The hot and energetic Universe

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

• How do black holes grow and influence the Universe?

• In addition:
  ‣ Fast ToO capability to study transient sources
  ‣ Observatory science across all corners of Astrophysics

http://www.the-athena-x-ray-observatory.eu

Nandra, Barret, Barcons et al. arXiv:1306.2307
ATHENA: Advanced Telescope for High ENergy Astrophysics

- 12 m focal length
- **1.4 m² area @1 keV, 5” HEW**
- Wide Field Imager (WFI)
  - Active Pixel Sensor Si detector
  - 40’x40’ FoV
  - 120-150 eV @6 keV
- X-ray Integral Field Unit (X-IFU)
  - Cryogenic imaging spectrometer
  - 5’ diameter equivalent FoV
  - 2.5 eV @7 keV
- **Launch 2030, Ariane 6.4, L2 orbit**
- 4 years nominal life-time + extensions

Courtesy of I. Maussang@CNES / ESA
ATHENA: Advanced Telescope for High ENergy Astrophysics

• Athena @ ESA
  ‣ Cost cap = 1.05B€, encompasses the optics, payload, launch+
  ‣ Phase A, i.e., accepted proposal in feasibility/definition phase
  ‣ Main Milestone: Mission Adoption Review by ESA in 11/2021

• Athena optics
  ‣ Silicon Pore Optics developed by ESA/Cosine are on a critical path
  ‣ Maintain pressure on ESA to secure the effective area and the adequate spatial resolution

• Instruments (X-IFU and WFI)
  ‣ Funded by national agencies + contributions by ESA, NASA, JAXA
  ‣ Instruments (X-IFU and WFI) configuration as proposed
Effective area

X-IFU

WFI

Effective area [cm²]

Energy (keV)

Effective area [cm²]

Energy [keV]
Assembly of the first massive halos

Schaye et al. 2015

Athena/WFI 1Ms simulation
MPE & WFI team
Assembly of the first massive halos

$z = 2.5 / 80 \text{ ks}$

Simulated

Detected

Courtesy of C. Zhang and F. Pacaud
AGN feedback in clusters

- Energetics of central AGN feedback
- Gas dynamic and jet energy dissipation in clusters

Sanders, Croston et al. 2013

Barret et al. 2016
Dynamical assembly of clusters

- Simulated ‘Perseus like’ cluster (from Rasia, Biffi, Borgani, Dolag)
- 100ks X-IFU observation with SIXTE

Hitomi Collaboration - “V”, 2017

Barret et al. 2016
Dynamical assembly of clusters

- Simulated Coma like ICM
  - from Gaspari & Churazov 2013
  - turbulence
  - thermal conduction

- X-IFU single pointing
  - SIXTE simulation of observation
  - bapec emission model

- Velocity measurement
  - bulk motion from line shift
  - turbulence from line broadening
Dynamical assembly of clusters

- Measuring velocities through line broadening
  - Phoenix cluster at $z \approx 0.6$
  - 1 arcmin diameter area, $\sim 15$ ksec, no instrumental noise
  - Statistical errors only

![Graph showing energy vs. counts per keV with velocities and redshifts marked]

Courtesy of C. Pinto
Chemical evolution

- 4 simulated clusters
  - from Rasia, Biffi et al.

- X-IFU simulations with SIXTE
  - 100 ksec per pointing
  - CXB, Galaxy, Instrument noise
  - J. Sanders binning scheme

PRELIMINARY
Chemical evolution

- Source of production for chemical elements

Mernier+16a,b,+17 on the CHEERS sample

Abundance ratios $Z_{\text{Fe}}/Z_{\text{Fe}}$

Abundance ratios $[0-0.3] R_{500}$

Cucchetti+ in prep
Chemical evolution

- Enrichment of the ICM across cosmic times

Cucchetti+ in prep
CDFS

- 150 ksec WFI and X-IFU

Courtesy of Thomas Dauser and Joern Wilms
Galactic centre

- 150 ksec WFI and X-IFU

Courtesy of Thomas Dauser and Joern Wilms
Galaxies and SNRs

- **Tycho**
  - WFI 1.5 ksec

- **M82**
  - WFI 150 ksec

Courtesy of Thomas Dauser and Joern Wilms
Take home messages

- Athena and its instruments are in feasibility/definition phase

- Cluster science is at the core of the Athena science case
  - Driving the telescope and instruments performance (effective area, spatial resolution, energy resolution, energy coverage, FoV, etc)

- Athena will enable a wealth of science on the hot and energetic Universe, and on observatory science