Synergies with Athena

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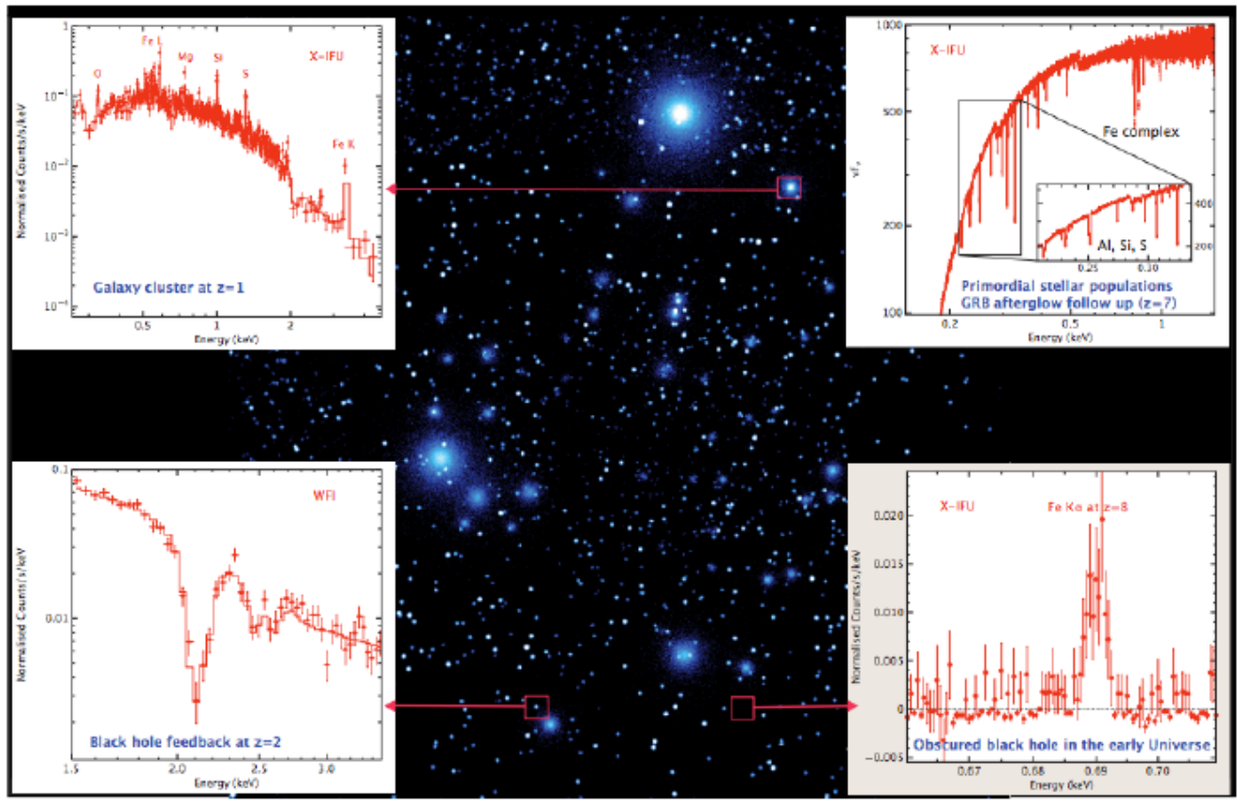
with extensive contributions by P.Nandra, F.J.Carrera, L.Piro, and the whole Athena Study Science Team (ASST)

The "Athena Synergy Exercises" are run by the ASST, under the leadership of X.Barcons (until March 2017) and in collaboration with the Athena Community Office

Athena in a nutshell

- Second Large (L2) mission of ESA Cosmic Vision 2015-2035
- 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:
  - Fast ToO capability to study transient sources (GRB & others)
  - Observatory science across all corners of Astrophysics

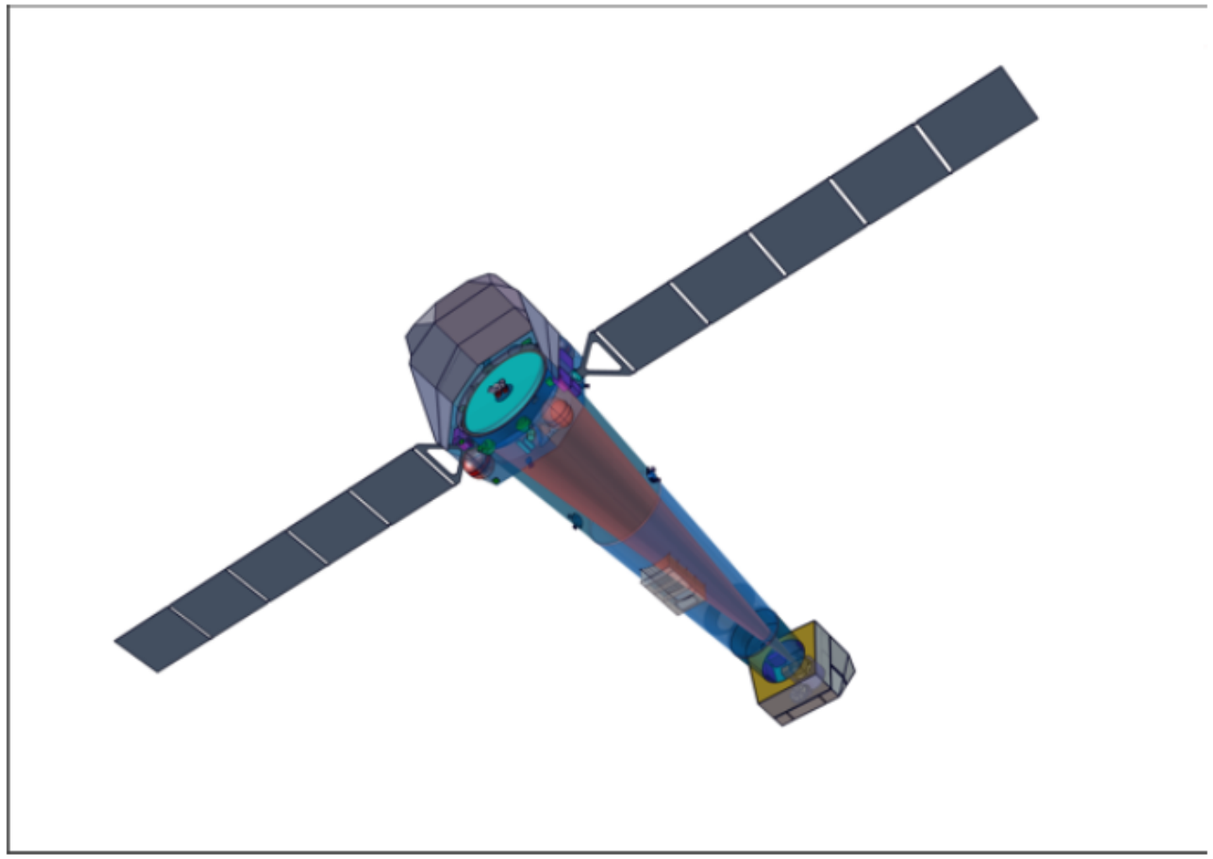


Nandra et al. 2013, arXiv: 1306.2307
Barcons et al. 2017, Astron Nachr

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

Athena mission concept

- Single X-ray telescope, using Si pore optics, 5” resolution on-axis, 12m focal length
- Science Instrument Module including two instruments:
  - WFI sensitive imaging & timing
  - X-IFU spatially resolved high-resolution spectroscopy
- Movable mirror assembly to switch between the two instruments
- Launch 2028, Ariane 6-4
- L2 halo orbit (TBC)
- Lifetime > 5 yr



Athena concept, ESA CDF (Phase 0)

Ayre et al 2016, SPIE Proc 9905

Key Athena performance

(Barret et al., 2013, SF2A-2013, 447)

Parameter	Requirements
Effective Area	2 m^2 @ 1 keV (goal 2.5 m^2) 0.25 m^2 @ 6 keV (goal 0.3 m^2)
Angular Resolution	5″ (goal 3”) on-axis 10” at 25’ radius
Energy Range	0.3-12 keV
Instrument Field of View	Wide-Field Imager: (WFI): 40’ (goal 50’) X-ray Integral Field Unit: (X-IFU): 5’ (goal 7’)
Spectral Resolution	WFI: $<$ 150 eV @ 6 keV X-IFU: 2.5 eV @ 6 keV (goal 1.5 eV @ 1 keV)
Count Rate Capability	$>$ 1 Crab (WFI) 10 mCrab, point source (X-IFU) 1 Crab (30% throughput)
TOO Response	4 hours (2 hours goal) with a 50% efficiency to observe a TOO source in a random position of the sky

Athena Synergy Exercises

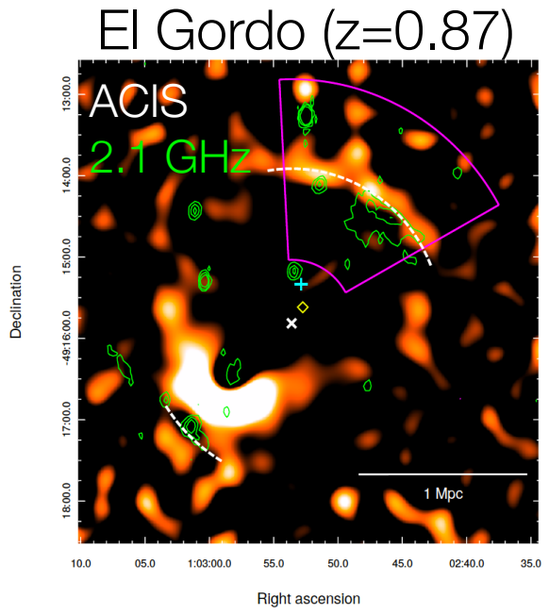
- Identify scientific synergies between the Athena X-ray observatory and contemporary observational facility
- Outcome: Synergy White Papers (SWP)
- ESO-Athena: SWP in preparation (expected to be published in ~April 2017)
- SKA-Athena: Workshop at Jodrell Bank (24-25 April 2017), 45 applications, writing meeting ~June 2017
  - "Scientific Synergies Enabled by SKA, CTA, and Athena", EWASS 2017 (26-27 June)
- Athena and wide-field optical/IR surveyors (Euclid, WFIRST, LSST, …): to be launched soon (lead: P.Nandra)
- Athena and Multi-messenger facilities (CTA, gravitational waves, SVOM, Einstein Probe, Neutrinos, Cosmic Rays …): to be launched by fall 2017 (lead: L.Piro)

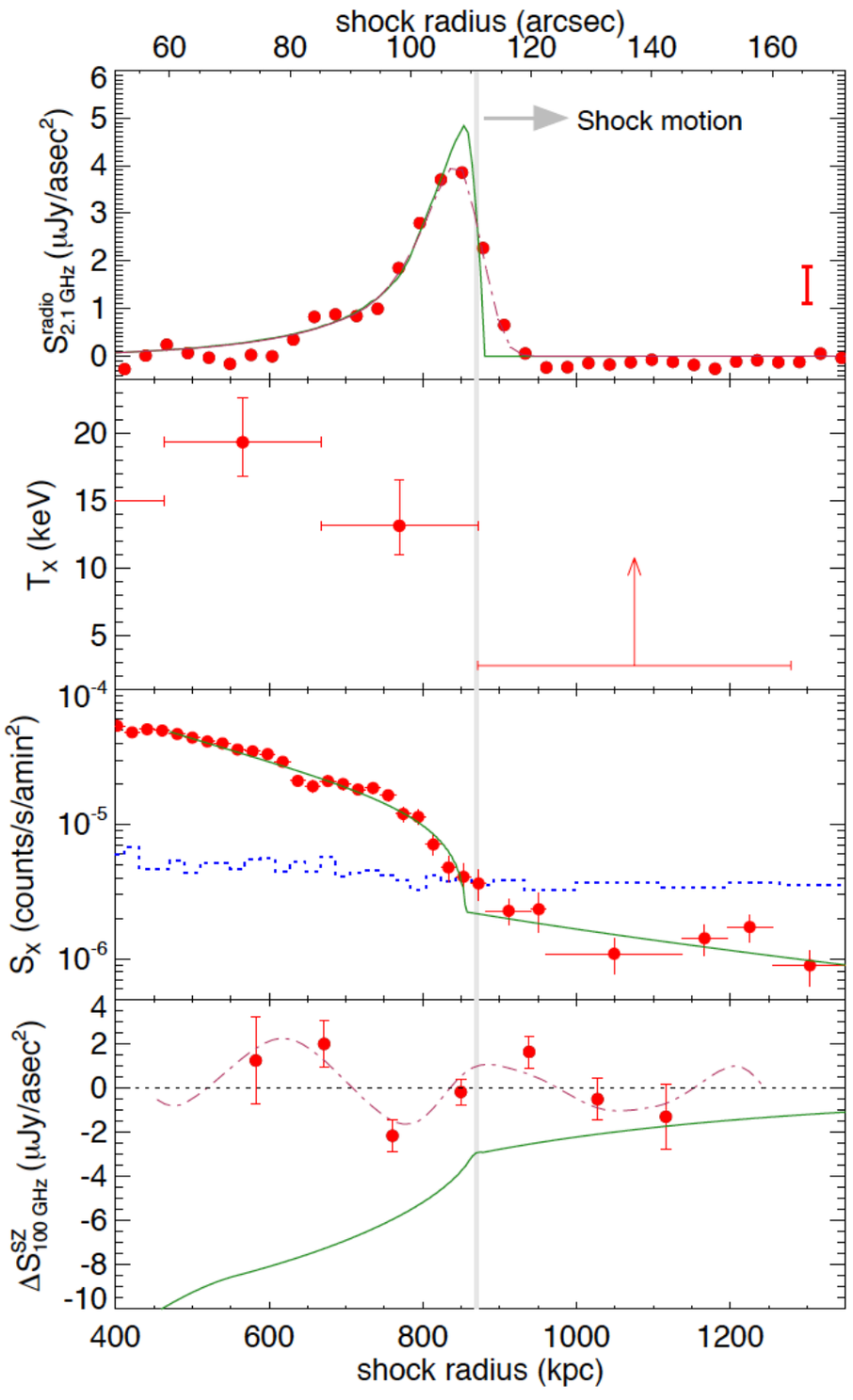
Physics of the Intra-Cluster Medium (ICM)

*Prokhorov et al., 2010, A&A, 520, 106

Basu et al., 2016, ApJ, 829, 23

- Deviations from the average ICM thermodynamic properties of the ICM
- Combination of Sunyaev-Zeldovich and X-rays to determine the Mach number and magnetic field of the shock
- Possible to determine the amount of thermal plasma in the bubbles inflated by the AGN through X-rays/SZ analysis*





Physics of the Circum-Galactic Medium/WHIM

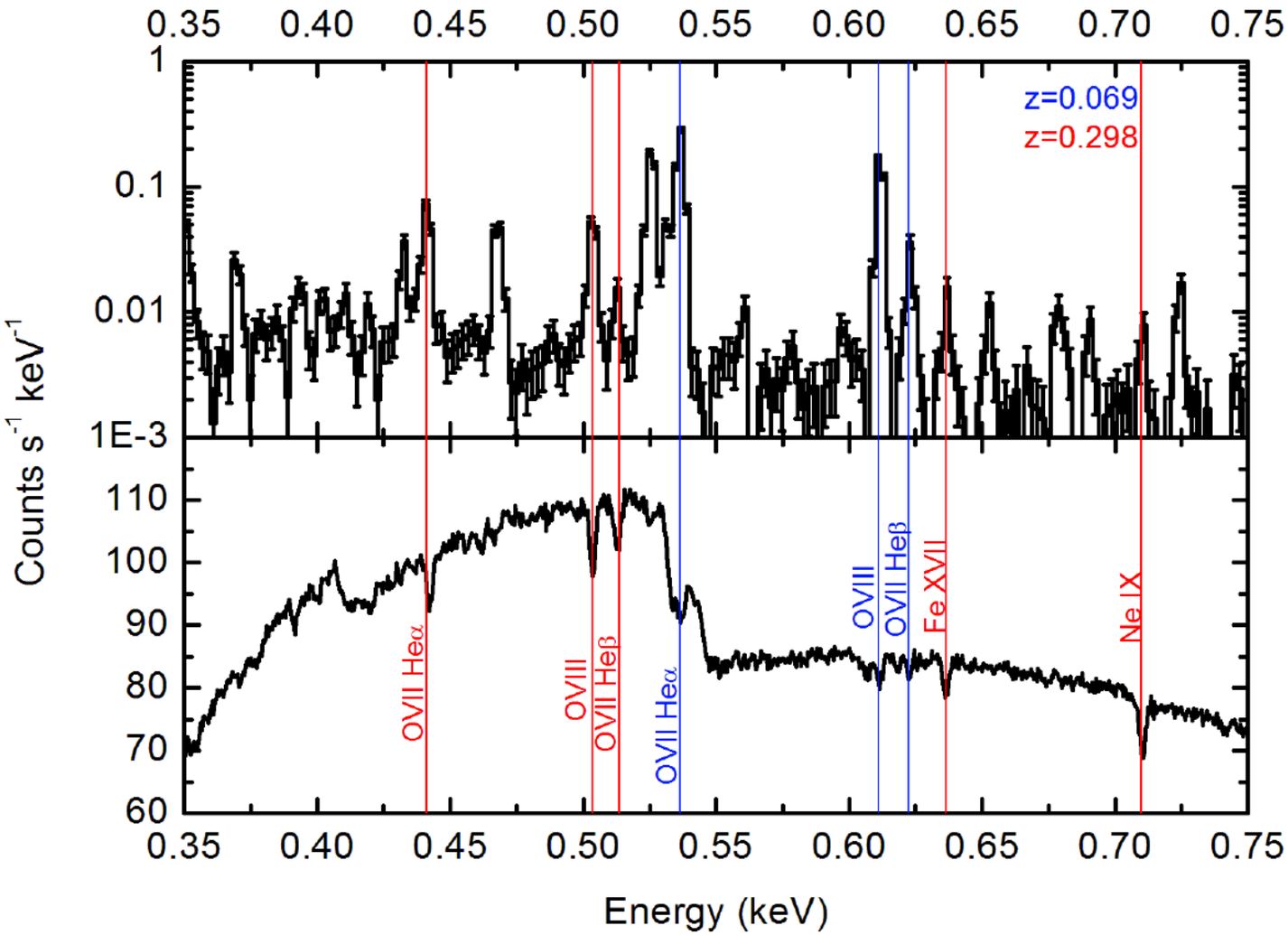
Kaastra et al, 2013, arXiv:13056.2324

- Characterise the population of galaxies associated to the CGM filaments (±500 km/s) across a few Mpc^2

- Correlation between the CGM and the galaxy properties (mass, SFR, morphology, chemical composition)

- Detection of molecular outflows from environment galaxies to estimate feed-back and metal enrichment

- To get the full WHIM Ω_b one need measurements in FUV, X-rays (OVII-OVIII, NeIX-NeX, NVIII, MgXI) and sub-mm (^{27}AlXI, ^{13}CVI)

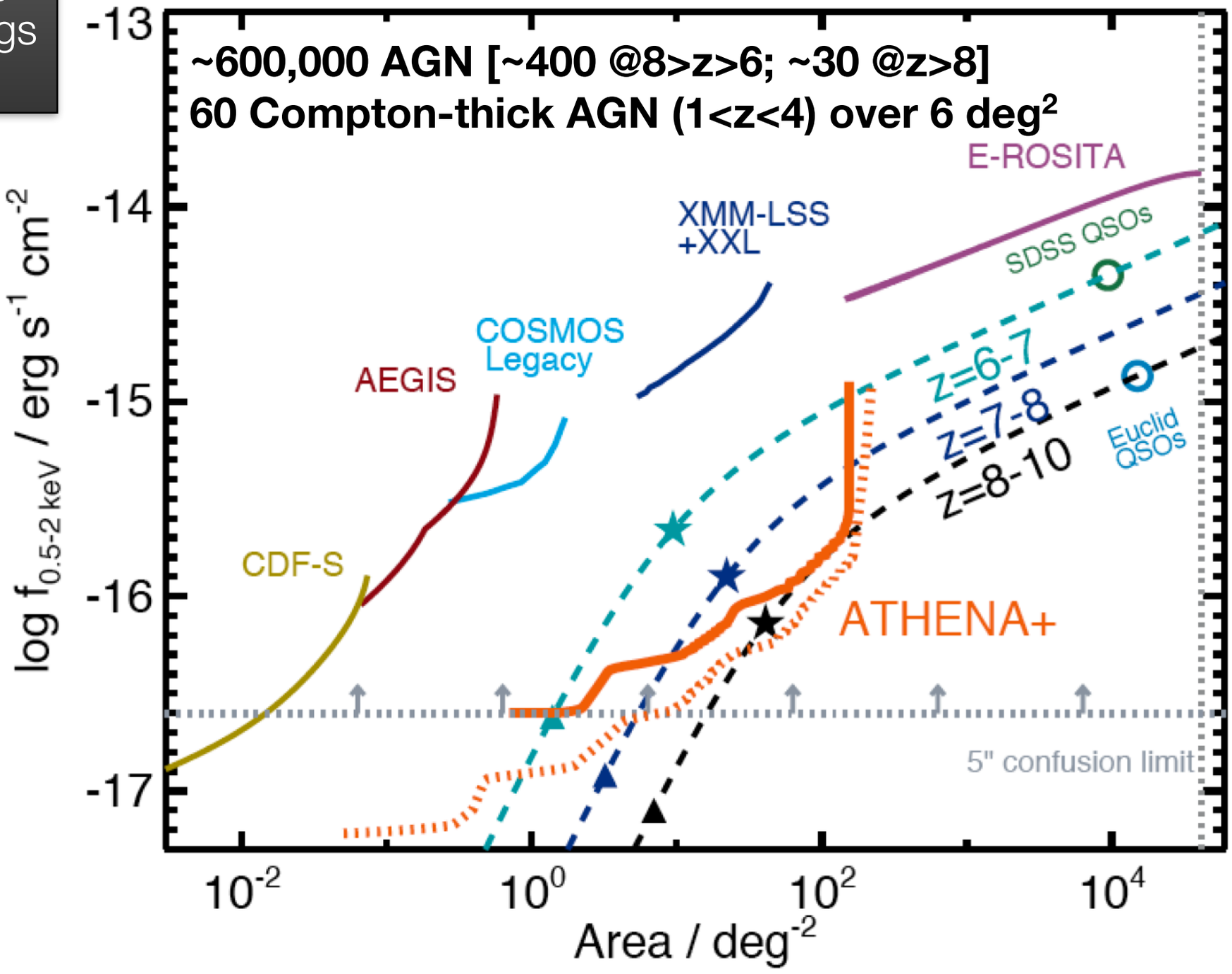


Physical condition of the host galaxy of early BH

Aird et al, 2013, arXiv:1305.2325

Athena multi-tier survey:
~53 deg^2 @7.2x10^{-17} cgs
~2.4 deg^2 @2.4x10^{-17} cgs
~1 deg^2 ultra-deep

- spectroscopic identification
- cold dust, molecular gas mass
- BH masses
- stellar masses and SFR



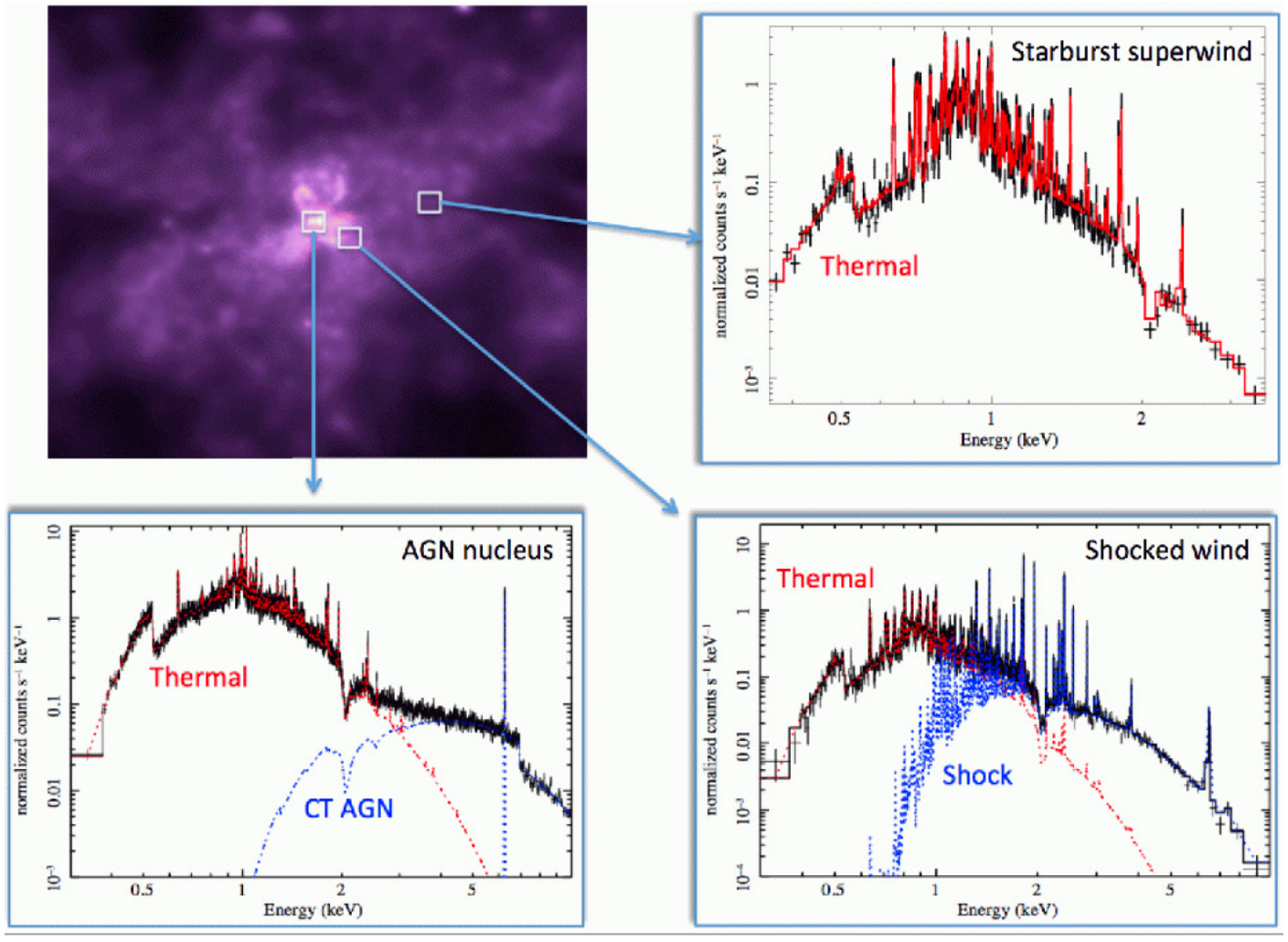
Accretion disk wind feedback

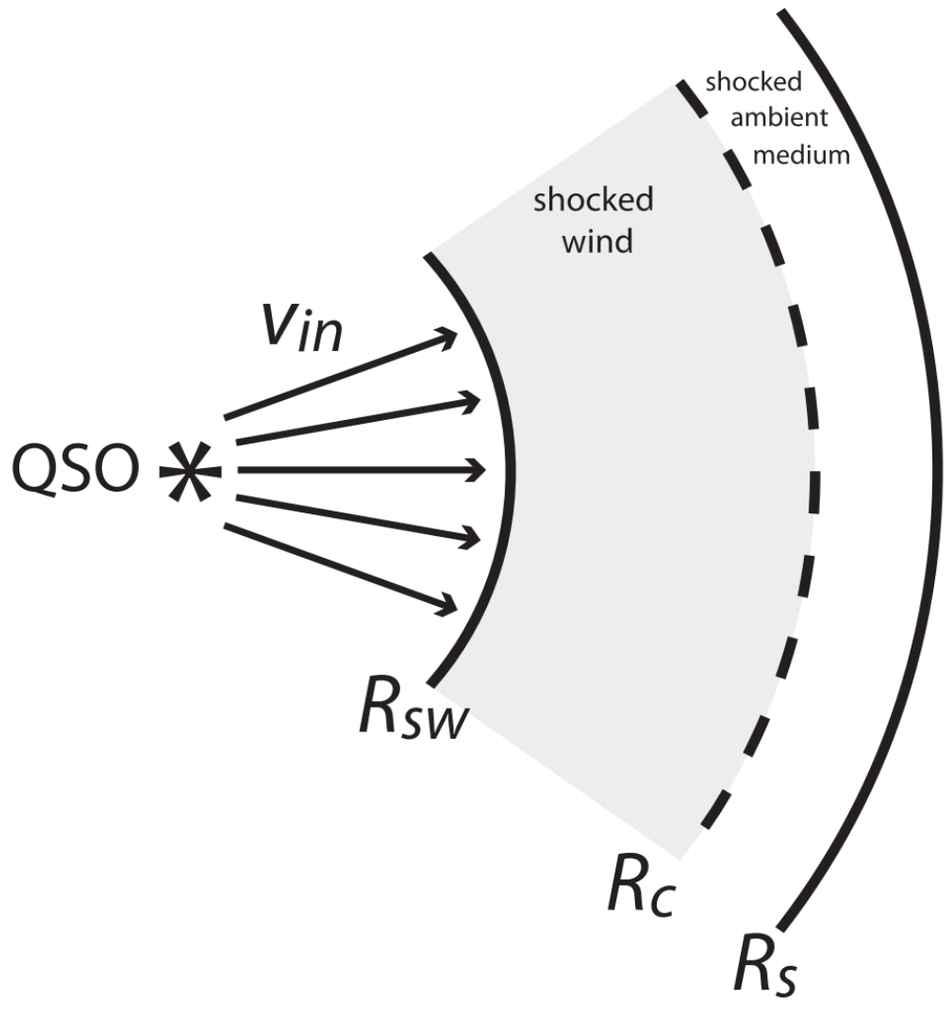
Cappi et al., 2013, arXiv:1306.2330

Faucher-Giguère & Quataert, 2012, MNRAS, 423, 605

NGC6240
Chandra/ACIS

Athena/X-IFU
simulations





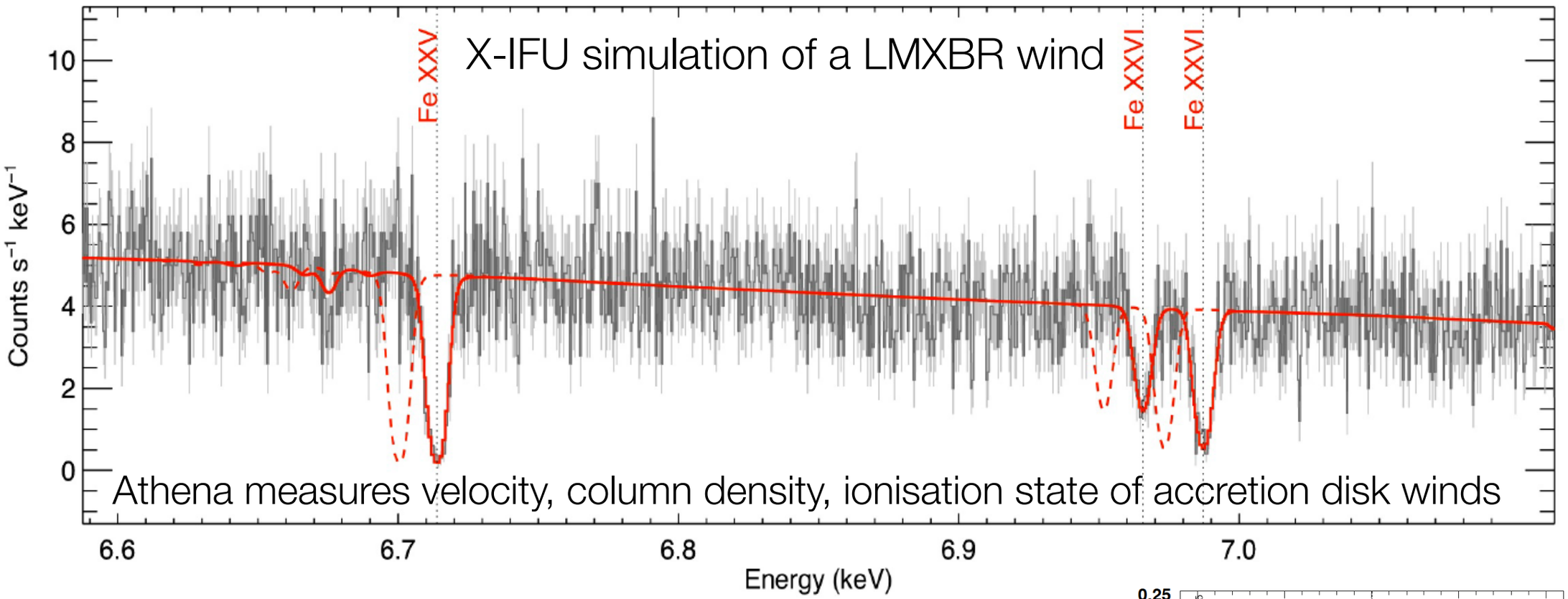
Search for the "smoking gun" of the interaction between X-ray outflows and the ISM, and the connection with ionised/molecular outflows

Black hole accretion/ejection physics (winds/jets)

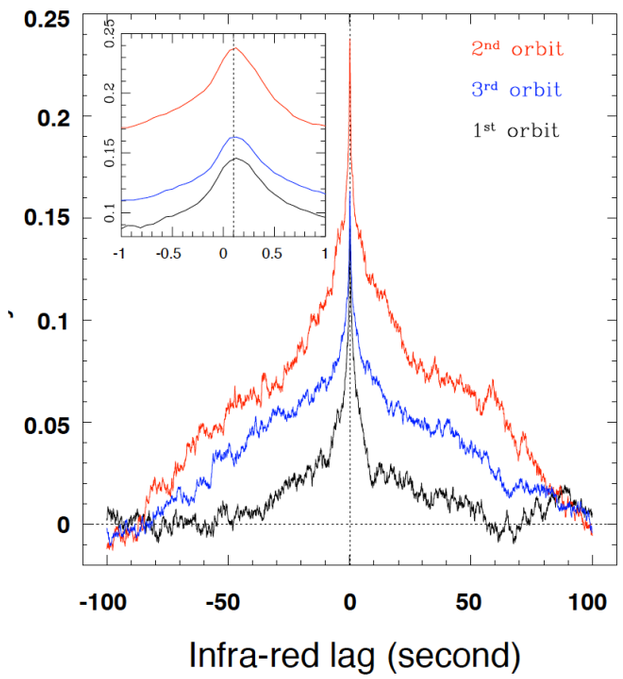
Motch et al., 2013, arXiv:1306.2334

*Muñoz-Darías et al., 2016, Nature, 534, 75

Casella et al., 2010, MNRAS, 404, 21



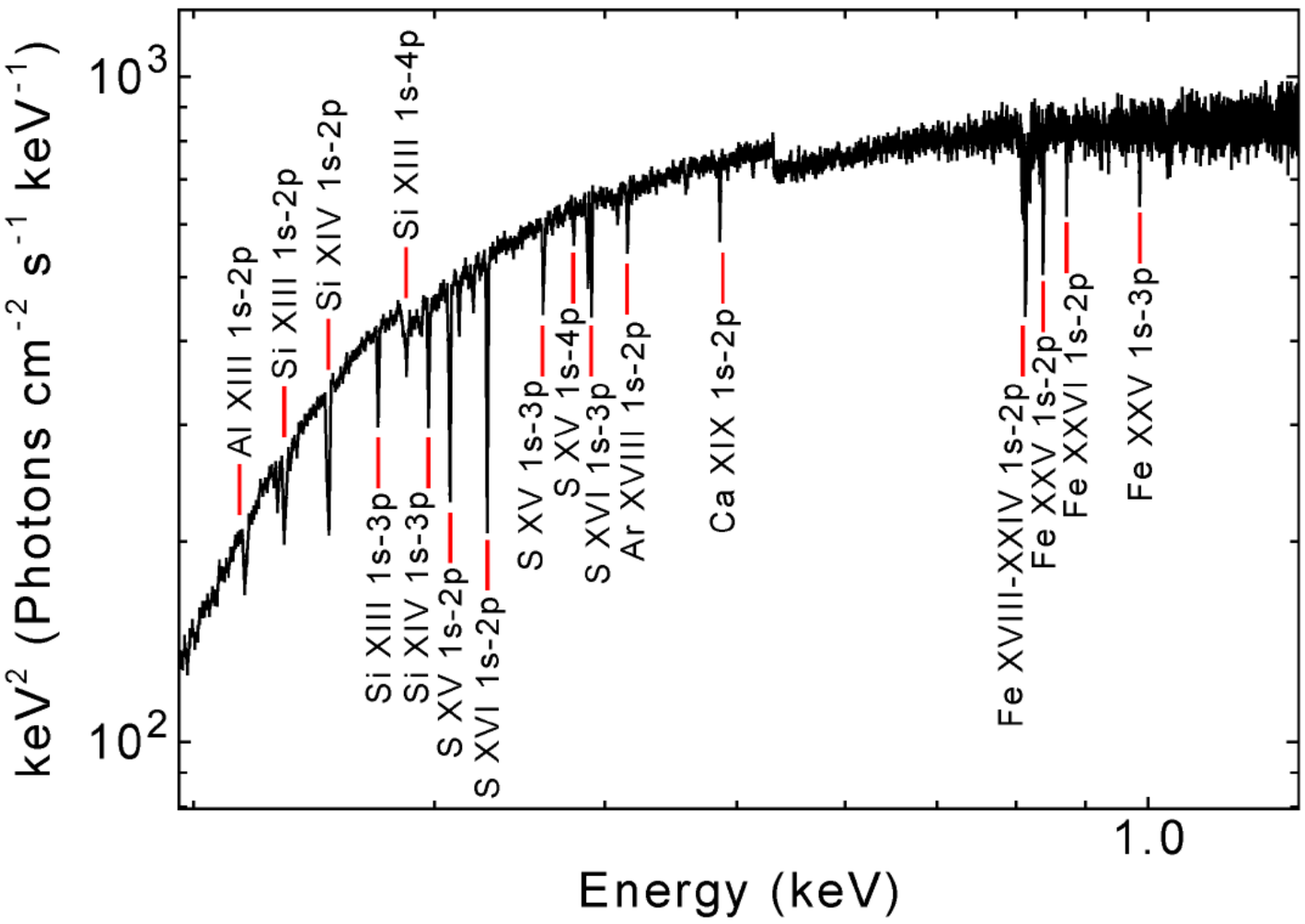
- Optical spectroscopy of X-ray disk winds ➔ acceleration site, structure of the accretion flow [e.g. V404 Cygni*]
- High timing resolution X-ray versus IR ➔ jet launching site, jet speed, size IR region



GRB hosts

Joncker et al., 2013, arXiv:1306.2236

X-IFU simulation of a z=7 GRB afterglow



Abundance pattern (S, Si, Fe) for ~10 GRB afterglows per year, $N_H \lesssim 10^{21}$ cm^{-2}, $Z \lesssim 0.01 Z_\odot$

- Identification of high-redshift GRB afterglows
- X-ray absorption spectroscopy characterises the (high ionised) progenitor environment while IR spectroscopy the host
- Host SFR, metallicity, mass, age? Association with of associated SN? ➔ GRB progenitor
- Jet physics: particle acceleration/emission processes
- Require facilities in Rapid Response Mode

Operation synergies

Ehle, 2016, ATHENA-Sa-Dc-0001

- Athena science operations to be run at the European Space Astronomy Centre (ESAC)

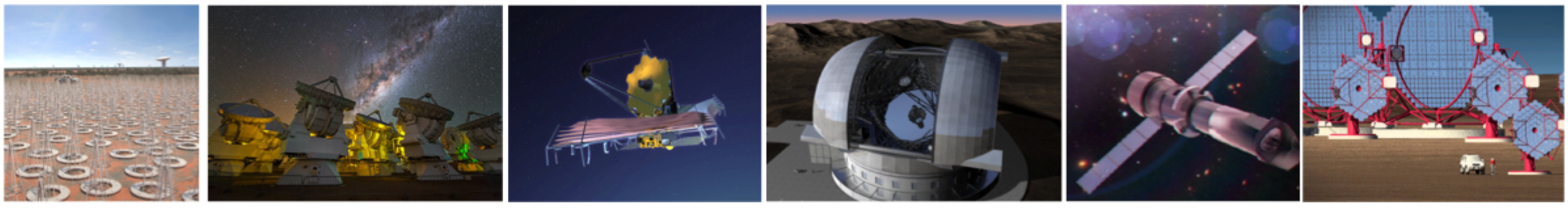
- Science Operation Assumption Document (SOAD) currently being elaborated

- Based on the ESA (primarily XMM-Newton and Herschel) legacy

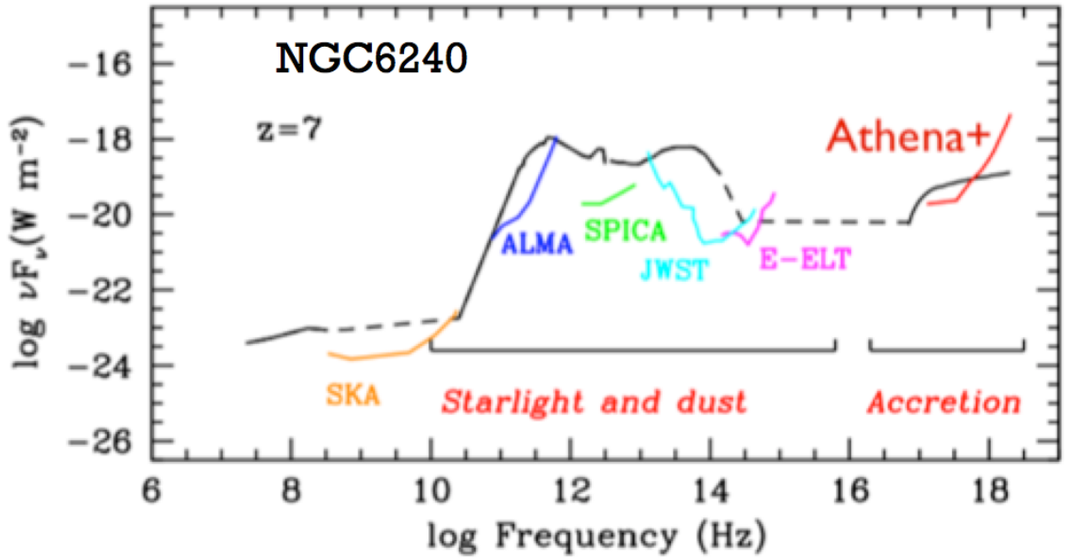
- Athena will inherit synergies implemented with ESA operational mission

Athena in the late 2020 astronomical landscape

SKA | ALMA | JWST | E-ELT | Athena | CTA



- Athena will be a transformational X-ray observatory addressing the Hot and Energetic Universe theme, with the potential to impact all corners of astrophysics
  - Will be part of the suite of large facilities in the late 2020s enabling unprecedented studies & discoveries
- Project development (currently Phase A) is making good progress



Credit: M. Türler & Athena team