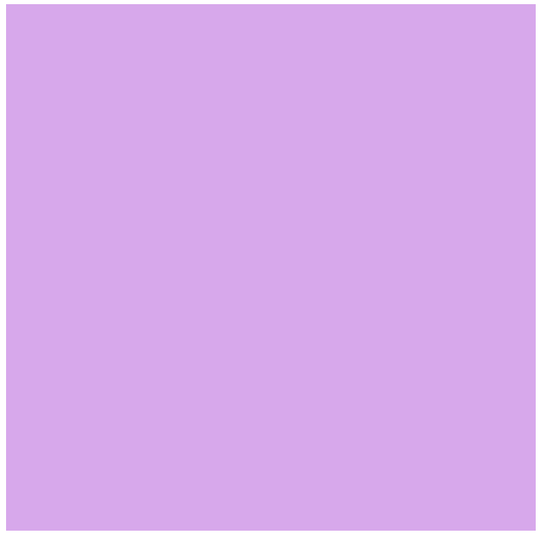
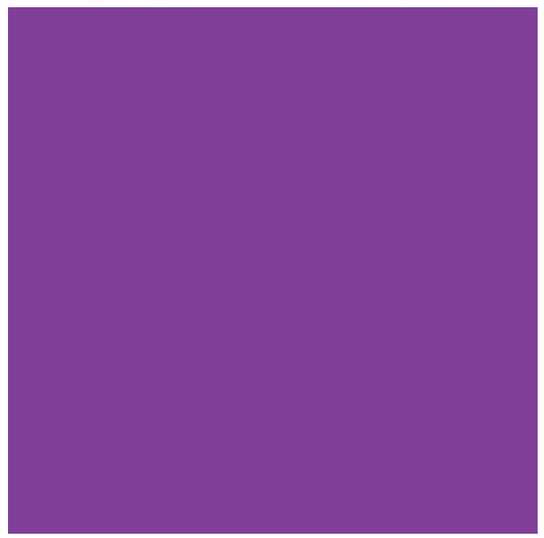
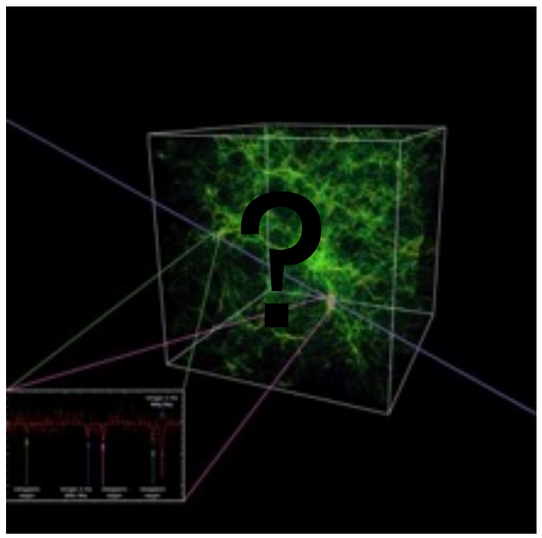
ATHENA

A systematic study of the WHIM







Jan-Willem den Herder

SRON the Netherlands Institute for Space Research

IAU Vienna, August 30-31 2018

Contents

- Athena in a nutshell
- The Athena science theme: Hot and Energetic Universe
- Athena science performance
- Mission concept & payload

Thanks

- the Athena Science Study Team (M. Guainazzi, K. Nandra. D. Barret, J.W. den Herder, A. Decourchelle, A.C. Fabian, H. Matsumoto, L. Piro, R. Smith, R. Willingale)
- The WHIM working group (led by J. Kaastra and A. Finogenov)
- The instrument teams
- The ESA study team

The Athena mission: an ESA flagship

Fundamental questions

- How does the **large scale structure** in the Universe form and evolve?
- How do **black holes** grow and help shape the Universe?
- How and when are the **chemical elements** formed?

Athena is an **observatory** with ~500 projects/year:

- stars, exoplanets, pulsars, neutron stars, gamma ray bursts, gravitational wave events, galaxies
- Unprecedented **discovery space**

SRON

Advanced Telescope for High-Energy Astrophysics

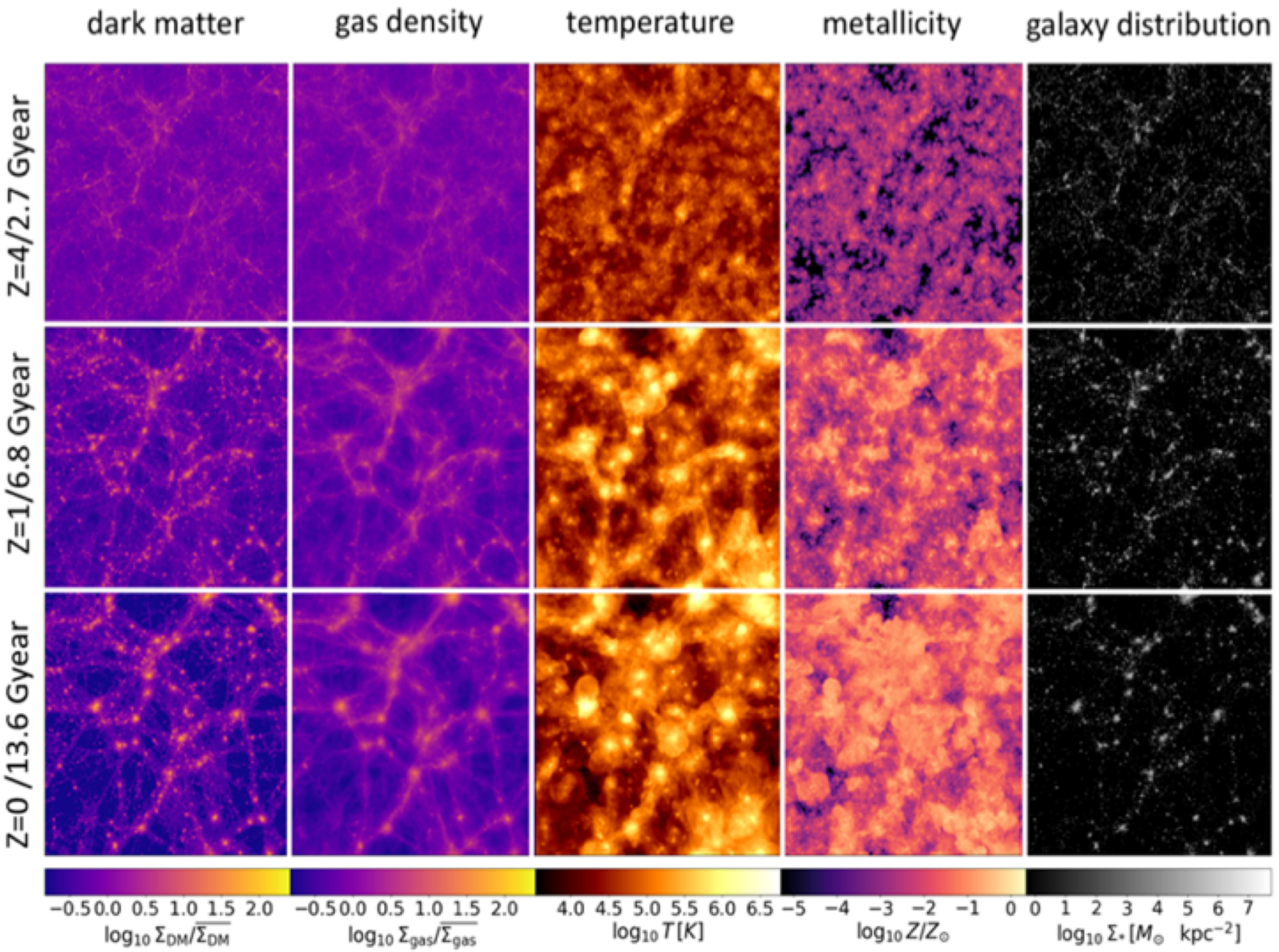
- Second Large (L2) mission of ESA Cosmic Vision 2015-2025
- Expected Launch: early 2030's
- X-ray collecting mirror (~ 1.4 m^2 at 1 keV, 5 arcsec HEW) but **~1.25 m^2 at 0.5 keV**
- 2 instruments:
  - **Wide Field Imager** (Si based DEPFET, 40 x 40 $arcmin^2$)
  - **X-ray integral Field Unit** (high spectral resolution (2.5 eV) over 5 arcmin FoV (diameter)
- Fast **ToO** capability to study transient sources
- Dithering to avoid systematic errors due to ΔQE between pixels

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

SRON

The Hot Universe: scientific goal

how and when large-scale hot gas structures formed in the Universe

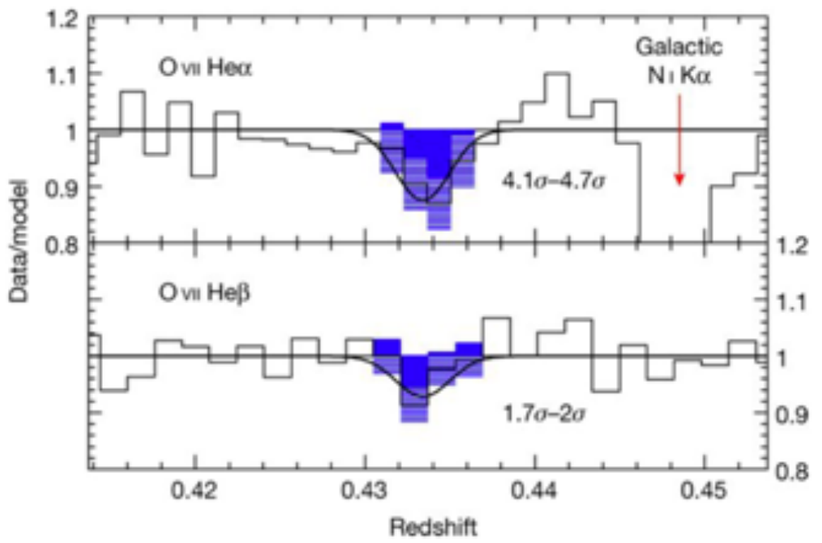


Credit: N Wijers, Leiden

Science Objectives

Baryon density by absorption measurements

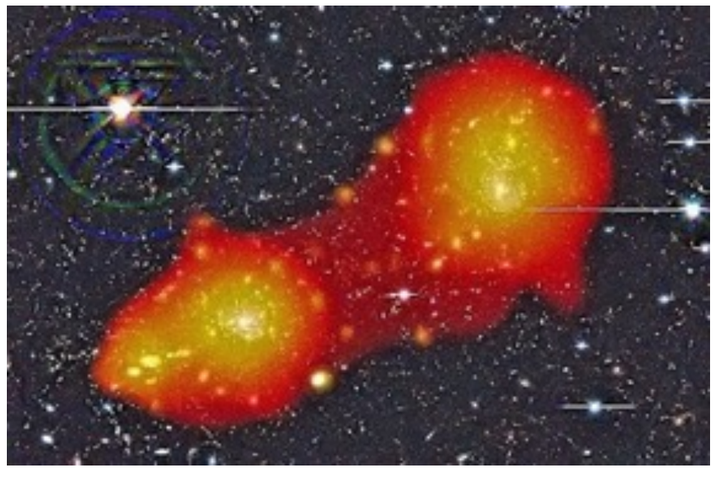
- 200 filaments < z=1 (100 AGN, 100 bright GRBs)



courtesy: Nicastro

Emission

- 7 GRB afterglows
- Filaments between clusters
- Statistical analysis of emission lines (cross correlation)

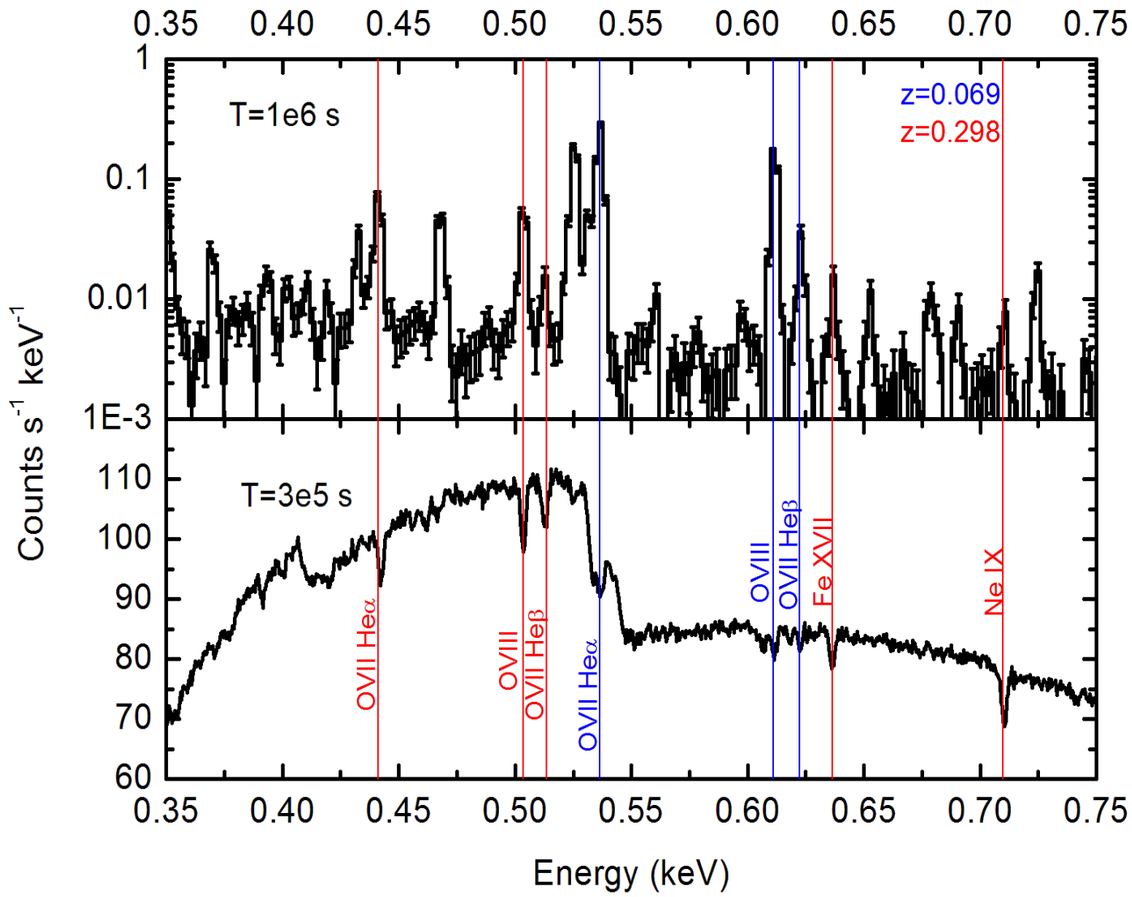


courtesy: `Werner/Dietrich

SRON

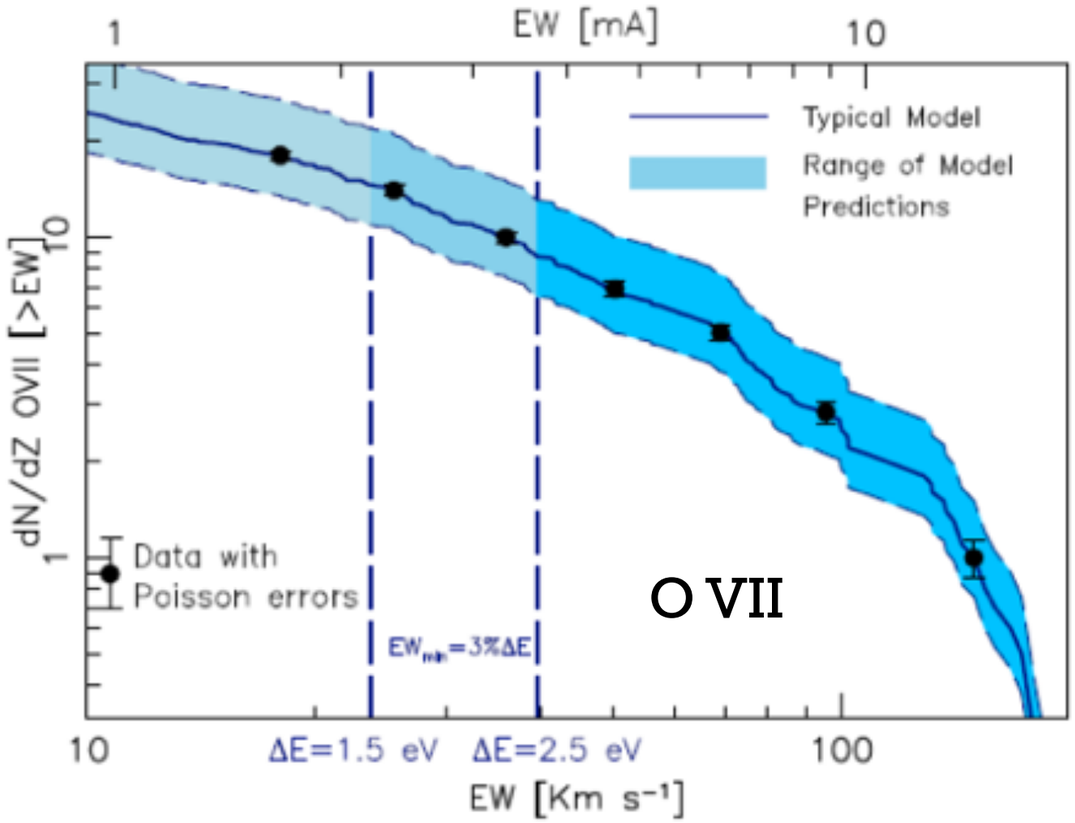
Missing baryons: the WHIM

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?

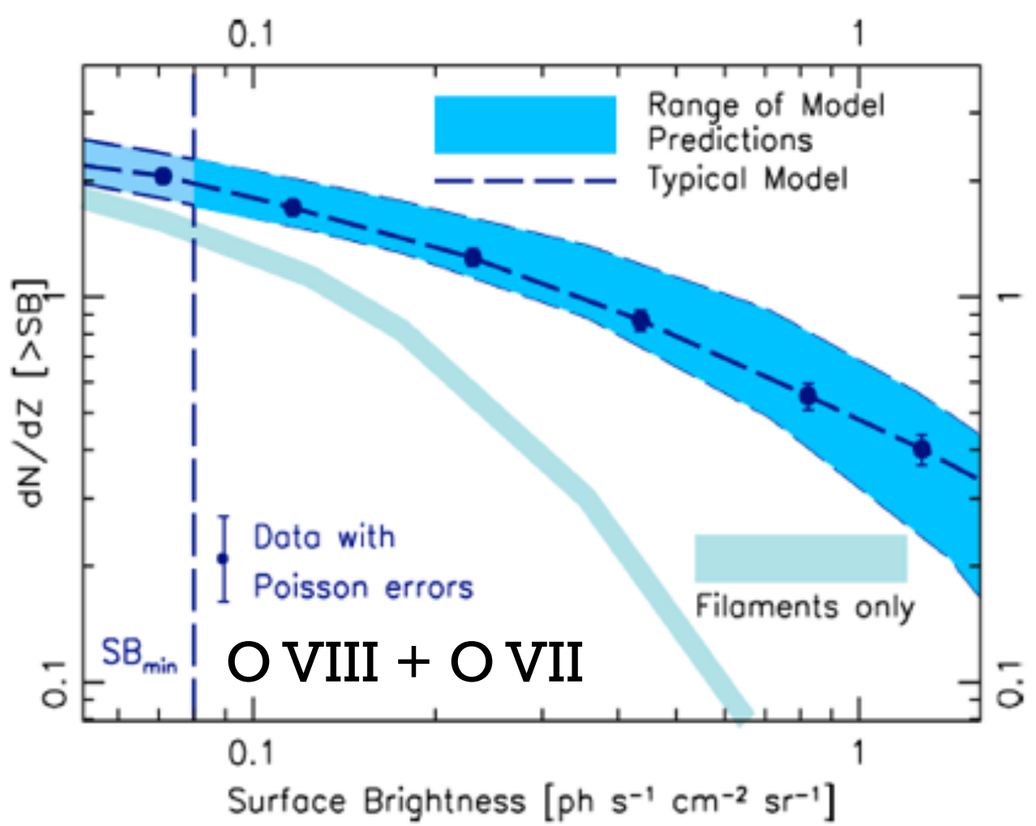


An observational program

absorption



emission



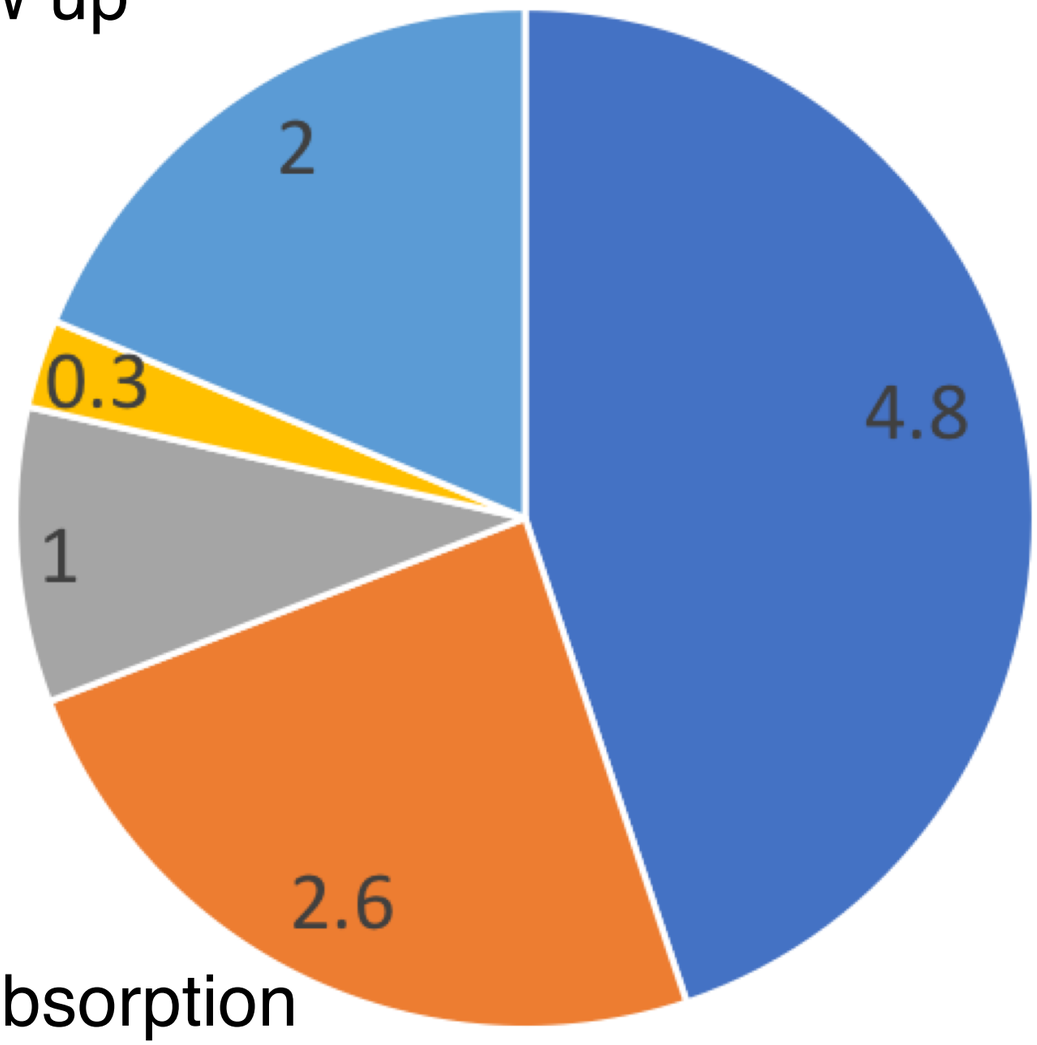
SRON

Planned observations [Ms]

7 GRB follow up
in Emission

A222-A223 bridge

COSMOS field



39 AGN

25 GRB in absorption

10% of observing plan

SRON

The mission

- Single telescope,
  - WFI sensitive imaging & timing
  - X-IFU spatially resolved high-resolution spectroscopy
- Movable mirror assembly to switch between the two instruments
- Launch 2030's, Ariane 64
- L2 halo orbit (TBC)
- Lifetime 4 years up to 10+ years

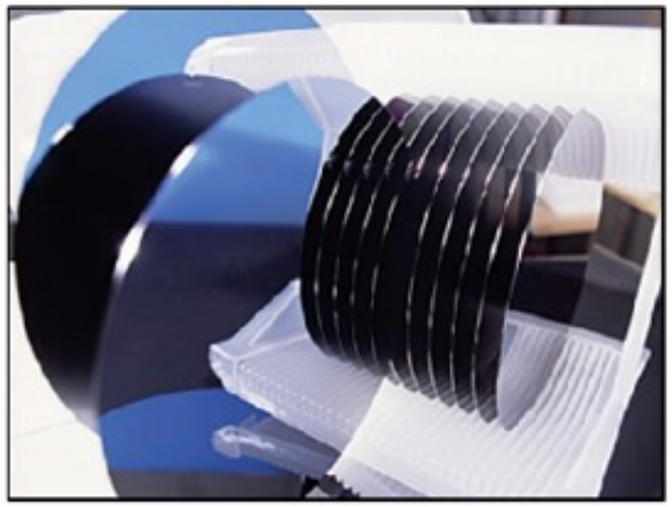
Athena Mission Requirements

Parameter	value	enables (driving science goals)
Effective area at 1 keV	1.4 m^2	Early groups, cluster entropy and metal evolution, WHIM, high redshift AGN, census AGN, first generation of stars
Effective area at 6 keV	0.25 m^2	Cluster energetics (gas bulk motions and turbulence), AGN winds & outflows, SMBH & GBH spins
PSF HEW (< 8 keV)	5'' on axis, 10'' off axis	High z AGN, census of AGN, early groups, AGN feedback on cluster scales
X-IFU spectral resolution	2.5 eV	WHIM, cluster hot gas energetics and AGN feedback on cluster scales, energetics of AGN outflows at z~1-4
X-IFU FoV	5' diameter	Metal production & dispersal, cluster energetics, WHIM
X-IFU background	< 5 10^{-3} counts/s/cm^2/keV (75%)	Cluster energetics & AGN feedback on cluster scales, metal production & dispersal
WFI spectral resolution	150 eV	GBH spin, reverberation mapping
WFI FoV	40' x 40'	High-z AGN, census AGN, early groups, cluster entropy evolution, jet-induced cluster ripples
WFI count rate	80% at 1 Crab	GBH spin, reverberation mapping, accretion physics
WFI background	< 5 10^{-3} counts/s/cm^2/keV (75%)	Cluster entropy, cluster feedback, census AGN at z~1-4
Recons. astrometric error	1'' (3s)	High z AGNs
GRB trigger efficiency	40%	WHIM
ToO reaction time	< 4 hours	WHIM, first generation of stars

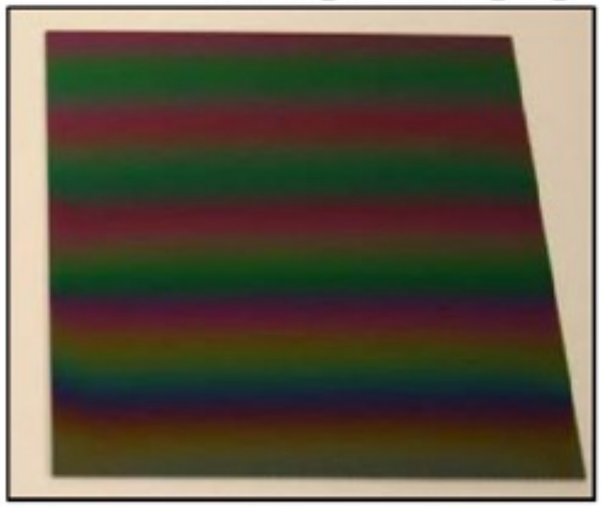
SRON

Silicon Pore Optics

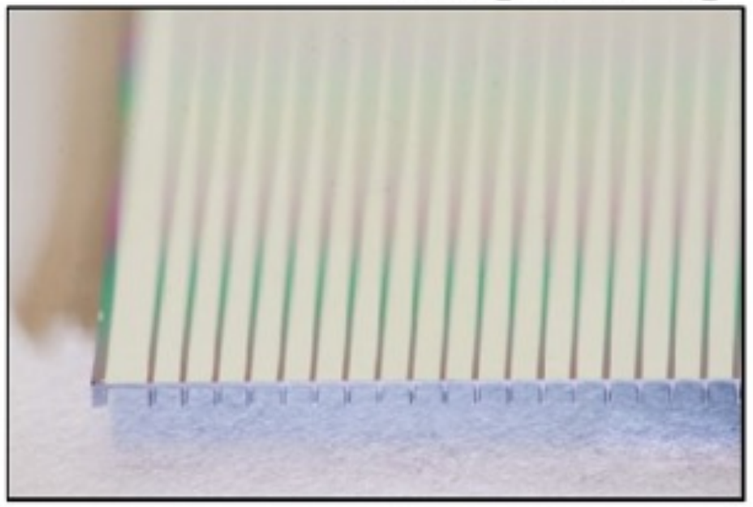
12" Si wafers

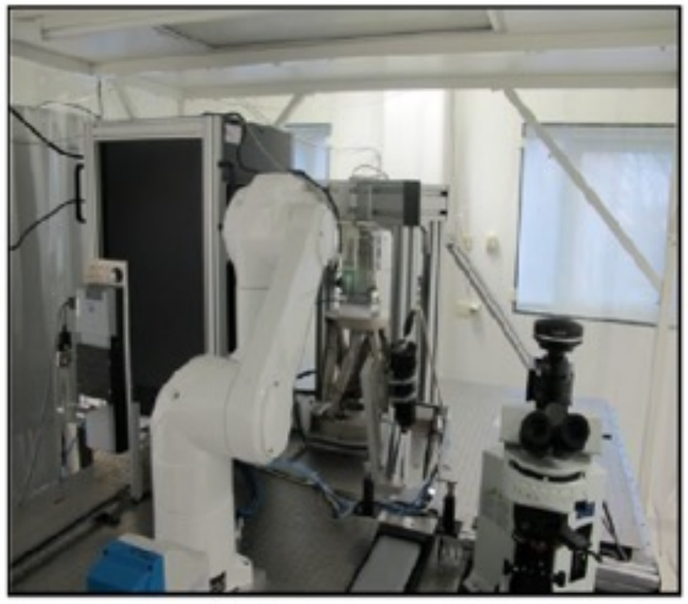


Dicing & Wedging



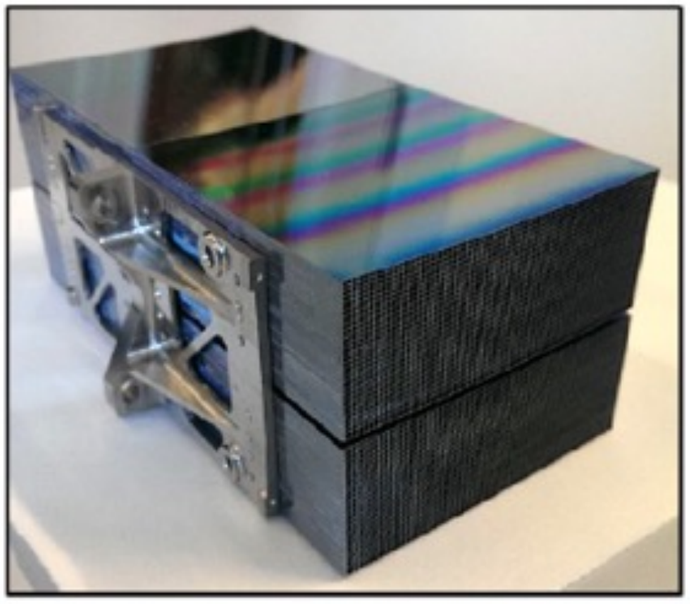
Ribbing & Coating



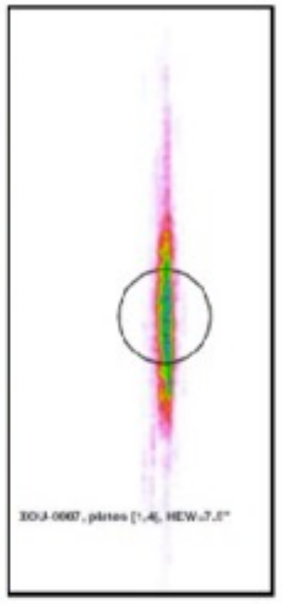


Automated stacking

Stack



Mirror module

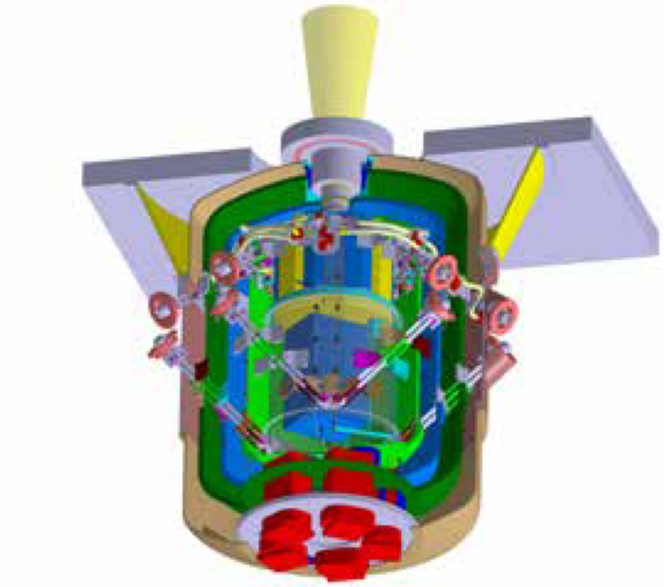


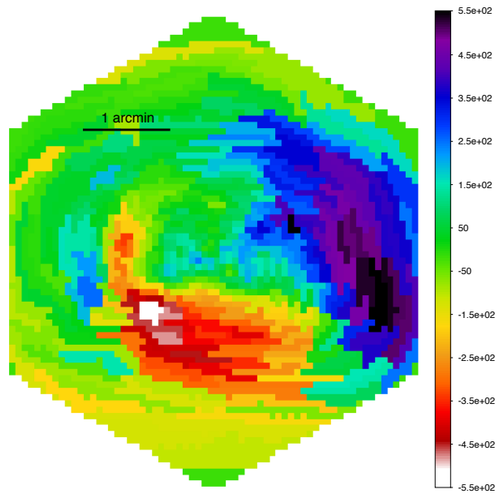
Testing

SRON

X-ray Integral Field Unit (X-IFU)

- Cryogenic imaging spectrometer, based on Transition Edge Sensors, operated at 50 mK
- Consortium led by CNES/IRAP-F, with SRON-NL, INAF-IT and other European partners (ES, CH, BE, FI, PL, DE), NASA and JAXA.
- Key performance parameters:
  - **2.5 eV energy resolution <7 keV**
  - FoV 5’ diameter
  - Pixel size <5”

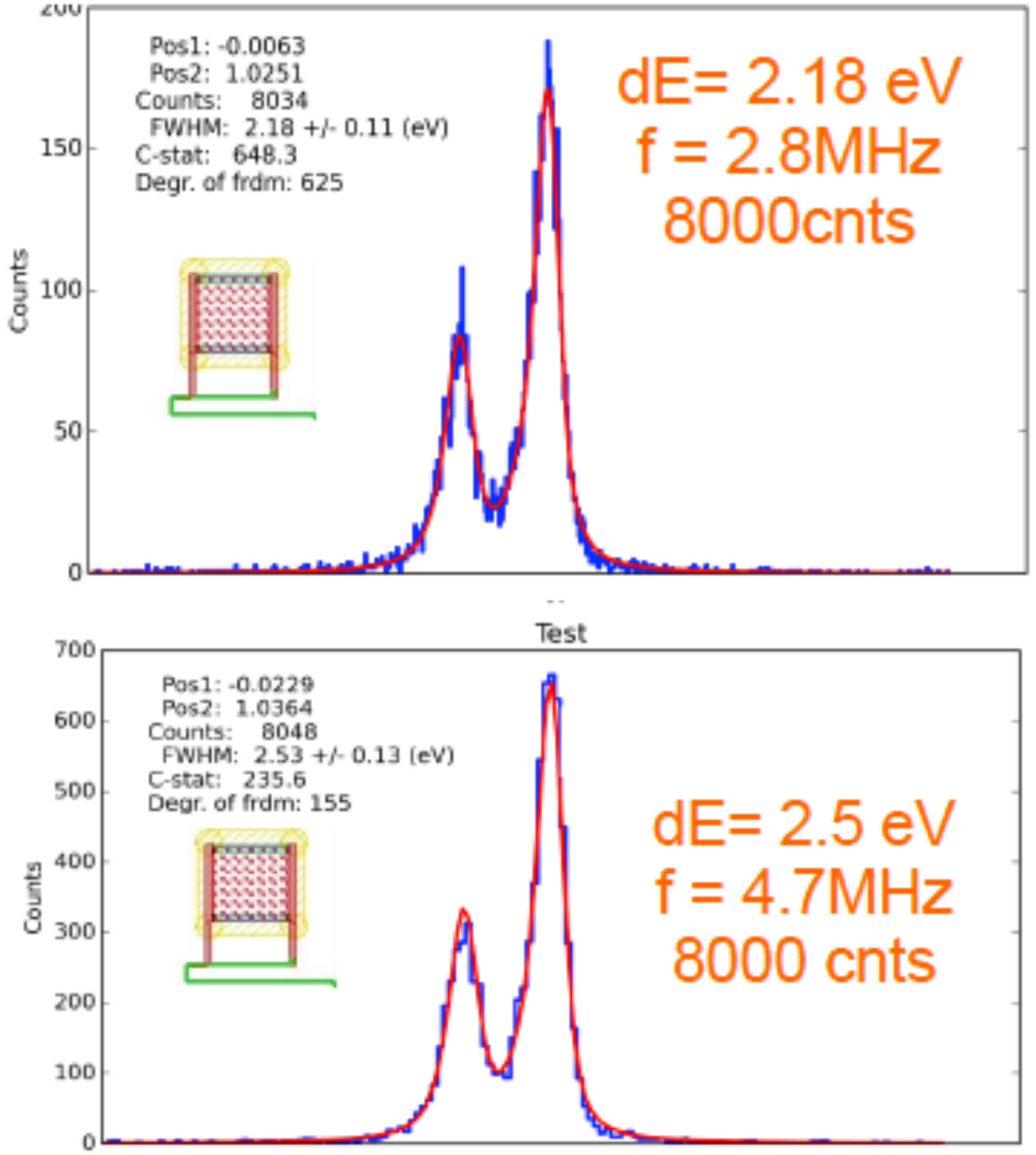




E. Pointecouteau, P. Peille, E. Rasia, V.Biffi, S. Borgani, K. Dolag, J. Wilms

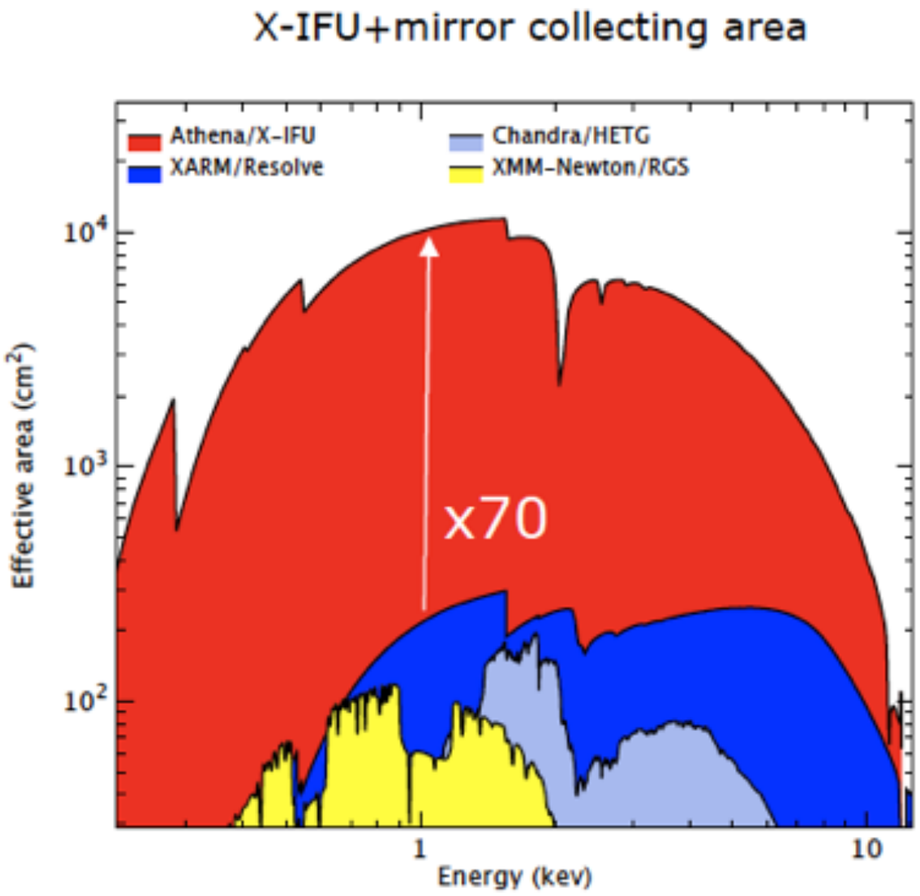
X-IFU spectral resolution

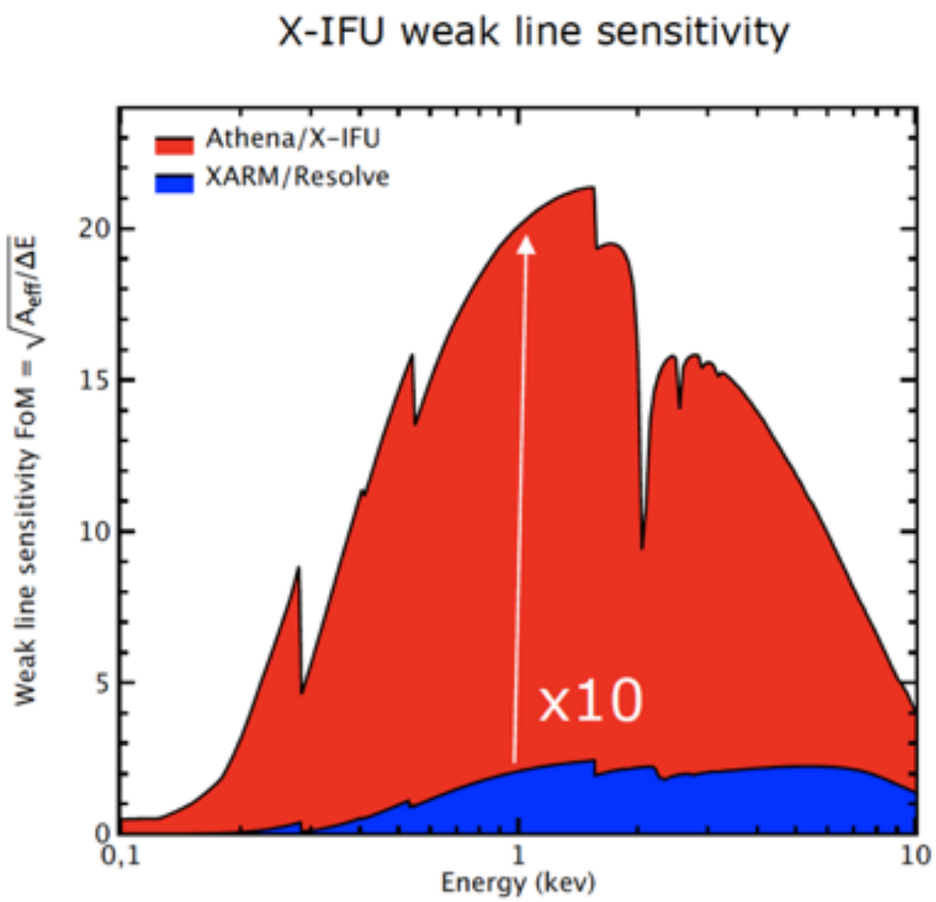
- Area and energy resolution are prime parameters for weak line detection
- Aeff limited by funding
- ΔE at low E < 2.5 eV
- Fast repointing compensates for Aeff for transient sources: 4 hour (and sometimes better) feasible



SRON

Athena: a transformational observatory

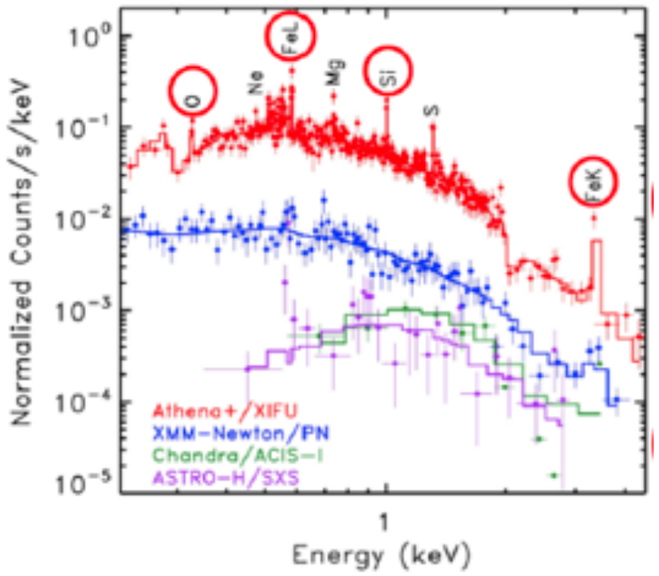




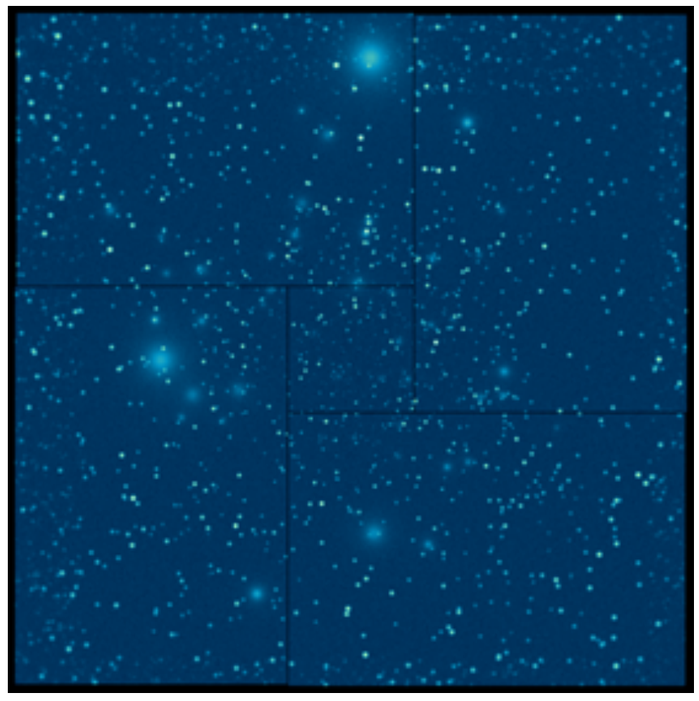
Credit: Athena team

Questions?

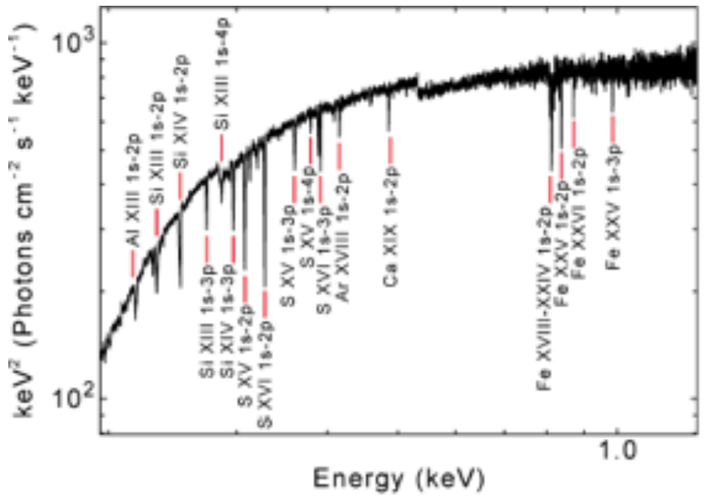
Galaxy cluster at z=1



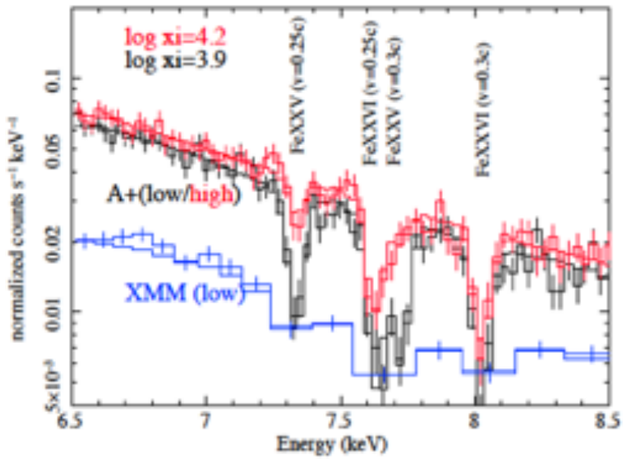
Wide field Image



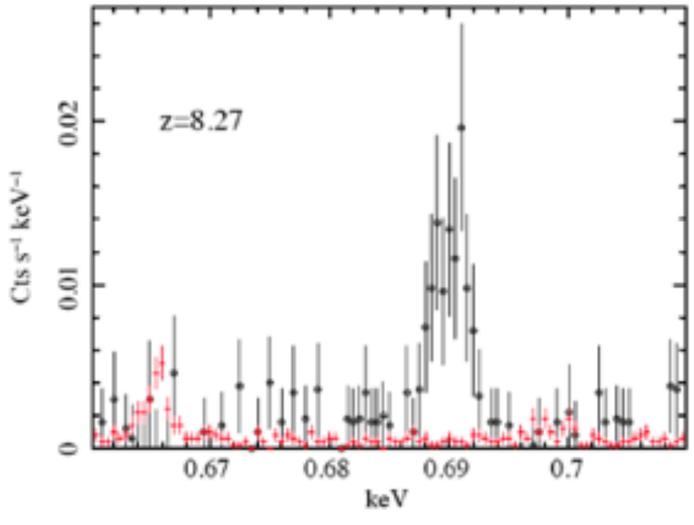
Primoridal stellar populations at z=7



BH feedback at z=2



Obscured BH at the early Universe



SRON