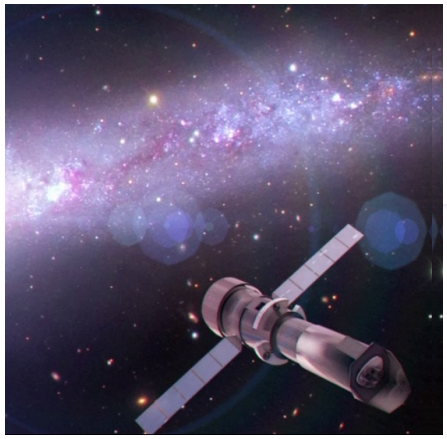
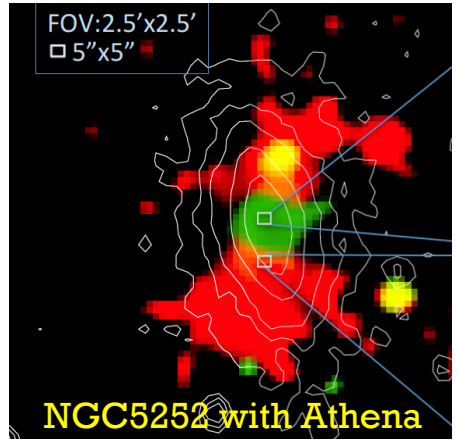
ATHENA

Athena: ESA's X-ray observatory to study the Hot and Energetic Universe





Matteo Guainazzi on behalf of the
Athena Science Study Team

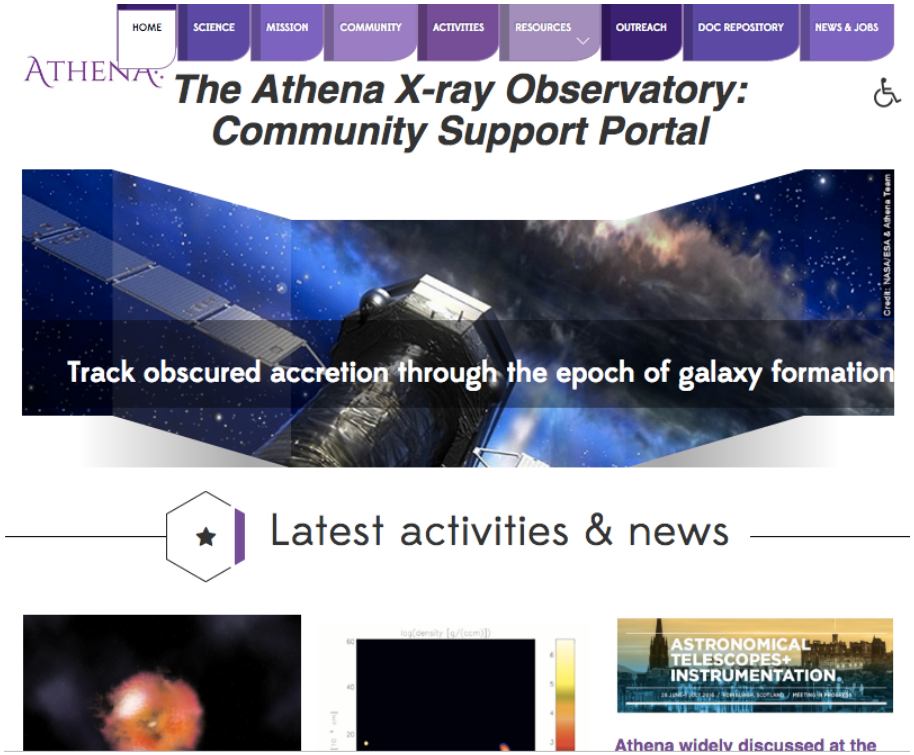
ESA/SCI-S, ESTEC, Noordwijk, Netherlands

X-ray SIG meeting, HEAD 2017, 22 August 2017

Advanced Telescope for High-Energy Astrophysics

- Second Large (L2) mission of ESA Cosmic Vision 2015-2035
  - International contribution by JAXA and NASA
- Science theme: The Hot and Energetic Universe
  - How does ordinary matter assemble in the large-scale structures?
  - How do black holes grow and shape galaxies?
- In addition:
  - ToO capability to study transient sources
  - Observatory science across all corners of Astrophysics

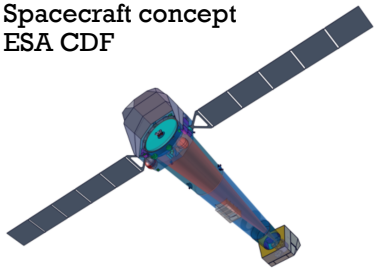
More info at: http://www.the-athena-x-ray-observatory.eu

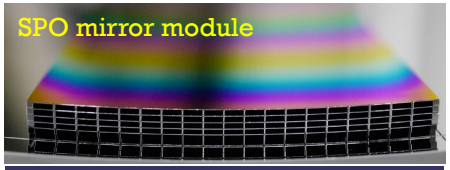


800+ scientists in the Athena community

Mission profile (current Phase A)

Spacecraft concept
ESA CDF

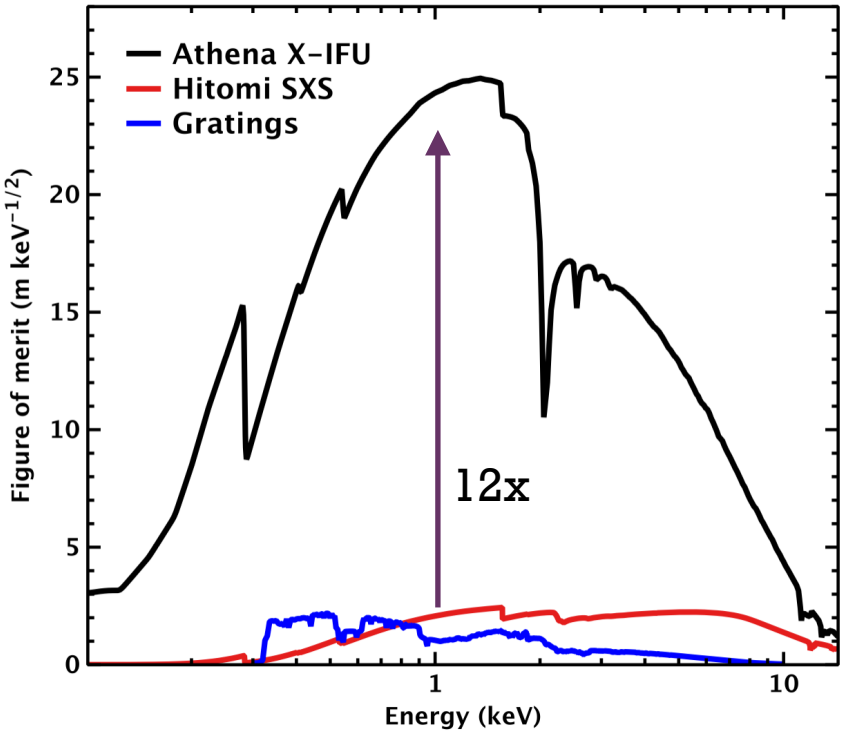




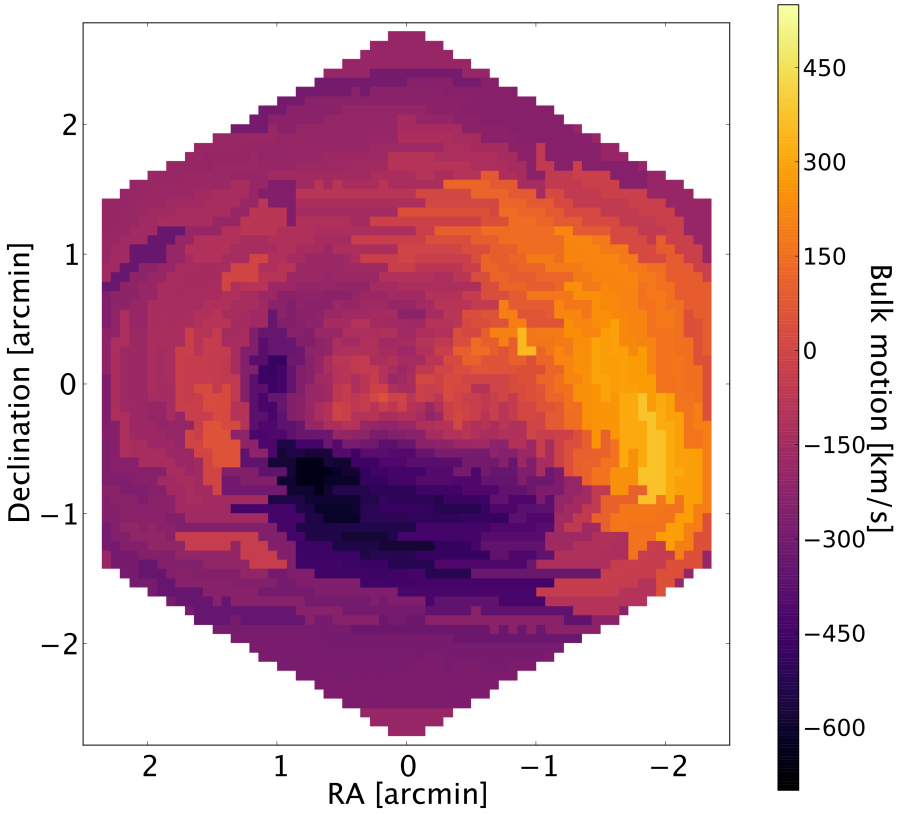
- Single telescope, Silicon Pore Optics (**SPO**) technology, 12 m focal length, ≥1.4 m^2 area@1 keV, 0.25 m^2 @6 keV
- **WFI** (Active Pixel Sensor Si detector): wide-field (40'x40') spectral-imaging, CCD-like energy resolution (120-150 eV @6 keV)
- **X-IFU** (cryogenic imaging spectrometer): 2.5 eV energy resolution, 5'x5' field-of-view, ~5" pixel size
- Count rates capabilities: >1 Crab (WFI)/~1 Crab (30% throughput) X-IFU (increased thanks to defocusing capabilities)
- ≥4 hours response with a ~50% efficiency to observe a ToO in a random position in the sky
- Launch 2028/9, Ariane 6.4, L2 halo orbit (TBC)
- Nominal life-time 4 years + extensions

A revolutionary mix of science performance - I

Effective area per energy resolution element

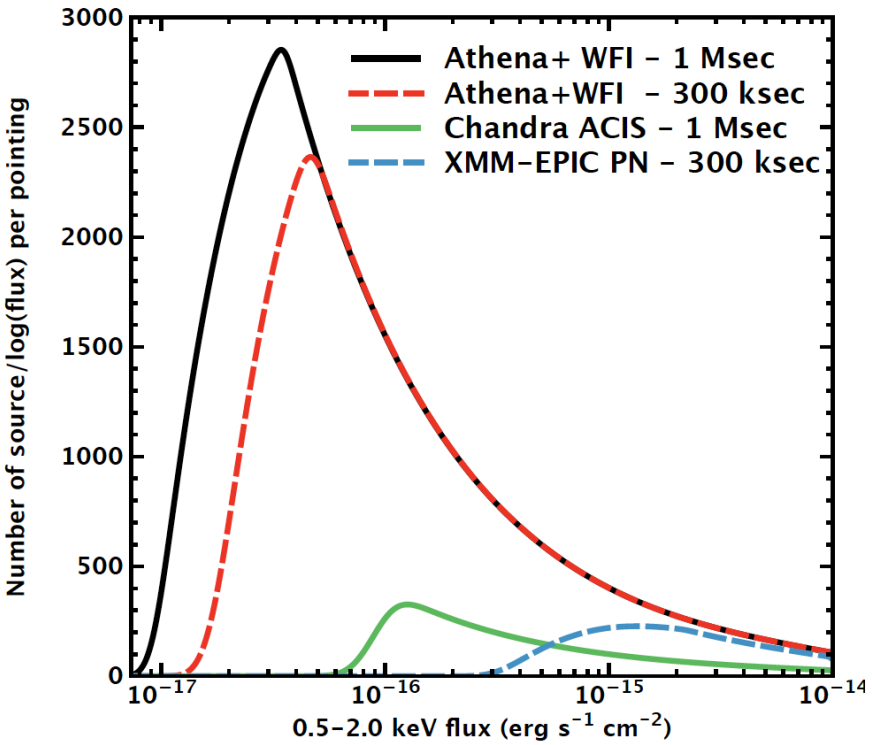


Simulated velocity map at a 5" pixel resolution

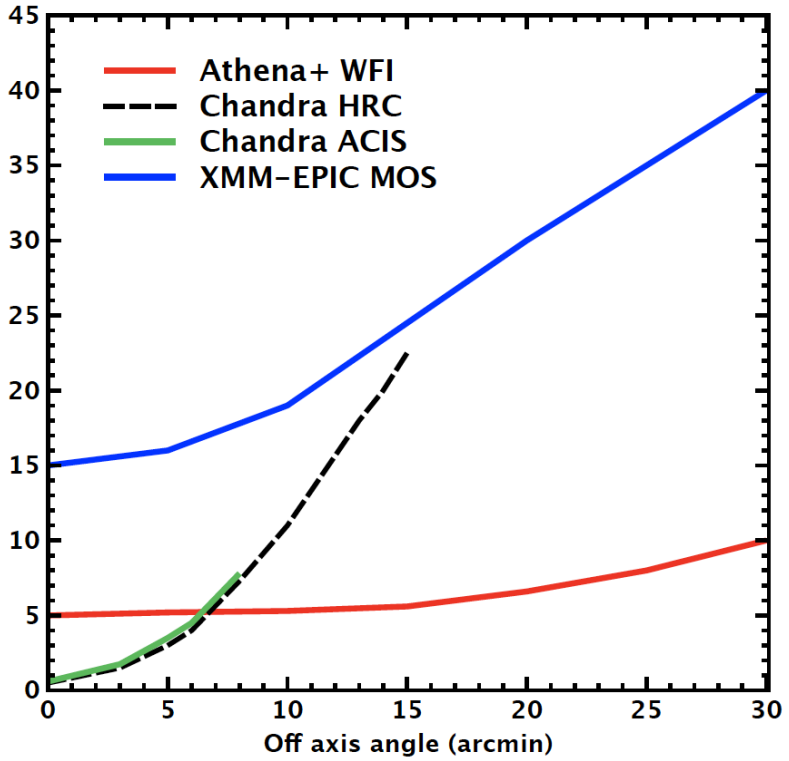


A revolutionary mix of science performance - II

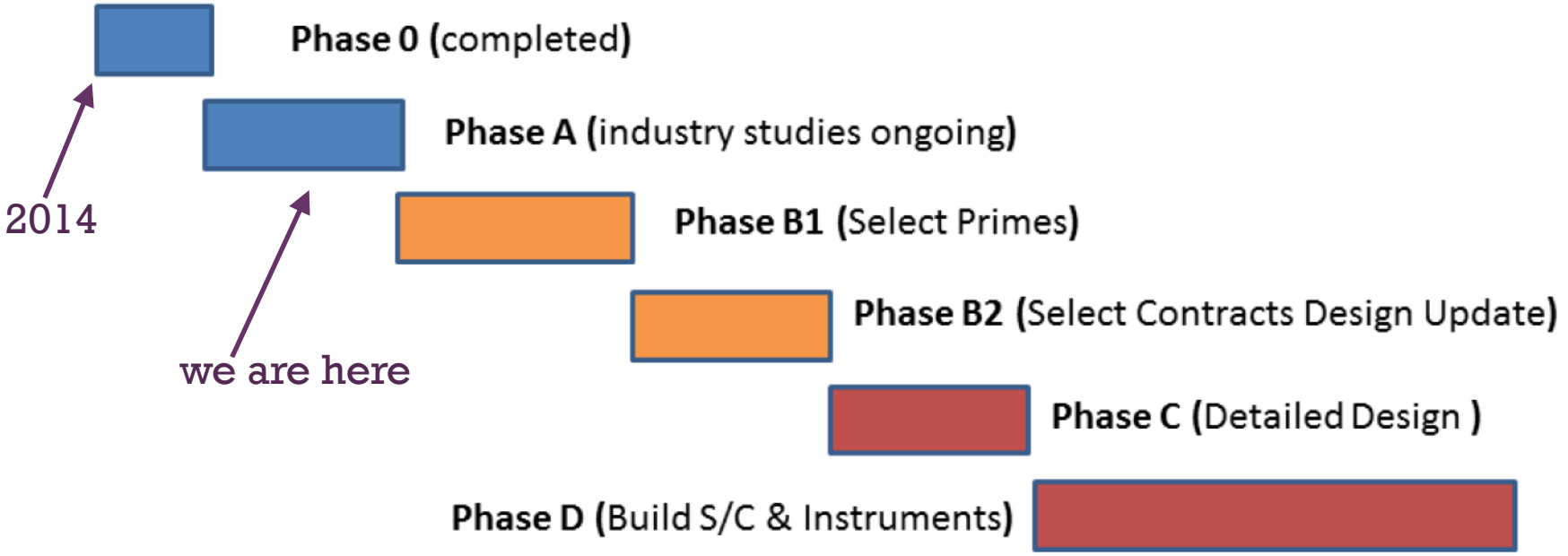
Number of sources per log(flux)



Gentle degradation of the off-axis HEW



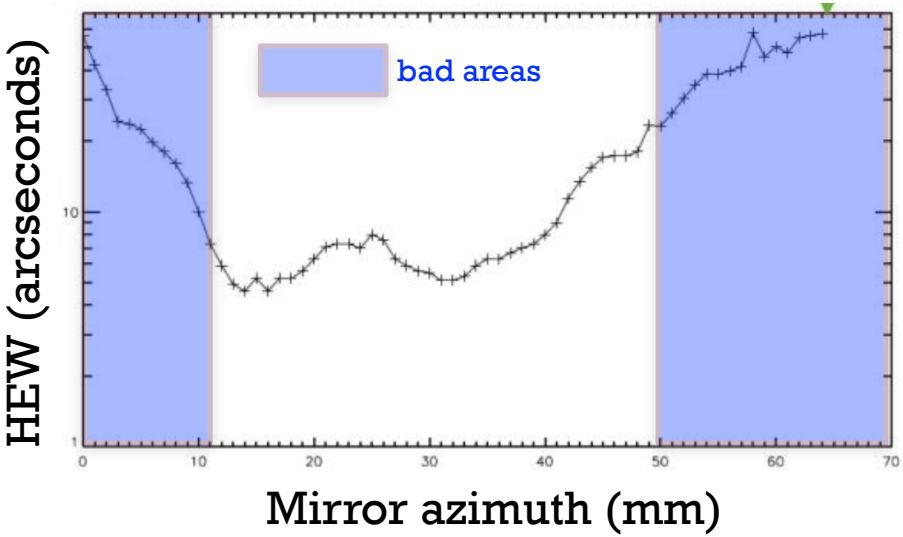
Study status



Next key date: 2020, adoption (= final inclusion in the ESA Science program)

Optics status

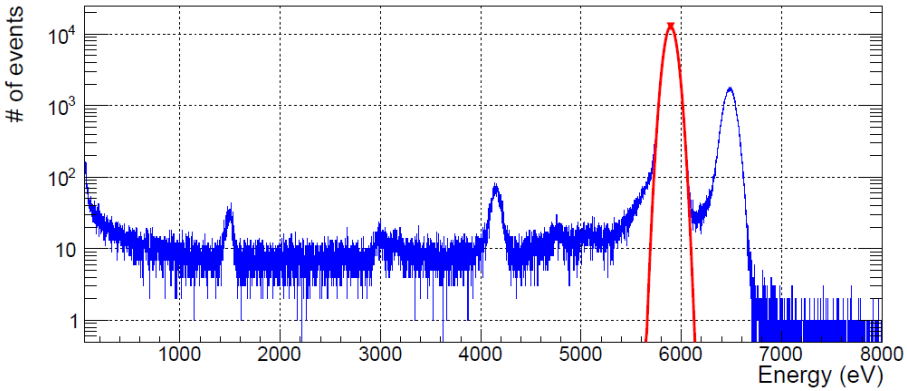
May 2016 measurements at BESSY
Half Energy Width per column
20 m focal length optics

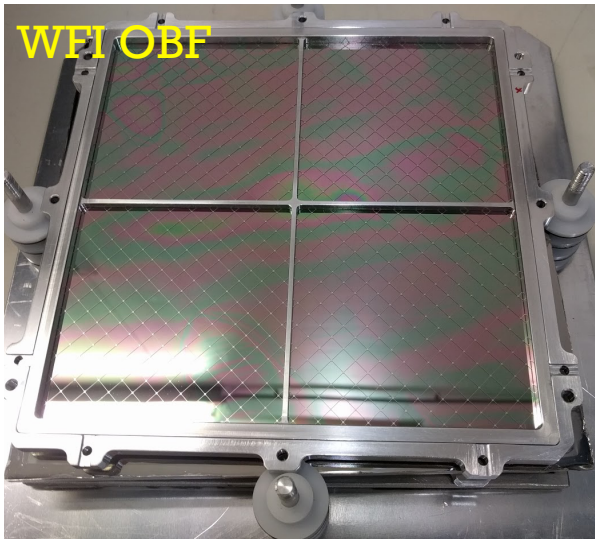


- <HEW>: ~22" in 2015 → 13.9" in 2016
- 60% of the optics have a HEW of 8"
- Best performance: ~5"
- Consistent results at BESSY (2.8 keV) and Panter (1.49 keV)
- Next measurement campaign (with 12 m focal length optics): fall 2017

WFI status

- Prototype sensor produced
  - 64x64 pixel matrix, 2.0-2.5 e^- r.m.s., FWHM≈130 eV
  - 256x256 pixel matrix, 2.5 e^- r.m.s, FWHM≈134 eV
- Detector electronics - frame processor module for real-time event processing at 100 Mpixel/s set-up for testing
- Instrument design w/o vacuum enclosure for the Optical Blocking Filter successfully tested based on Ariane-5 launch reference

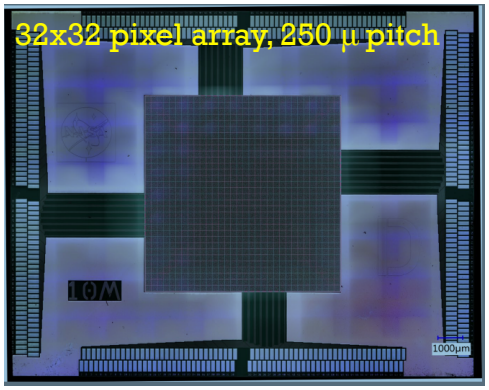


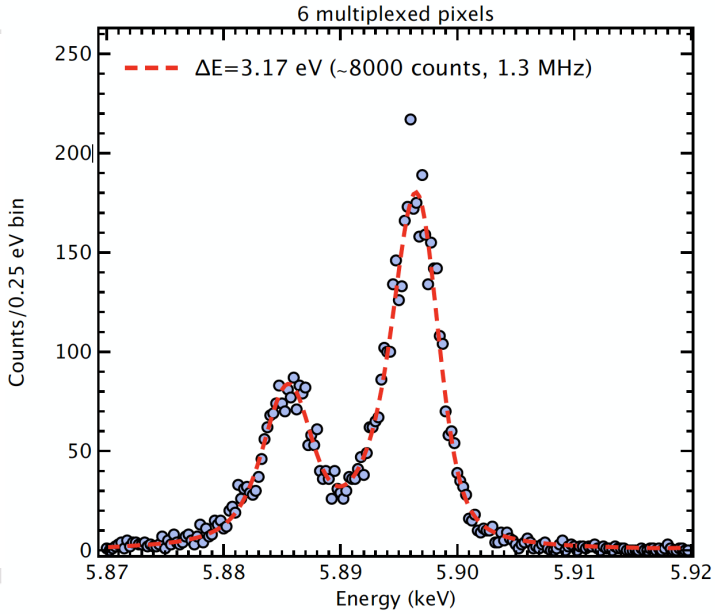


Courtesy D.Barret (IRAP) and X-IFU Team. Sensor image: Courtesy S.Bandler (GSFC). FDM results: Courtesy H.Akamatsu (SRON)

X-IFU status

- 50 mK cooling chain technology demonstrator being developed under ESA contract with CNES lead and X-IFU consortium partners
- Large format TES arrays being fabricated and tested at GSFC
- Frequency domain multiplexing approach reaching the required resolution
- New (and promising) cryo-chain architecture under analysis. First results on the thermal budget expected in the next months

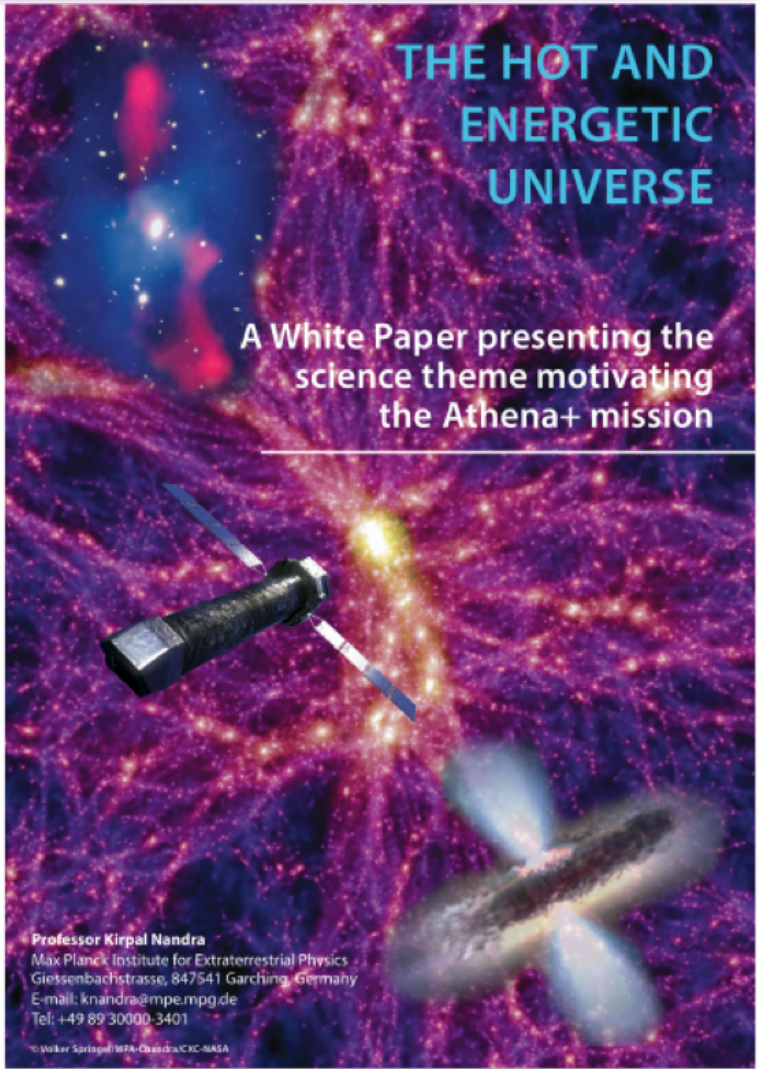




Nandra, Barret, Barcons et al. 2013, arXiv:1306.2307

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 times the binding energy of a galaxy
  - 15% of the energy output in the Universe is in X-rays



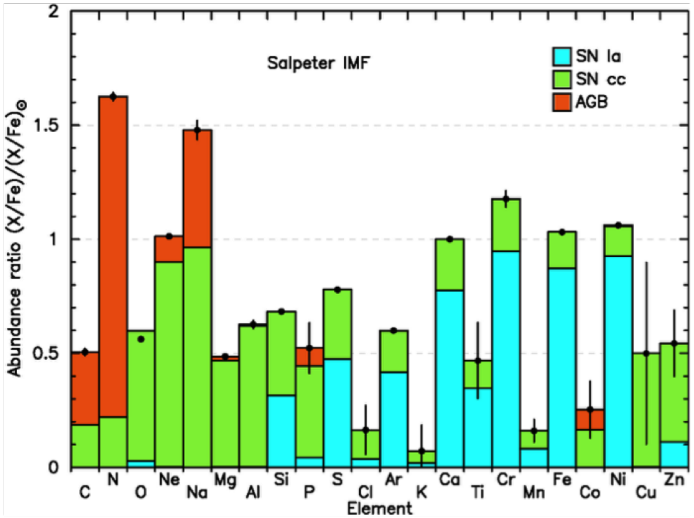
Courtesy: J. de Plaa (SRON)

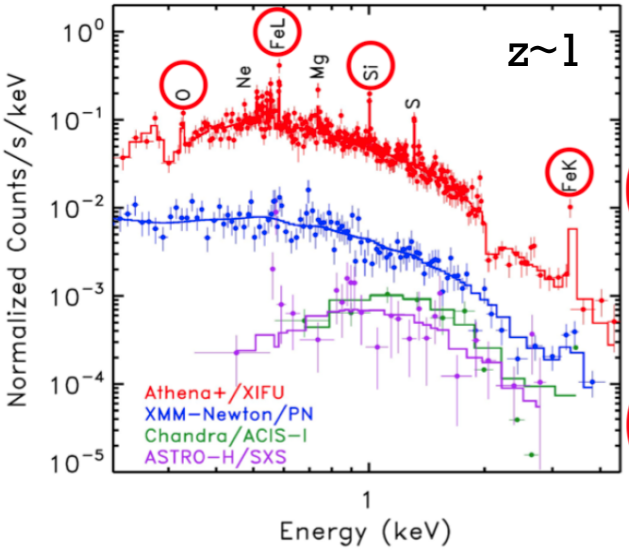
Pointcouteau, Reiprich et al., 2013, arXiv:1306.2319

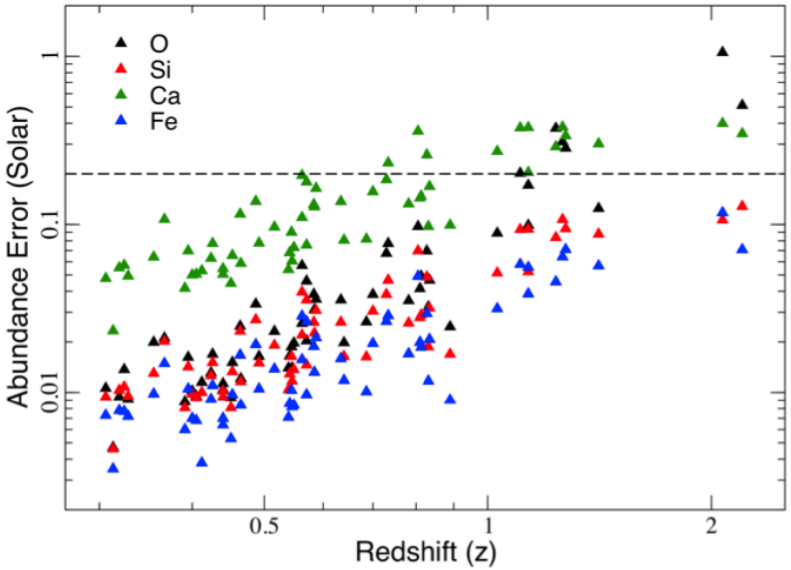
The Hot Universe - I.

Chemical evolution of the inter-cluster gas

- Clusters of galaxies are closed boxes, all gas is virialised in the DM potential well
- Cosmic chemical evolution best traced by cluster gas
- Constraints on SN types and IMF
- Probing clusters *and* groups up to z~2







Perseus cluster: courtesy A.C. Fabian (IoA)

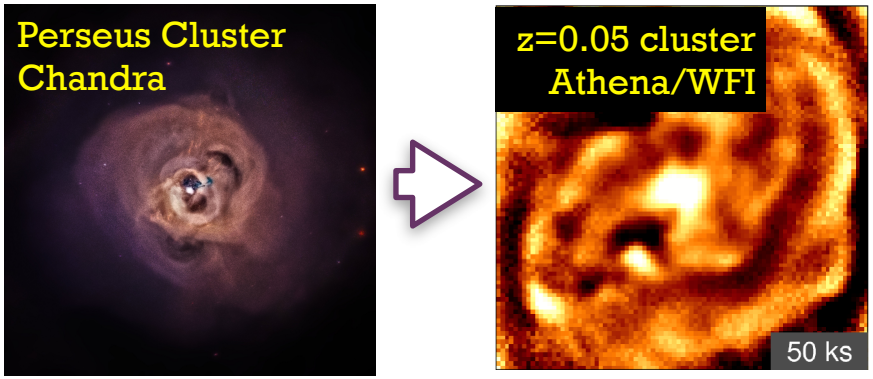
Croston, Sanders et al. , 2013, arXiv:1306.2323; Simulations by S. Heinz (University of Wisconsin)

The Hot Universe - II.

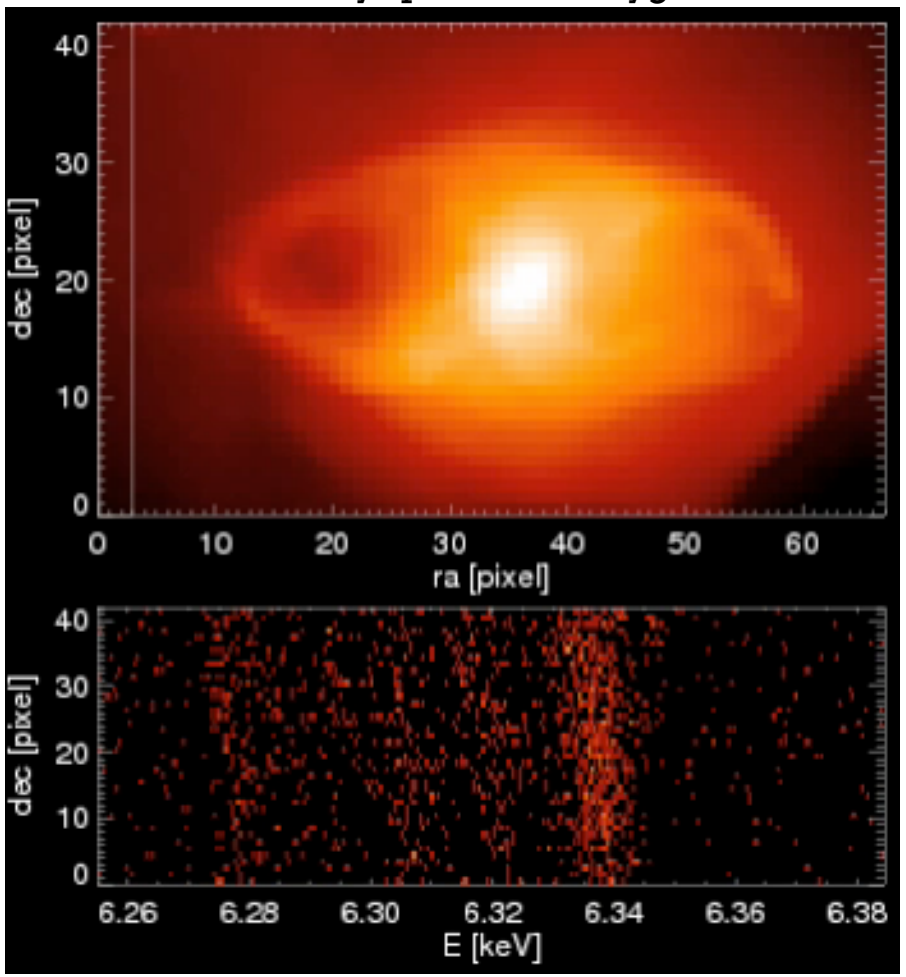
AGN feedback on cluster scales

Dissipation AGN energy into ICM

- Energy stored in hot gas around bubbles via bulk motions and turbulence.
- History of radio cluster feedback via ripples.
- AGN jet fuelling vs. cooling through temperature distribution.
- Shock speeds of expanding radio lobes



FeXXV cavity spectrum in Cygnus A



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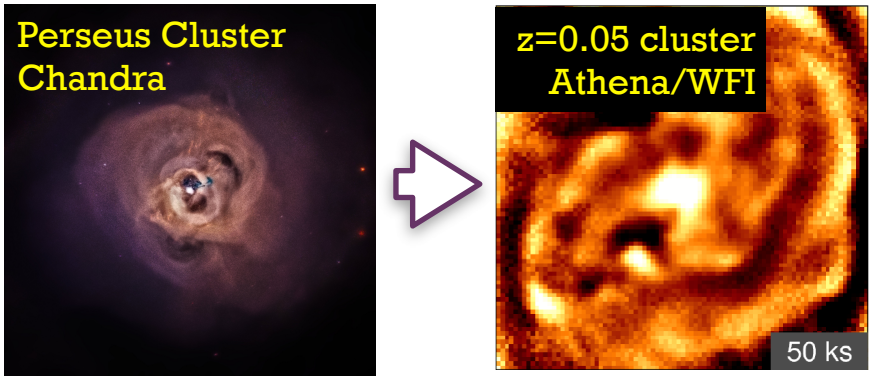

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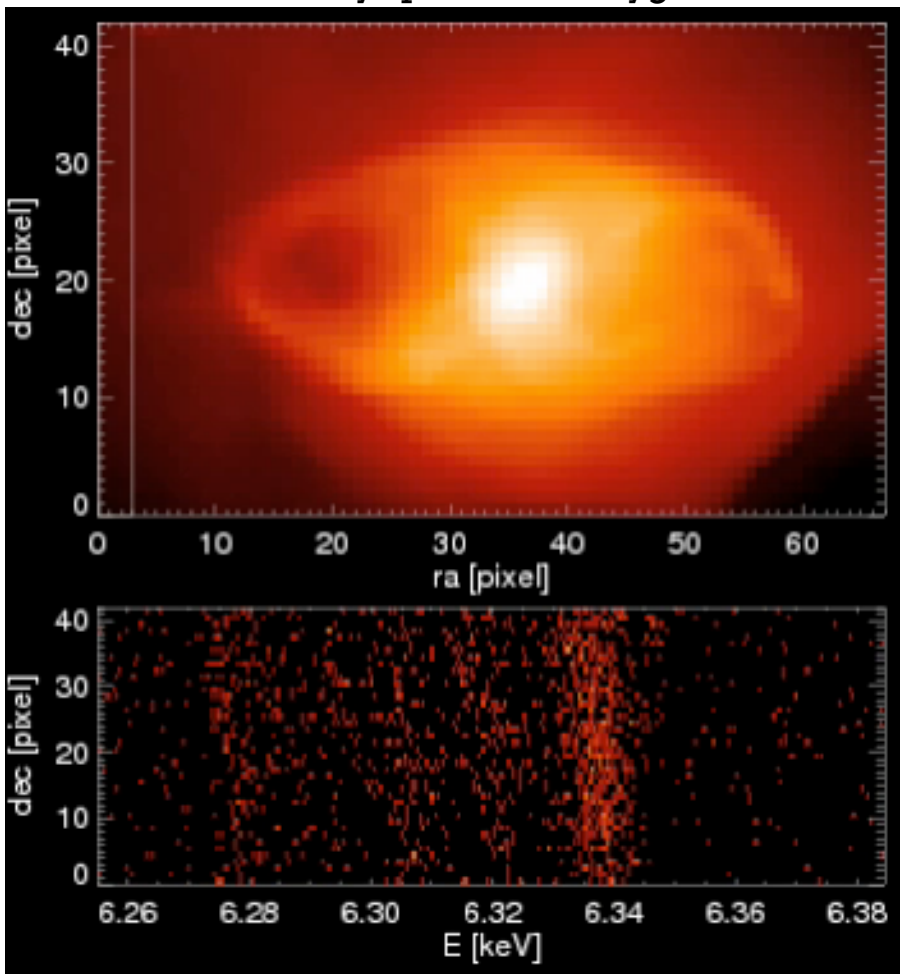


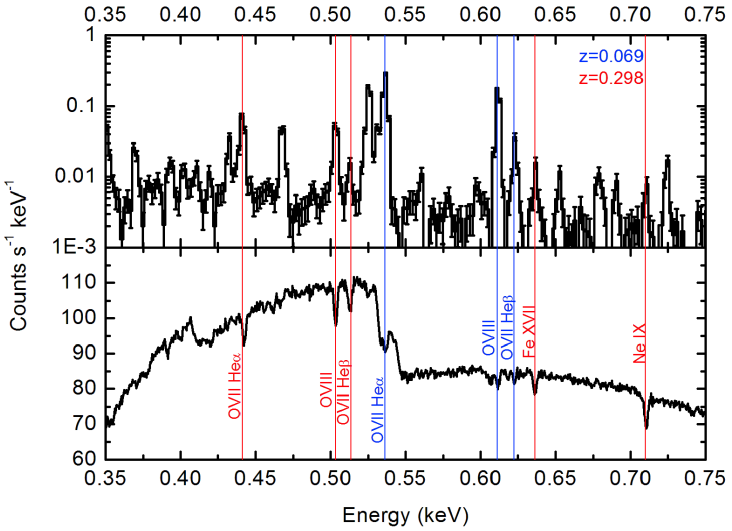
Kaastra et al., 2013, arXiv:; Courtesy: F. Nicastro (OaR)

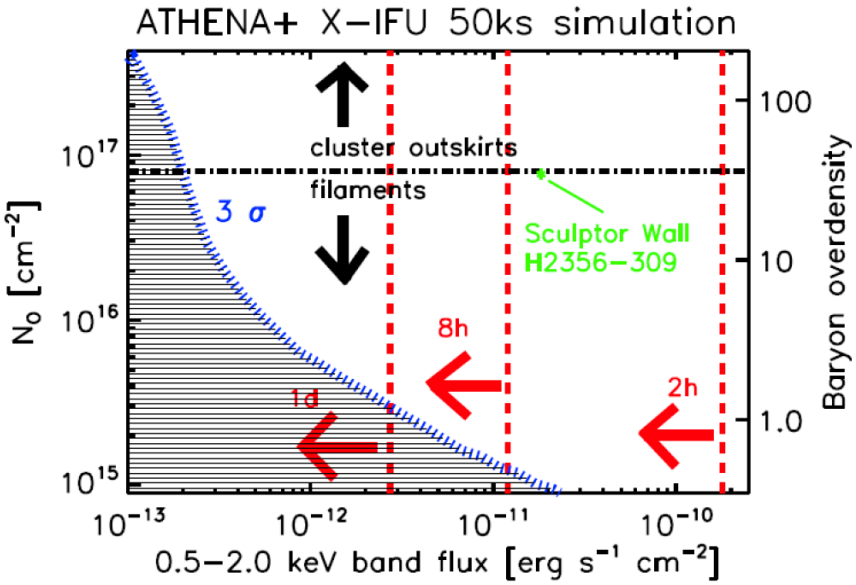
The Hot Universe - III.

Missing baryons: the WHIM*

*Warm-Hot Intergalactic Medium

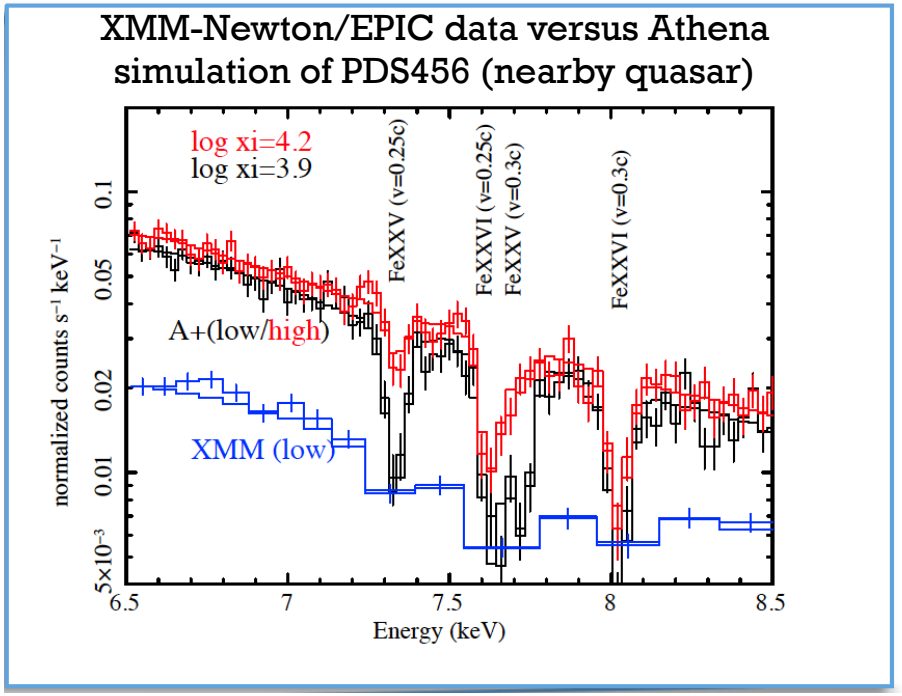
- Cosmological hydro simulations show ~50% of baryons at **T~10^5-10^7** K in the IGM.
  - Unvirialised and filamentary distribution
- How can they be detected?
  - In absorption:
    - Against a **bright background sources**
  - In emission:
    - Tenuous and extended
    - Key to understand CGM and feedback





AGN disk wind feedback with Athena

- AGN outflows with $L_{mech} \gtrsim 1\% L_{bol}$ may be the "feedback messenger"
- Relativistic ($v \gtrsim 0.1c$) disk outflows discovered at X-ray CCD-resolution However:
  - no plasma diagnostic possible
  - no estimate of mass and kinetic energy outflow possible
- High-resolution at the Fe band (6-7 keV) is the key
- Athena will make this possible, up to z~4

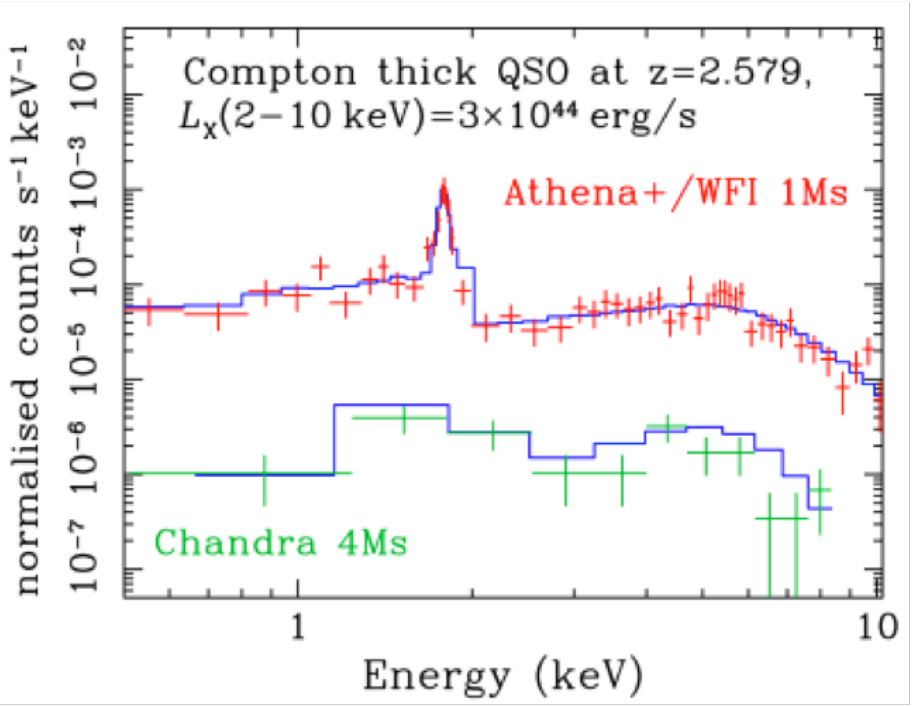


Cappi et al., 2013, arXiv:1412.1171

Obscured AGN census @ z~1-3

#AthenaNuggets Carrera

- Most SMBH growth expected in heavily obscured environment.
- Athena/WFI observations can uncover Compton-Thick ($N_H \geq 10^{24}$ cm^{-2}) AGN at z~3
  - MIR observations can reliably uncover heavily obscured AGN, but **only** when the AGN is very powerful
- Expected about 60 Compton-thick AGN ($1 \leq z \leq 3$) over 6 degrees^2 down to $L_x \sim 10^{44}$ erg s^{-1}

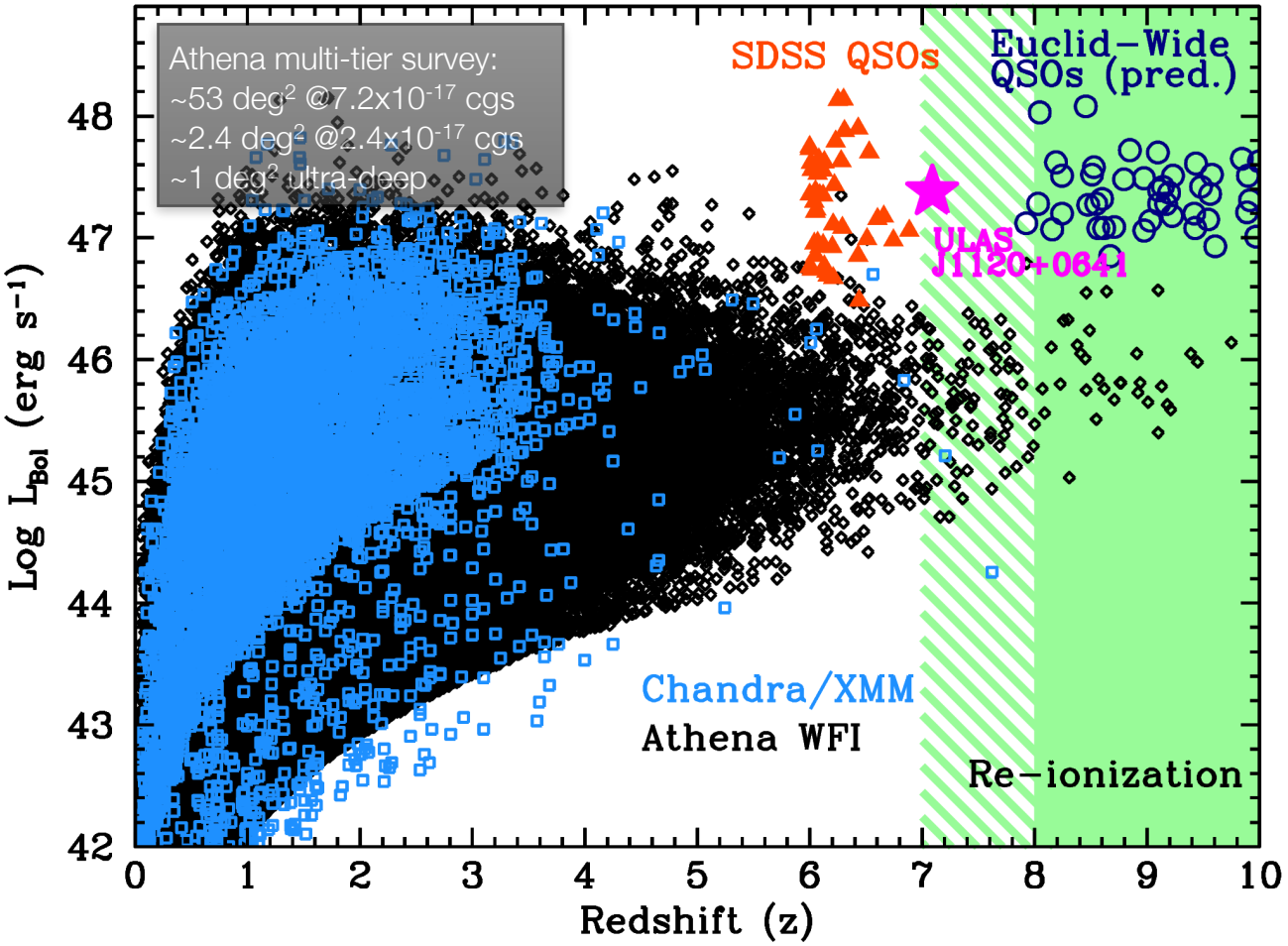


Georgakakis, Carrera et al. 2013, arXiv:1306.2328

Aird, Comastri et al. 2013, arXiv1306.2325

The Energetic Universe - III.

The history of SMBH growth



Only extreme AGN expected in opt/IR surveys

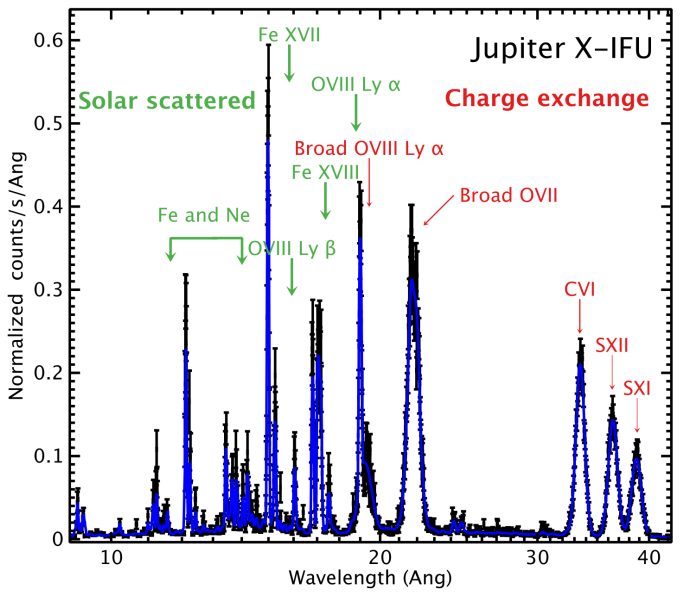
X-rays needed to signpost average AGN

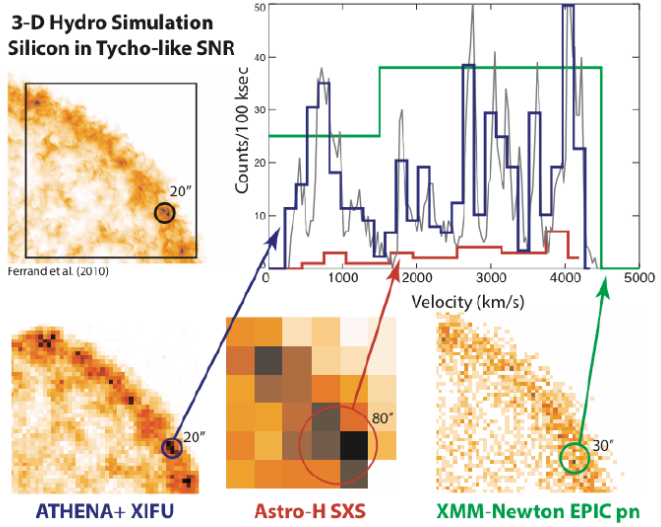
~4-600,000 AGN
~160-400 @8>z>6
[~30 @z>8]

Branduardi-R, Sciortino et al. 2013, arXiv:1306.2332; Sciortino, Rauw et al. 2013, arXiv:1306.2333
Decourchelle, Costantini et al. 2013, arXiv:1306.2335; Motch, Wilms et al. 2013,arXiv:1306.2334

Observatory Science – all corners of astrophysics

- Planets and solar system bodies
- Star formation, brown dwarfs
- Massive stars: mass loss
- Outflows in X-ray binaries
- Supernovae: explosion mechanisms
- Supernova remnants: shock physics
- Interstellar medium
- Dark Matter candidates
- …





Outlook

- Athena will be a transformational X-ray observatory
  - Designed to address the Hot and Energetic Universe science theme
  - Will impact virtually every corner of astronomy
- It will be an essential part of the observational landscape in the late 2020s, together with ALMA, E-ELT, SKA, CTA, etc.
- Vibrant community supporting it
- Good progress with Phase A.
  - Key milestone in 2020: Mission adoption by ESA for a launch in 2028/9.

- Follow Athena on
  - Web: www.the-athena-x-ray-observatory.eu
  - Twitter: @athena2028
  - Facebook: The Athena X-ray Observatory
  - Athena Community Office email: aco@ifca.unican.es