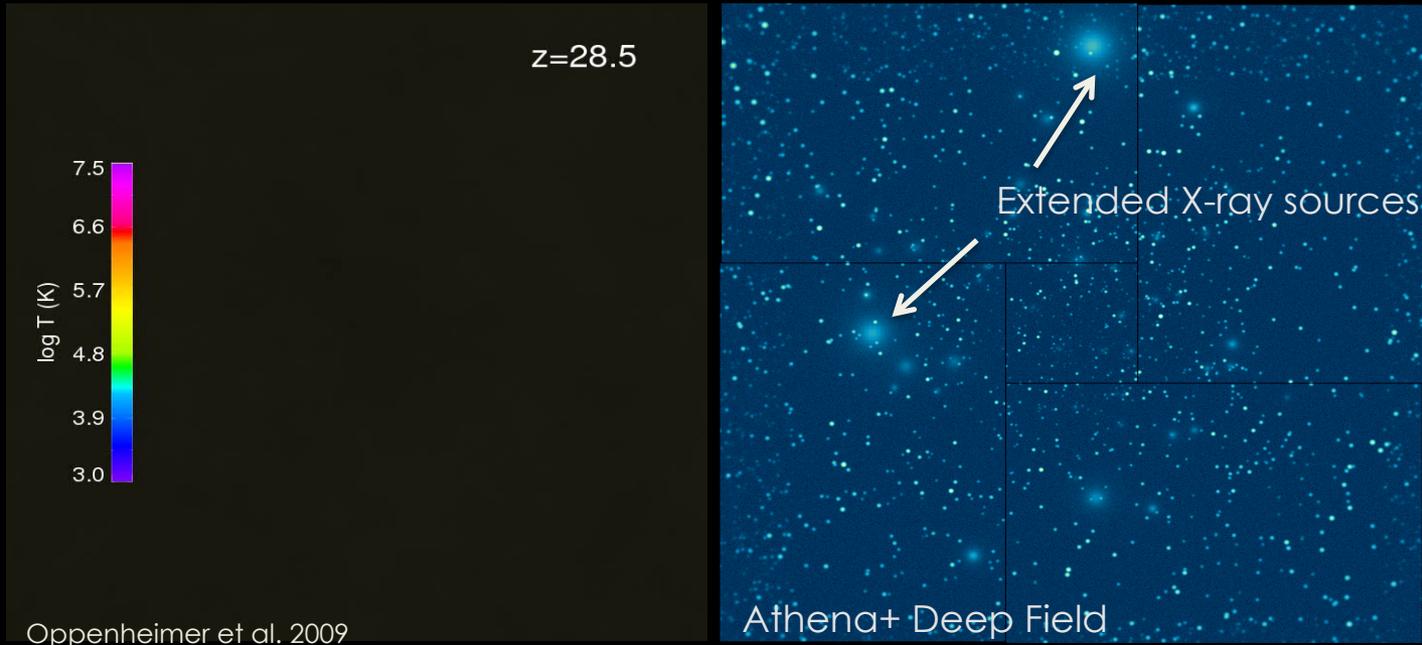
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Mission proposal submitted on behalf of the Athena team

Key questions for observational astrophysics in 2028

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



Oppenheimer et al. 2009

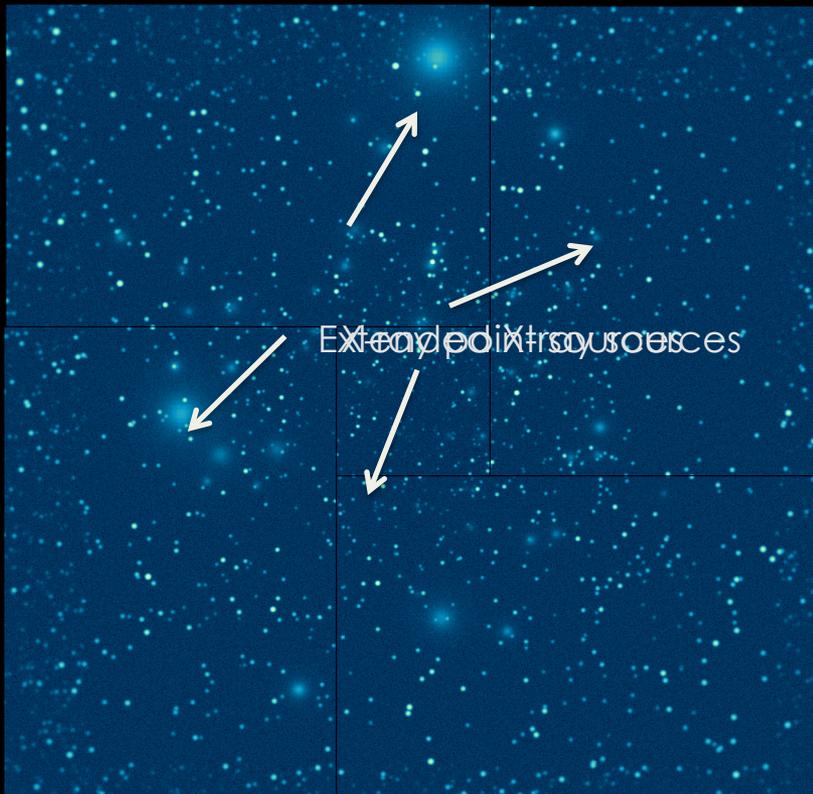
Pointecouteau, Reiprich et al., 2013
arXiv1306.2319

>50% of the baryons today are in a hot ($>10^6$ K) phase:

- first groups and clusters characterization and evolution
- cluster astrophysics (bulk motion, turbulence, outskirts, Ab.)
- AGN-clusters feedback
- WHIM

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 Deep Field



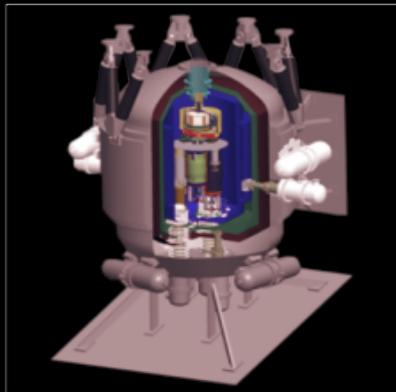
Building a SMBH releases $30 \times$ the binding energy of a galaxy; and 15% of the energy output in the Universe is in X-rays (mostly released via accretion)

[High-z (>6) QSOs, CT AGN, QSO feedback, AGN astrophysics, BH spins, High-z GRBs and transient]

The Athena Observatory

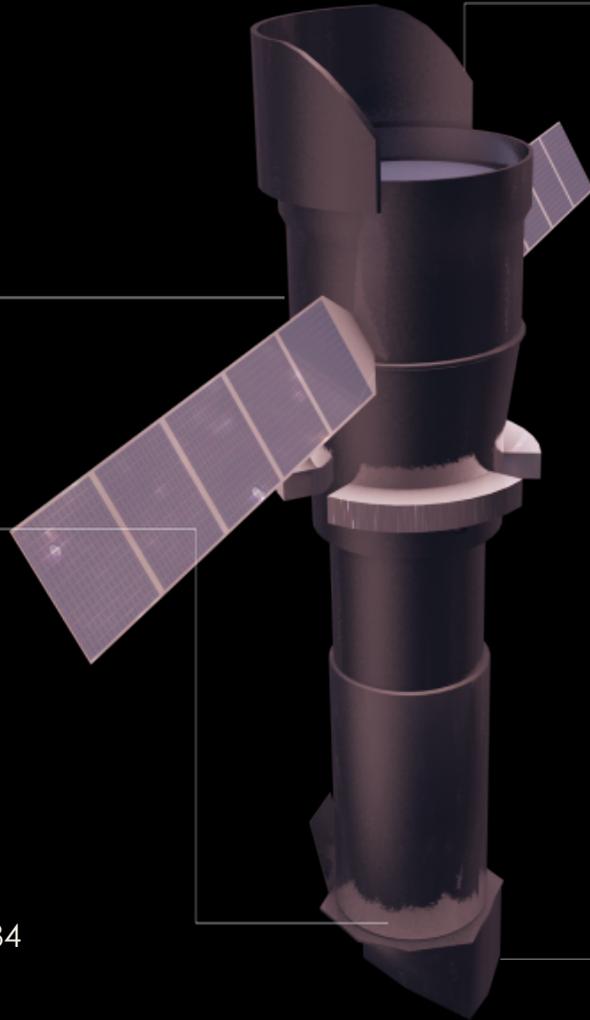
Willingale et al, 2013
arXiv1308.6785

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

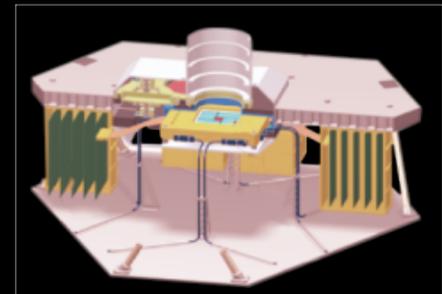


X-ray Integral Field Unit:
 ΔE : 2.5 eV
Field of View: 5 arcmin
Operating temp: 50 mk

Barret et al., 2013 arXiv:1308.6784



Silicon Pore Optics:
2 m² at 1 keV
5 arcsec HEW
Focal length: 12 m
Sensitivity: $3 \cdot 10^{-17}$ erg cm⁻² s⁻¹



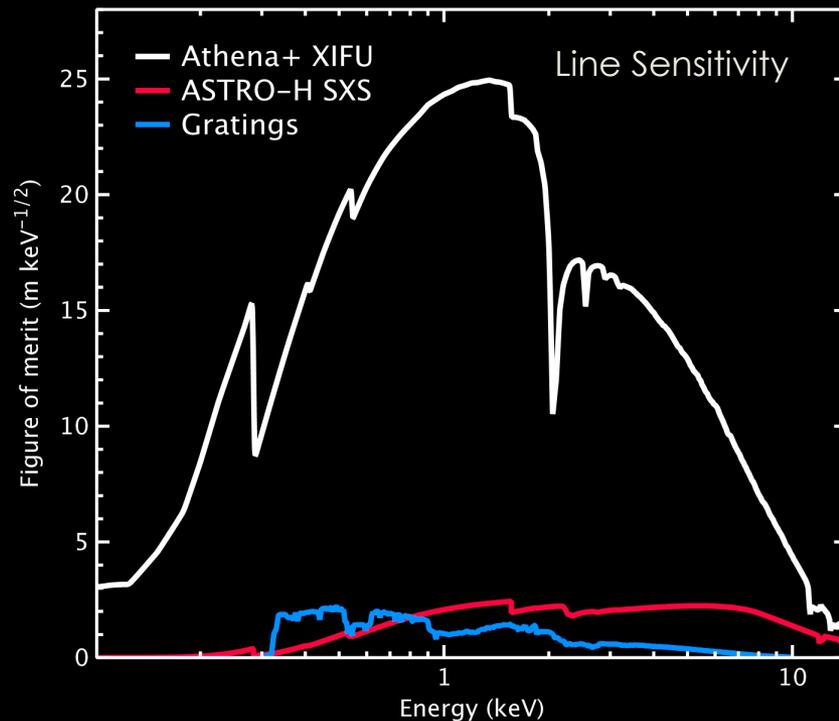
Wide Field Imager:
 ΔE : 125 eV
Field of View: 40 arcmin
High countrate capability

Rau et al. 2013 arXiv1307.1709

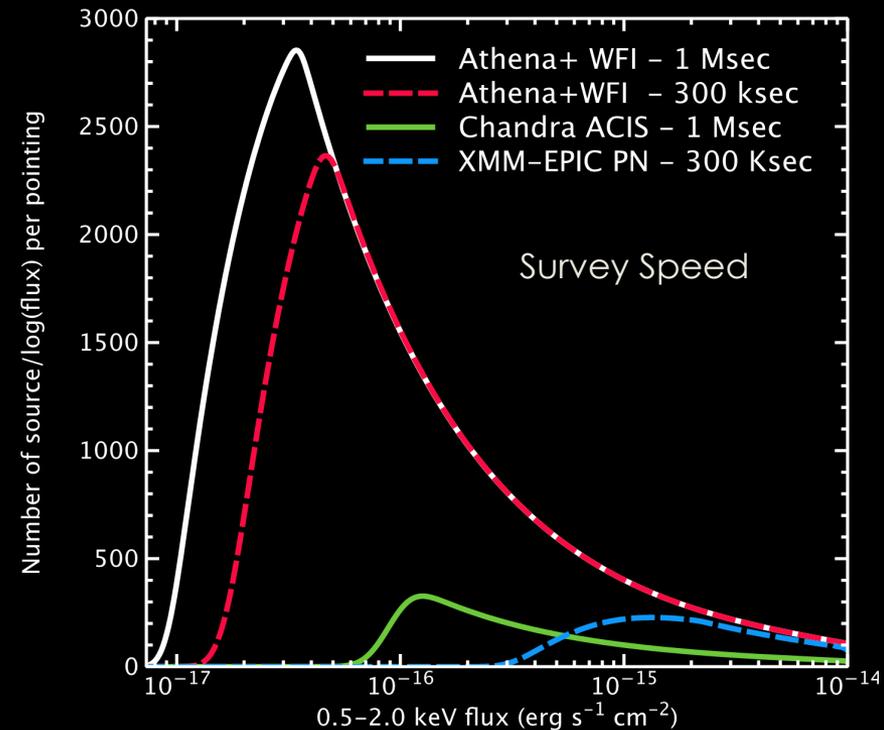
Launch 2028, Hexapod switch mechanism, Ariane 6 (TBC), L2 (TBC)

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

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

(Recall that Athena will be YOUR mission/observatory!)

I- Point sources (from very faint to very bright)

Accretion+ejection mechanisms

- AGN astrophysics (X-IFU spec + WFI survey)
- Blazars (WFI-timing, X-IFU diverter?)
- Binaries +Pulsars (WFI-timing, X-IFU diverter?)
- GRBs (X-IFU) up to $z \sim 10$? (ToO in 4 hrs)
- SNe, tidal disruption events (X-IFU)
- ULXs (WFI, imaging)

II- Diffuse sources (typically faint)

Acceleration mechanisms

- Clusters (X-IFU imaging, WFI)
- Radio galaxies (X-IFU imaging)
- PWNe (X-IFU imaging, WFI)
- SNRs (X-IFU imaging, WFI)

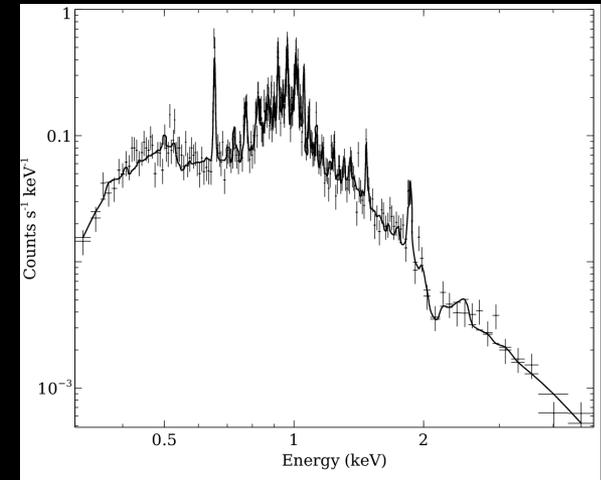
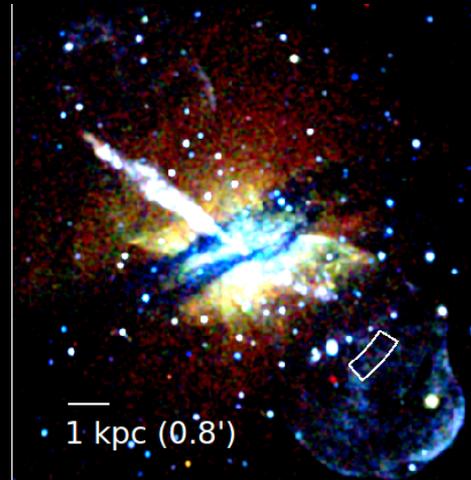
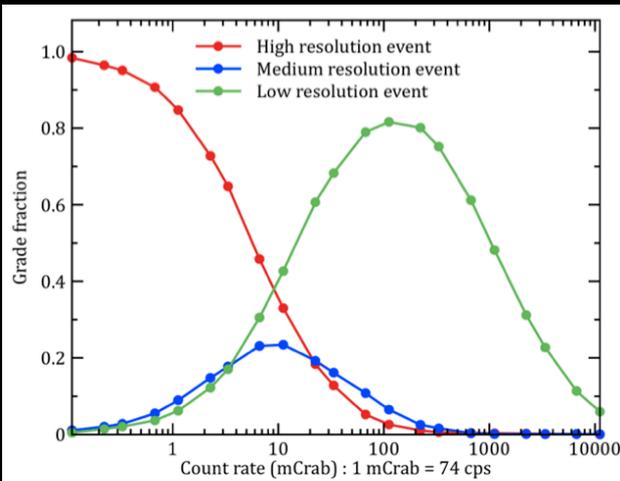


Fig. 5. Simulated WFI pseudo-colour image (l) and X-IFU spectrum (r) from the region indicated, for a 50-ks observation of Centaurus A, demonstrating *Athena+*'s ability to obtain the first direct measurements of advance speed for a strong radio-lobe shock. The shock speed can be determined to within 10% via measurements of line broadening from small regions of the X-ray shell emission dominated by thermal emission (Croston et al. 2009).

International context The only “approved” X-ray mission



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)

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: Christophe Adami (FR), **James Aird (UK)**, Jose Manuel Afonso (PT), Dave Alexander (UK), Costanza Argiroffi (IT), Monique Arnaud (FR), Jean-Luc Atteia (F), Marc Audard (CH), Carles Badenes (US), Jean Ballet (FR), Lucia Ballo (IT), Aya Bamba (JP), Anil Bhardwaj (IN), Ela Stefano Battistelli (IT), Werner Becker (DE), Michaël De Becker (BE), Ehud Behar (IL), Stefano Bianchi (IT), Veronica Biffi (IT), Laura Birzan (NL), Fabrizio Bocchino (IT), Slavko Bogdanov (US), Laurence Boirin (FR), Thomas Boller (DE), Stefano Borgani (IT), Katharina Borm (DE), Hervé Bourdin (IT), Richard Bower (UK), Valentina Braito (IT), Enzo Branchini (IT), **Graziella Branduardi-Raymont (UK)**, Joel Bregman (USA), Laura Brennemman (USA), Murray Brightman (DE), Marcus Brügggen (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 (F), Amalia Corral (GR), **Andrea Comastri (IT)**, **Elisa Costantini (NL)**, **Judith Croston (UK)**, Mauro Dadina (IT), Antonino D'Al (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 Etori (IT)**, Yuichiro Ezoë (JP), Eric Feigelson (US), Rob Fender (UK), Chiara Feruglio (FR), **Alexis Finoguenov (FI)**, Fabrizio Fiore (IT), Massimiliano Galeazzi (IT), Sarah Gallagher (CA), Poshak Gandhi (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), Manul 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), Ian McCarthy (UK), Brian McNamara (CA), Antonio Maggio (IT), Roberto Maiolino (UK), Barbara De Marco (DE), 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 Picconcelli (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 (IT), David Rosario (DE), Mariachiara Rossetti (IT), Agata Roszanska (PL), Emmanouil Rovilos (UK), Ruben Salvaterra (IT), Mara Salvato (DE), Tiziana Di Salvo (IT), **Jeremy Sanders (DE)**, Jorge Sanz-Forcada (ES), Kevin Schawinski (CH), Joop Schaye (NL), **Salvatore Sciarlino (IT)**, Paola Severgnini (I), Francesco Shankar (FR), Stuart Sim (IE), Christian Schmid (DE), Randall Smith (US), Andrew Steiner (US), Beate Stelzer (IT), Gordon Stewart (UK), Tod Strohmayer (US), Lothar Strüder (DE), Ming Sun (US), Yoh Takei (JP), Andreas Tiengo (IT), Francesco Tombesi (US), Ginevra Trinchieri (IT), Asif ud-Doula (US), Eugenio Ursino (NL), Lynne Valencic (US), Eros Vanzella (IT), Simon Vaughan (UK), Cristian Vignali (IT), Jacco Vink (NL), Fabio Vito (IT), Marta Volonteri (FR), Daniel Wang (US), Natalie Webb (FR), Richard Willingale (UK), **Joern Wilms (DE)**, Michael Wise (NL), Diana Worrall (UK), Andrew Young (UK), Luca Zampieri (IT), Jean In't Zand (NL), Andreas Zezas (GR), Yuying Zhang (DE), Irina Zhuravleva (US)

Bold Face Denotes Working Group Chairs

Athena Study Science Team (ASST):

D. Lumb, K. Nandra, D. Barret, A. Decourchelle, X. Barcons, J.-W. den Herder, A. Fabian, K. Matsumoto, L. Piro, R. Smith, D. Willingale

Athena Working Group Members

(>800 community researchers)

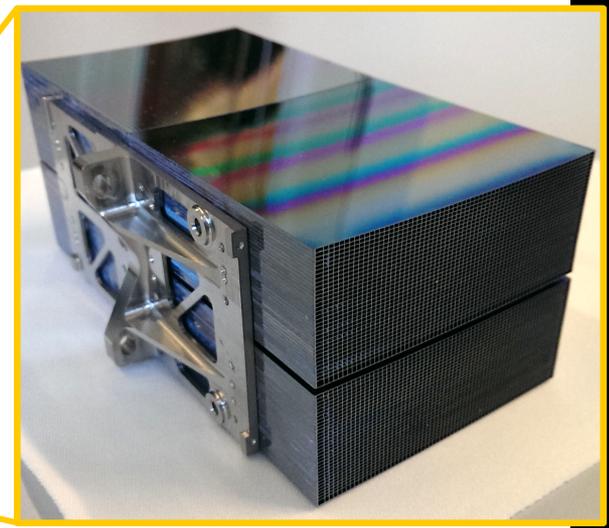
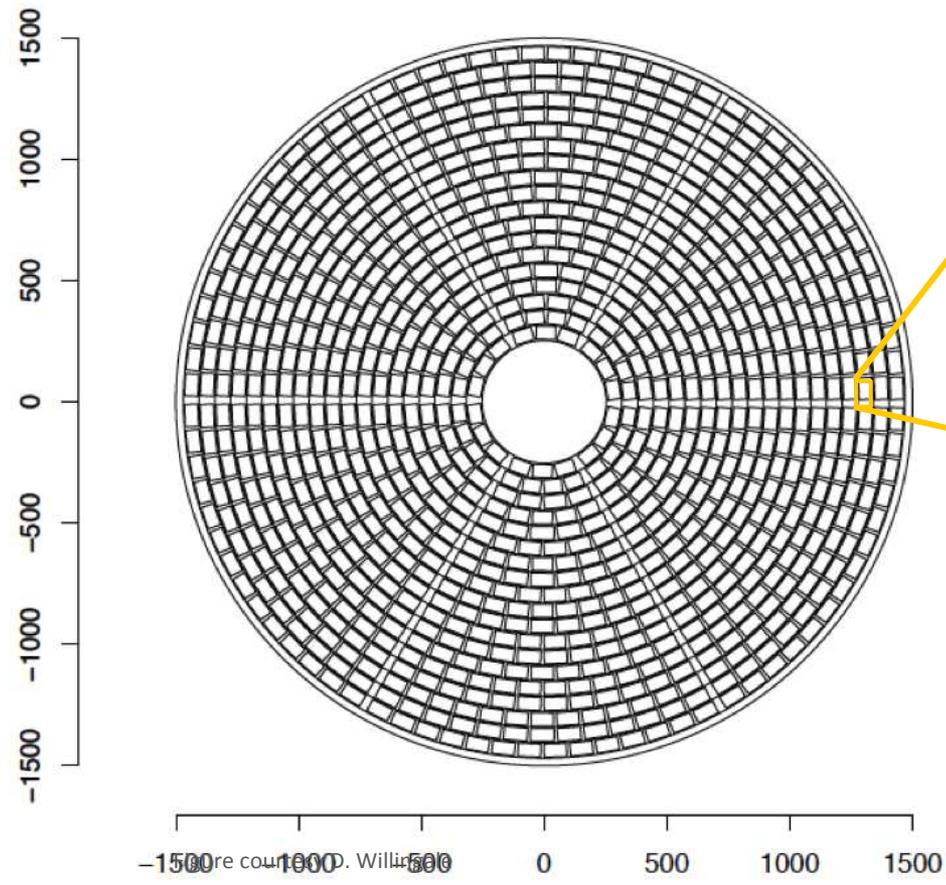
Athena supporters

(>2000+ astronomers)

More information, white paper, mission proposal, supporting papers, technical supplements, etc. at: <http://the-athena-x-ray-observatory.eu/>

Optics

ESA responsibility



Wide Field Imager

WFI consortium lead: Germany

FoV = 40 arcmin ↔ **Size = 140 mm**

4 large DEPFET sensor chips

512 x 512 pixels with $130\ \mu\text{m} \times 130\ \mu\text{m}$

sensitive area → $67 \times 67\ \text{mm}^2$

Time resolution: **1.28 ms**

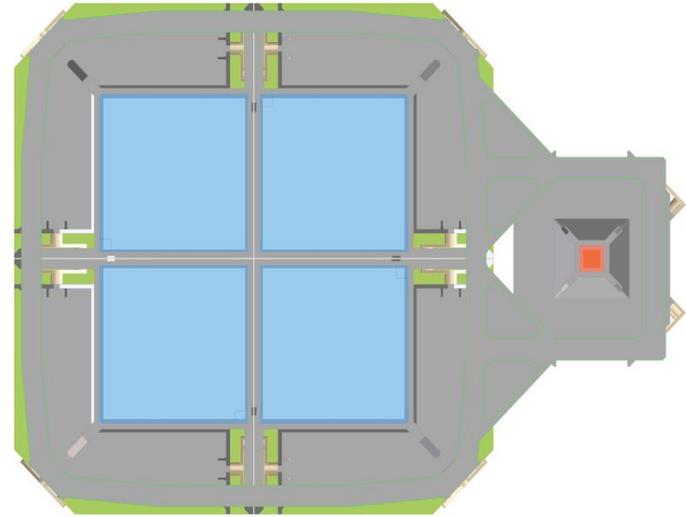
1 fast timing DEPFET sensor

64 x 64 pixels with $130\ \mu\text{m} \times 130\ \mu\text{m}$

sensitive area → $8.3 \times 8.3\ \text{mm}^2$

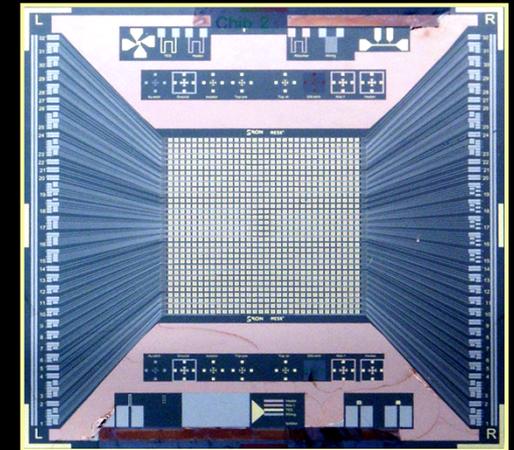
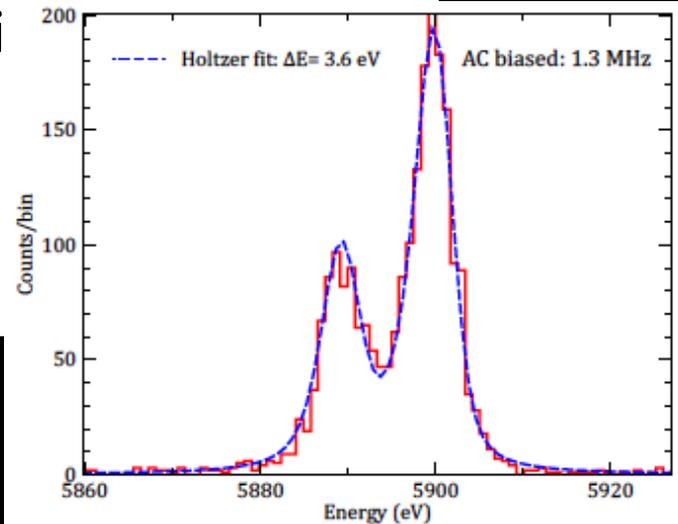
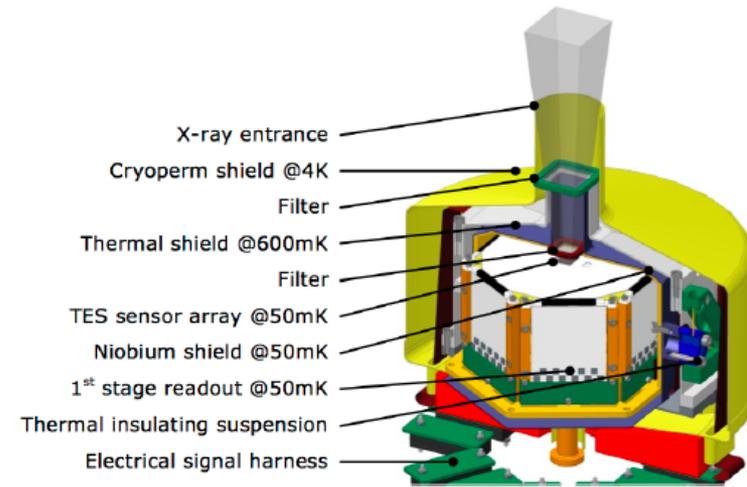
Time resolution: **160 μs** (or **80 μs** with 2-line readout option)

Window mode: 8+8 lines ($36\ \text{arcsec} \approx 7 \times \text{PSF}$): **20 μs** (or **10 μs** with 2-line readout option)



X-Ray Integral Field Unit

- XIFU consortium lead: France (PI), Italy & Holland (CoPI)
- Transition Edge Sensor microcalorimeter in cryo (50 mK)
- 4-kpixel array
- Large TES-based CryoAC for Low instrumental background
- Read-out: FDM multi



Programmatics

- ESA led missions, but international collaboration allowed (<20%)
- NASA and JAXA are partners
- ESA responsible of mission systems, spacecraft, launcher, mirror, operations and SOC
- Instruments and Science Ground Segment elements to be provided by the Member States < ~ 400 M€
- ESA Cost at Completion ~ 1 B€

Schedule

- ✓ Hot&Energetic Univ. Theme selected for ESA L2 Nov. 2013
- ✓ Athena Mission selected Jun. 2014
- ✓ Phase A and B1 on going
- ✓ Implementation Phase 2019
- ✓ Launch 2028
- ✓ Operations: 5 +5 years

- Science, Mission and Instruments with a leading role of Italian scientists and industry.
- **XIFU CoPI** + synergical participation to WFI
- Roles & Community: 1 in the ESA Study Team, 9 Italian co-chairs of Mission & Science WGs + 160 Italian members
- Italian Key institutions are:
 - INAF: IAPS(RM), IASF-MI, IASF-Bo, IASF-Pa, OABrera, OABo, OATo, OAPa, OaTs, OAArcetri, OARM, OANa
 - Univ. & INFN Genova, Univ Rm1,Rm2Rm3, Univ. Bo, Univ. Pa, Un.Mi
 - CNR, INFN-RM
- Industrial role from mission prime-ship, subsystems, instrument cutting-edge technologies, mirror assembly (TAS,CGS,FBK, Mediolario,..)
- Italian contributions formalized at the ESA-Leading Funding Agencies meeting in Oct. 2014

ATHENA XIFU Items with Italian responsibility

- **Crucial for science (Bkg. reduction, Area at low E=> filters)**
- Critical tech. items to be integrated in the Demonstration Model by 2018
- **Lead role in Instrument Design and Control (Bkg. Simu;, ICU)**
- Responsibilities in the Consortium:
 - CryoAnticoincidence, front end electronics, digital and Data processing (IAPS/INAF, Uni.Ge, CNR/IFN, IASF-Mi)
 - Background simulations and instrument design (IAPS/INAF, IASF-Pa, Mi, Bo)
 - Optical/IR blocking filters (Univ. Pa & Oss. Pa/INAF)
 - Instrument Control Unit (IASF/Bo, Oss. To, IAPS)
 - Contribution to instrument calibrations on ground and in-flight (IAPS/INAF +) under assessment
- **GS, Science Innovation Center (OaR)**

Conclusions

- Athena is THE large observatory for X-ray Astronomy for the next 20 years.
- Athena offers the unique opportunity of a leading Italian role and large scientific, technological and industrial return to a vast national community
- Complement the suite of major class facilities at other v 's
- Athena science is **already** driving present research providing:
 - guidance for the formation of the new generations of researchers
 - Pathfinder experiments with present facilities (XMM, Chandra, etc.) and theoretical studies
 - Need strong political and financial support!!
- Next 4 years critical to enhance the TRL of enabling technologies before mission adoption