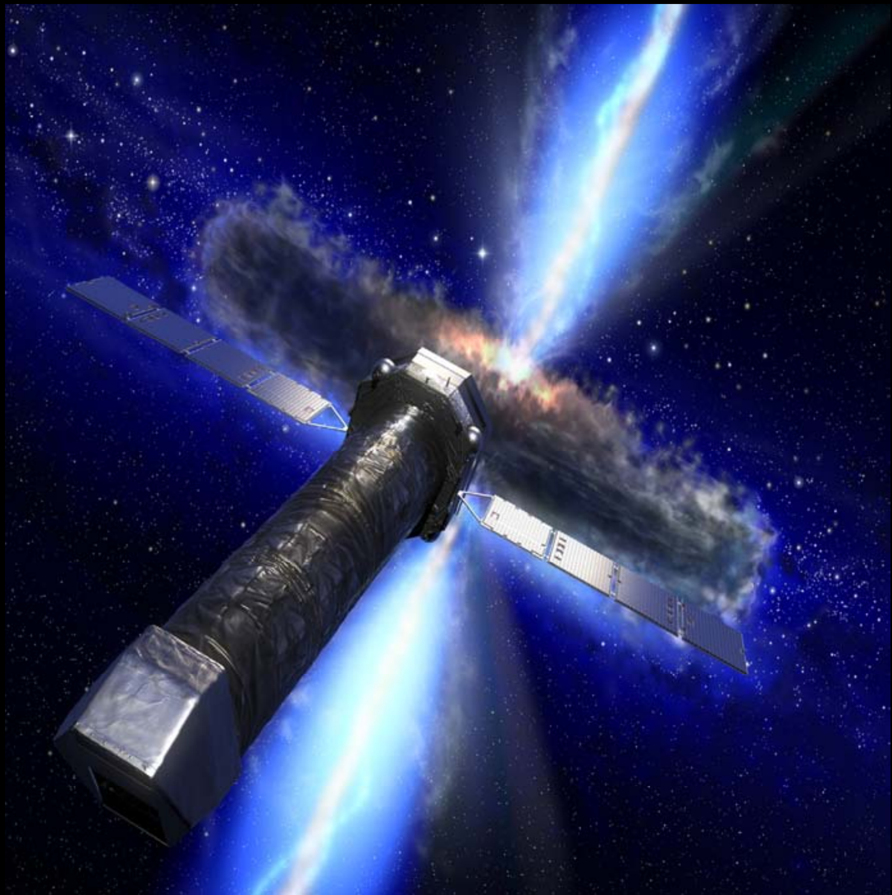
Studying AGN winds and feedback with Athena

Massimo Cappi

INAF/IASF-Bologna



Outline

1. Athena in Cosmic Vision
2. Athena general Science Goals
3. Athena's possible contribution(s) to studies of AGN winds and feedback
4. Future

In collaboration with, and with contributions from: M.Giustini, F. Tombesi, G. Lanzuisi, M. Dadina,

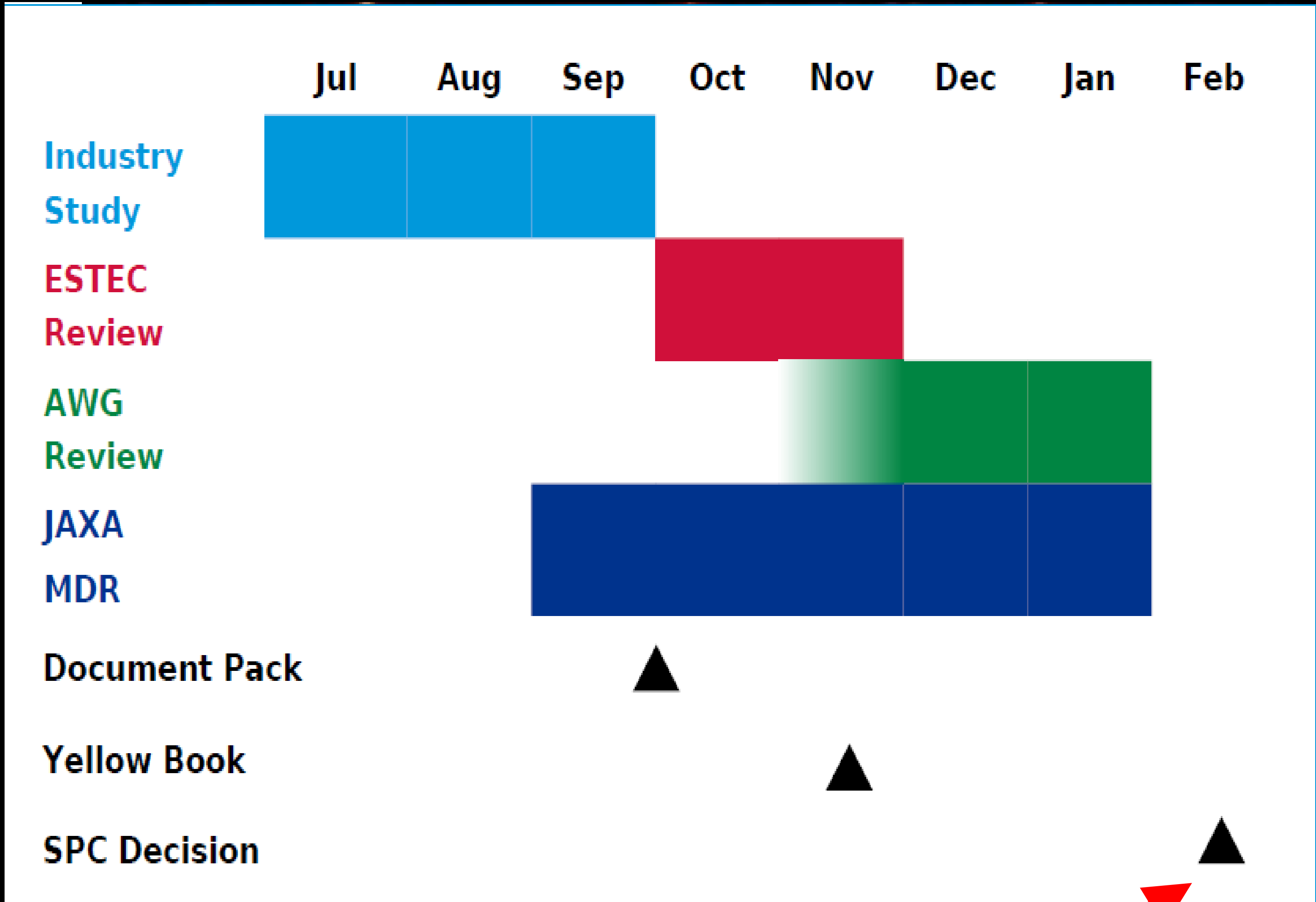
The ESA's cosmic vision selection process - Overview

- Oct 2007 ESA selects XEUS as candidate L-mission (together with Laplace/JSEM and LISA)
- June 2008 XEUS and Con-X merge into IXO
- Feb 2011 presentation of ESA IXO assessment study
- Feb/Mar 2011 Decadal Surveys, new budget realities

⇨New Plan Required!

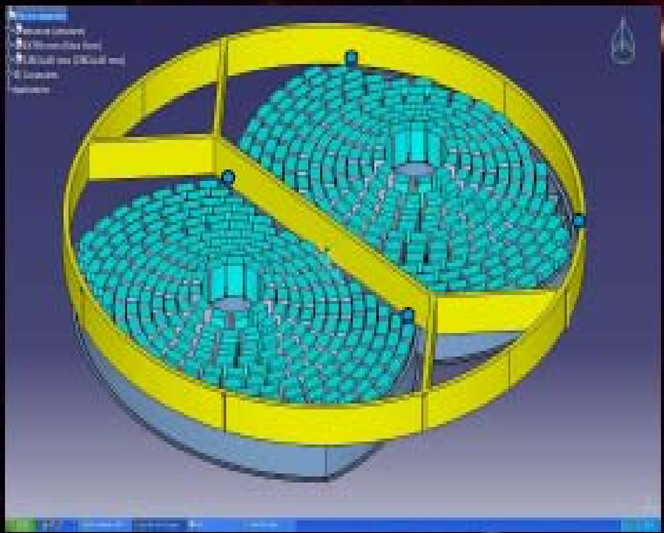
March 14th 2011: ESA announces decision to re-formulate L-class missions: European-led.
Mar-Apr 2011: New Study Team formed, rapid Scientific and Technical evaluation of new options
April 29th 2011: Baseline mission chosen by Athena Study Team (AST) - "The Event"

ESA Cosmic Vision – L missions: On-going activities and next coming step



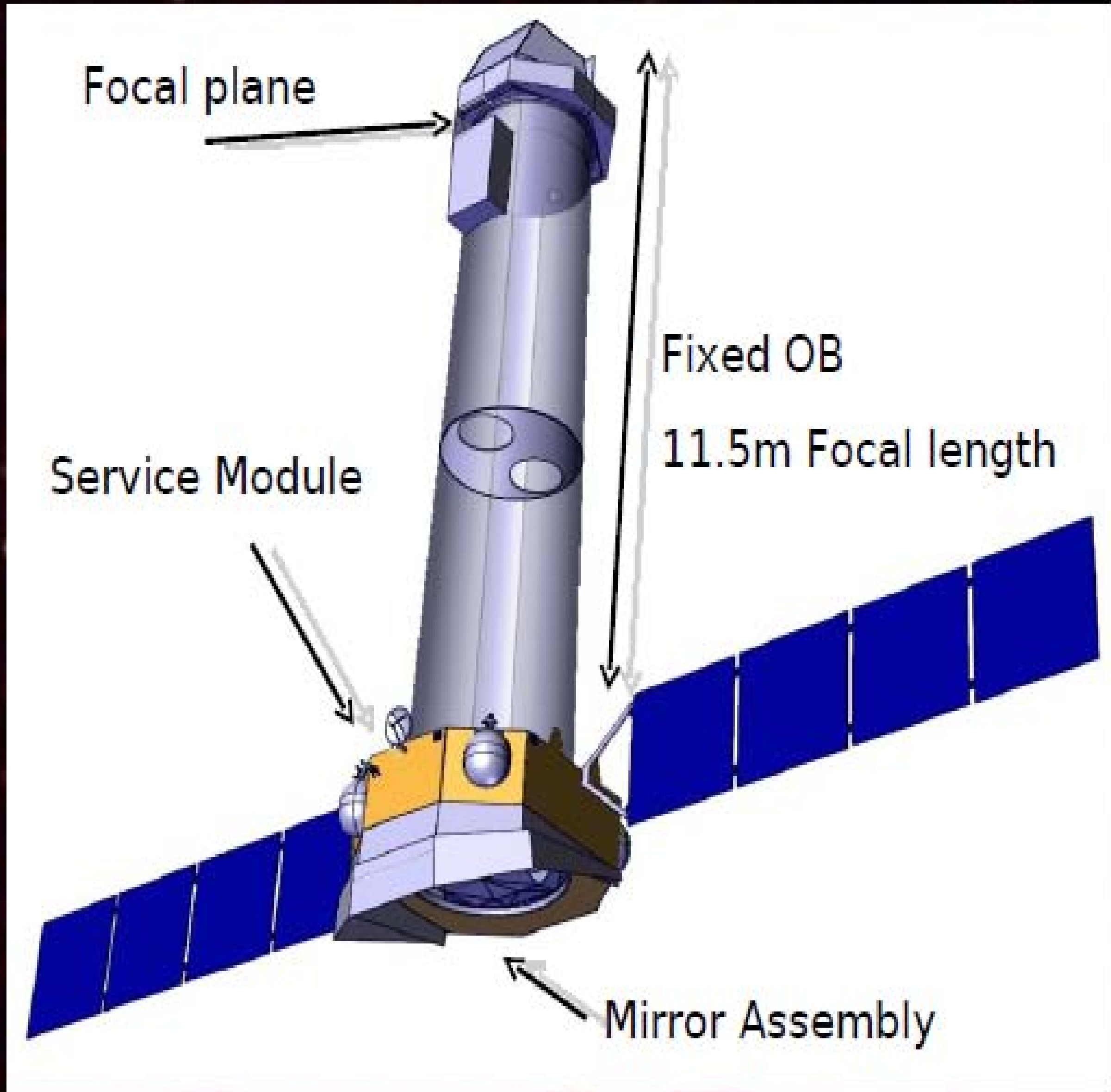
Down-selection from 3 (Juice, New Grav. Wave Obs. and Athena) to 2, 1 or 0

Mission core focusing optics set-up



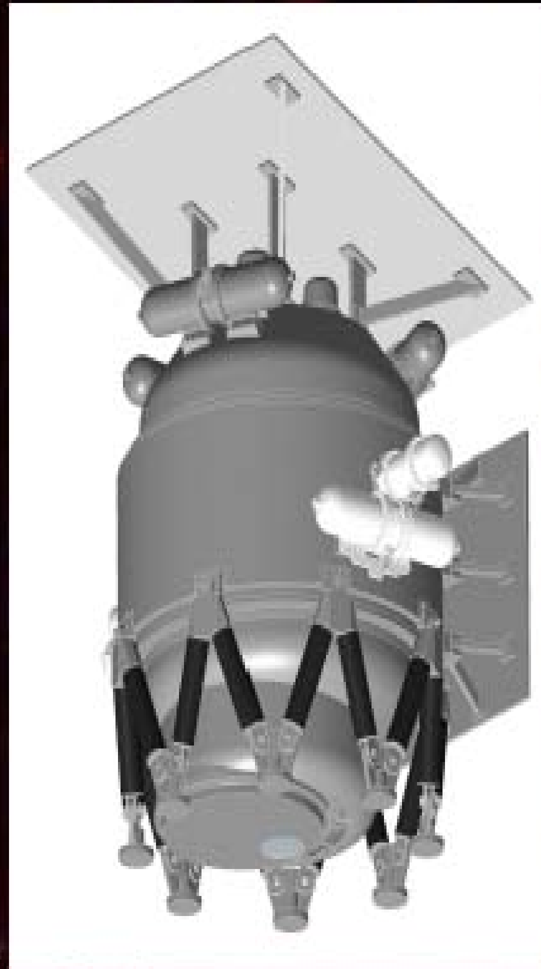
ESA Silicon Pore Optics
"OWL" design
5-10" resolution

Ariane V launch to L2
5yr nominal mission



Mission core instruments set-up

Wide Field Imager (WFI)



Microcalorimeter (XMS)

JAXA, NASA contributions

Athena's overall science case in a nutshell

Black holes and accretion physics → **Cosmic feedback** → **Large-scale structure of the Universe**

Black holes and accretion physics

- Determine the behaviour of gas accreting onto black holes and other compact objects.
- Probe matter under strong gravity and high density conditions.

Cosmic feedback

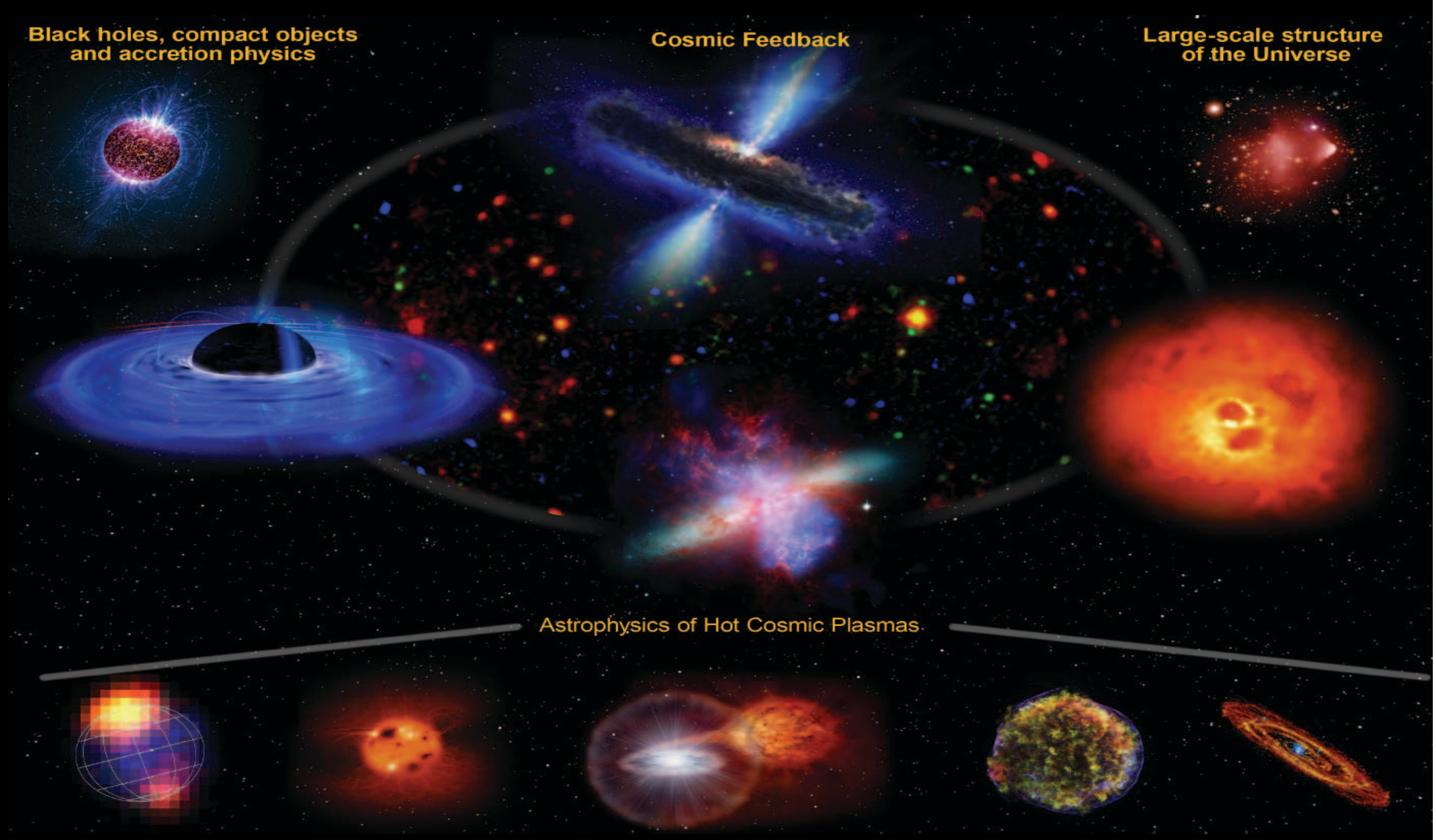
- Reveal the physics of cosmic feedback on all scales.
- Quantify supermassive black hole growth, and its relationship to galaxy evolution.

Large-scale structure of the Universe

- Trace the formation and evolution of large-scale structure via hot baryons in galaxy clusters, groups and the intergalactic medium comprising the cosmic web.

Astrophysics of hot cosmic plasmas

- Diagnose hot cosmic plasmas in all astrophysical environments via X-ray imaging and high resolution X-ray spectroscopy.


Black holes, compact objects and accretion physics
Cosmic Feedback
Large-scale structure of the Universe
Astrophysics of Hot Cosmic Plasmas

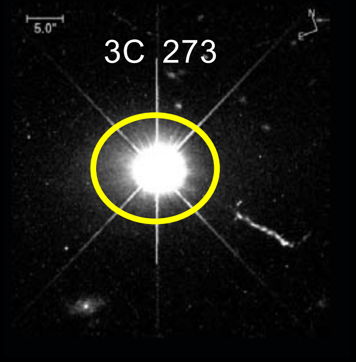
Athena's science requirements in a nutshell

Effective Area	1 m^2 @1.25 keV (goal 1.2 m^2) 0. 5 m^2 @ 6 keV (goal 0.7 m^2)	Black hole evolution, large scale structure Strong gravity, cosmic feedback
Spectral Resolution (FWHM)	ΔE = 3 eV (@6keV) within 2 x 2 arc min (goal 2.5 eV and 4x3 arc min) ΔE =150 eV at 6 keV within 25 arc min diam	Large scale structure, Cosmic Feedback Black Hole evolution, Large scale structure
Angular Resolution	10 arc sec HPD (0.1 – 7 keV) (goal of 5 arc sec)	Black hole evolution, Cosmic feedback, Large Scale Structure
Count Rate	1 Crab with >90% throughput. ΔE < 200 eV @ 6keV (0.3 – 15 keV)	Strong gravity
Astrometry	1.5 arcsec at 3σ confidence	Black hole evolution
Absolute Ti...	100 μsec	Compact Objects

Athena will address all "modes" of feedback

1. radiative feedback:

$$L_{acc} = \eta\left(\dot{M}_{acc}\right)c^2$$



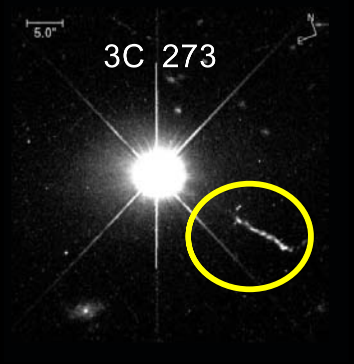
Able to quench the star formation and the cooling flow at the center of elliptical galaxies

e.g. Ciotti & Ostriker 2001, Sazonov et al. 2005

But it is not enough to reproduce the M_{BH}-б relation

e.g., Ciotti et al. 2009

2. mechanical/kinetic feedback: relativistic and/or sub-relativistic outflows



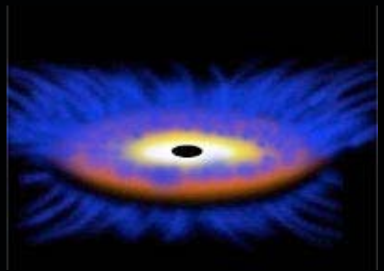
2a. **collimated, radiatively bright, relativistic radio jets**

Heat the IGM and the ICM, quench the cooling flow in rich Clusters of Galaxies

e.g. Fabian et al. 2009, Sanders et al. 2009

But jets involve only ~10% of AGN, and are highly collimated:
low global impact for AGN with L/L_{Edd} > 0.01

e.g., Ciotti et al. 2009

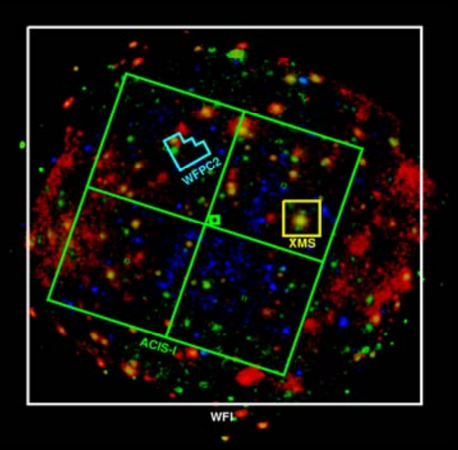


2b. **wide angle, radiatively dark, massive winds/outflows**

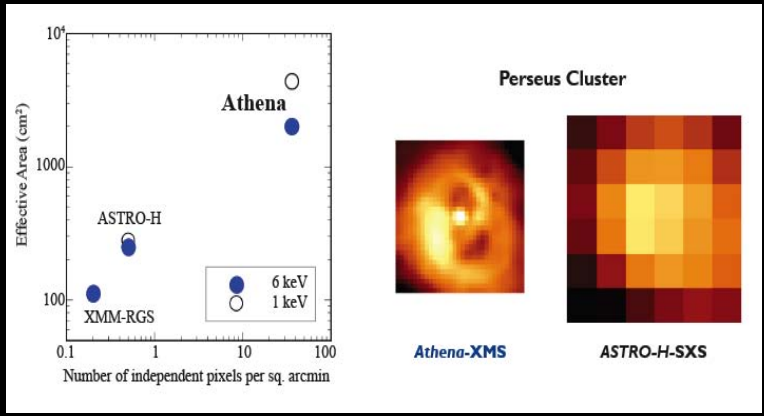
e.g., Silk & Rees 1998
e.g., Begelman 2003

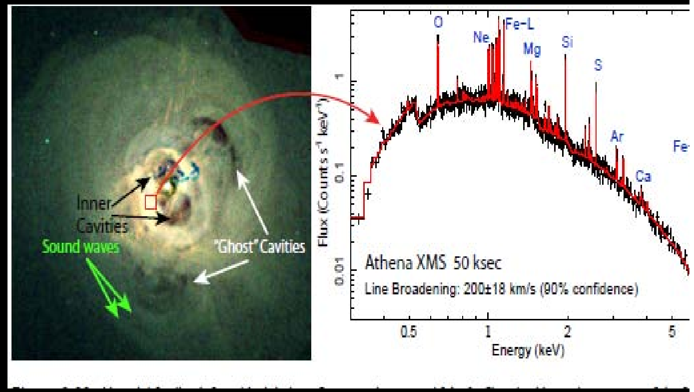
Athena will address all “modes” of feedback

1. **Radiative feedback:** via census of supermassive black holes across cosmic time and evolution of absorption
   (Deep, and wide area surveys with WFI)



2. **Feedback from relativistic jets in clusters and groups:** via measure of bulk velocities and line broadening in cool core regions of clusters where feedback are observed directly, revealing how the AGN couples to the intracluster gas, the energy content and timescale. (Spatially-resolved XMS spectra)

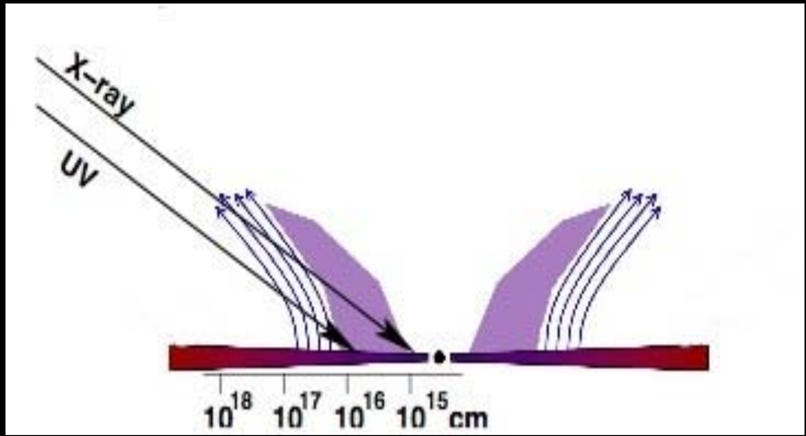




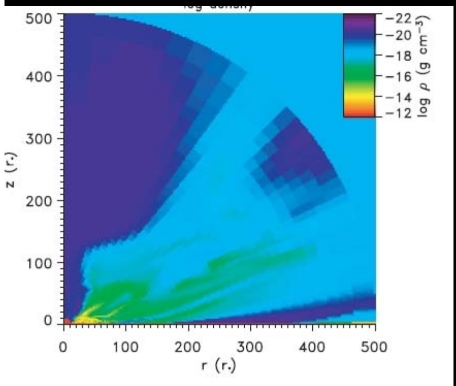
3. **Feedback from wide-angle outflows/winds:** understand models of winds/outflow and characterise their properties up to z=2
   (Detailed and time-resolved XMS spectra)

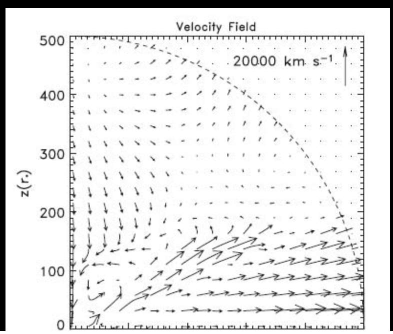
AGN Winds/outflows theoretical interpretation(s): Still an open issue

Radiation driven



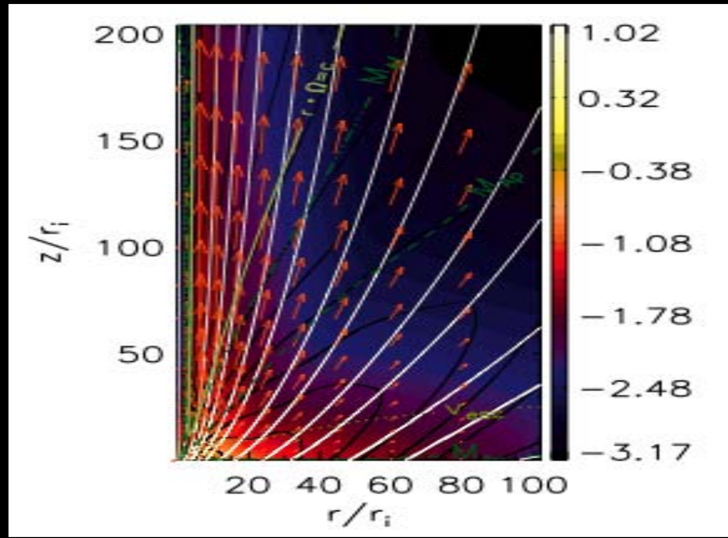
UV Line Driving: effective if the wind is shielded against the central ionizing continuum (Murray et al. 1995)





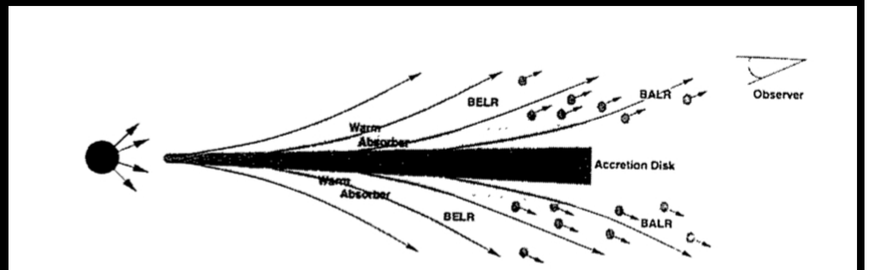
A “shield” of highly dense gas naturally arises in state-of-the-art hydrodynamical simulations of highly accreting AGN (Proga et al. 2000, 2004)

Magnetic driving



No need for shielding
(e.g. Konigl & Kartje 1994, Everett 2005, Porth & Fendt 2009, Fukumura et al. 2010)

Hybrid Models



e.g. launched by magnetic pressure, accelerated by radiation pressure
(Everett, Konigl & Kartje 2001)

Bottom line for ionized absorbers and their importance for feedback is

- ✓ N_w (cm^{-2})
- ✓ Location (R, DeltaR)
- ✓ Ionization state (ξ)
- ✓ Velocity
- ✓ Covering factor
- ✓ Filling factor/duty cycle
- ✓ Density

WA Location and feedback budget:

- NGC3783: ~25pc (Gabel+05)
- NGC4151: ~0.1 pc (Crenshaw & Kraemer 09)
- NGC5548 < 7pc (Kraemer+09)
- Mrk279 < 29 pc (Ebrero, Costantini+10)
- NGC3516: 0.2 pc (Netzer+02)
- NGC 4051 0.5-3 l.d. 1-3pc (Krongold+07, Steenbrugge+09)
- Mrk 509: >0.04 pc (Ebrero+11; Detmers+11; Kaastra,+11))

UFOs:

Sample of AGN: few 100s to 1000s Rs (Tombesi+11, Reeves+, Chartas+)

Feedback efficiency: $\varepsilon_w \propto \frac{\dot{M}_{out} v_{out}^2}{L_{acc}}$

Kinetic energy: $L_{kin} = 1/2\,\dot{M}_{out}\,v^2$

Outflow rate: $\dot{M}_{out} = 4\pi r N_H m_H C_g v_r$ $M_{sun} yr^{-1}$

Filling factor????

WA seem to be energetically unimportant,

even if current estimates have order of magnitude uncertainties,

and go from: dM/dt ($\propto L_{kin}$) fraction of % to several % dM_{acc}/dt ($\propto L_{edd}$)

This is, though, a fundamental and still open issue

The final impact of UFOs?: Some progress on QSOs still TBD

- ✓ Nw (cm^{-2}) ⇒ up to 1e23-1e24
- ✓ Location (R, DeltaR) ⇒ down to few Rsch
- ✓ Ionization state (ξ) ⇒ up to log xi ~ 4-5
- ✓ Velocity ⇒ up to v~0.3c
- ✓ Detection fraction ⇒ >40%, up to 60% in AGNs, less clear in QSOs

Detection fraction = f(covering factor, Frequency, filling factor/clumpiness)

⇒ these values are still unknown, in particular in high-z QSOs

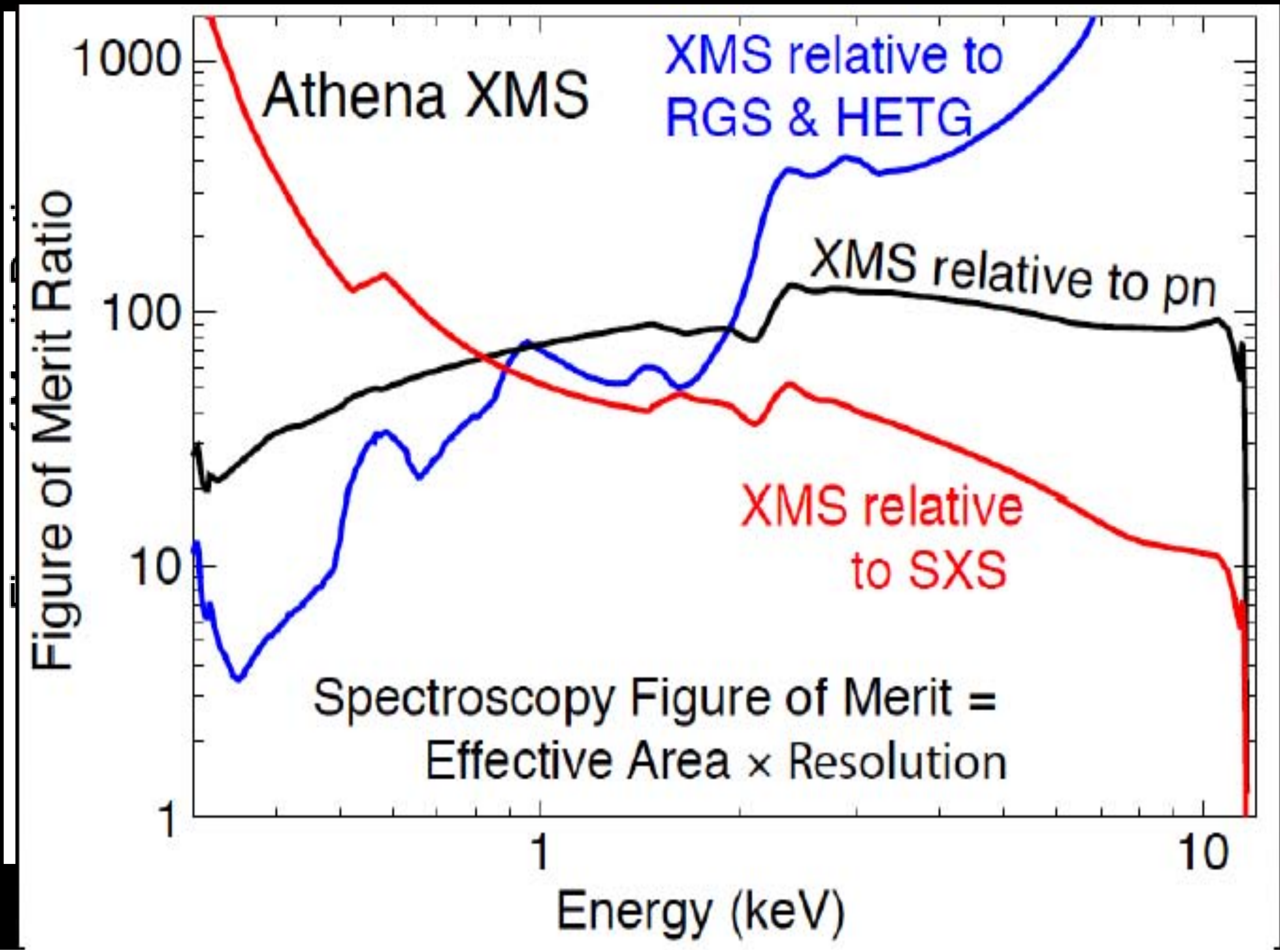
UFOs in AGNs ⇒ kinetic energy 100-1000 x > Warm abosrbers

UFOs in QSOs ⇒ still large unkowns (Cov. Fact., Filling factor), even more if at z~2

But clearly, energetically, UFOs could have significant impact on host galaxies.

⇒ need of higher X-ray throughput and energy resolution

Future: ATHENA mission: Aeff x E/DeltaE



Future: ***Athena?***

Final characterisation of outflows from AGNs & QSOs and their feedback impact on galaxies/groups/clusters:

Most important is to:

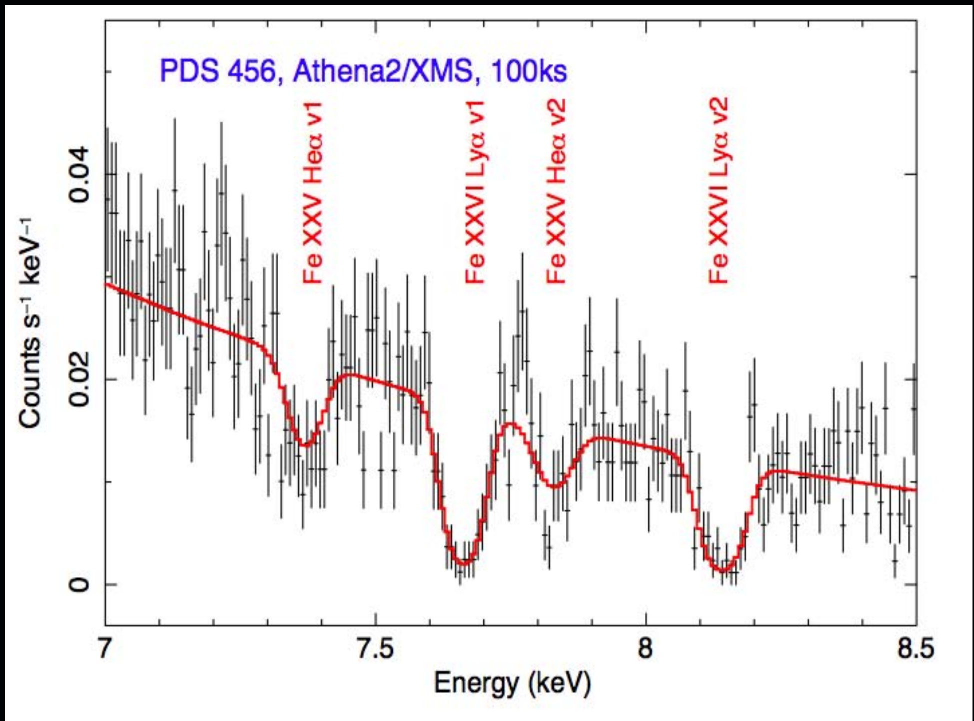
i) Do detailed modeling and probe the outflow dynamics in brightest AGNs (to constrain geometry and location, hence energetics);

ii) Characterize the outflow properties (N_w, ξ, υ_{out}) in QSOs up to z=2.

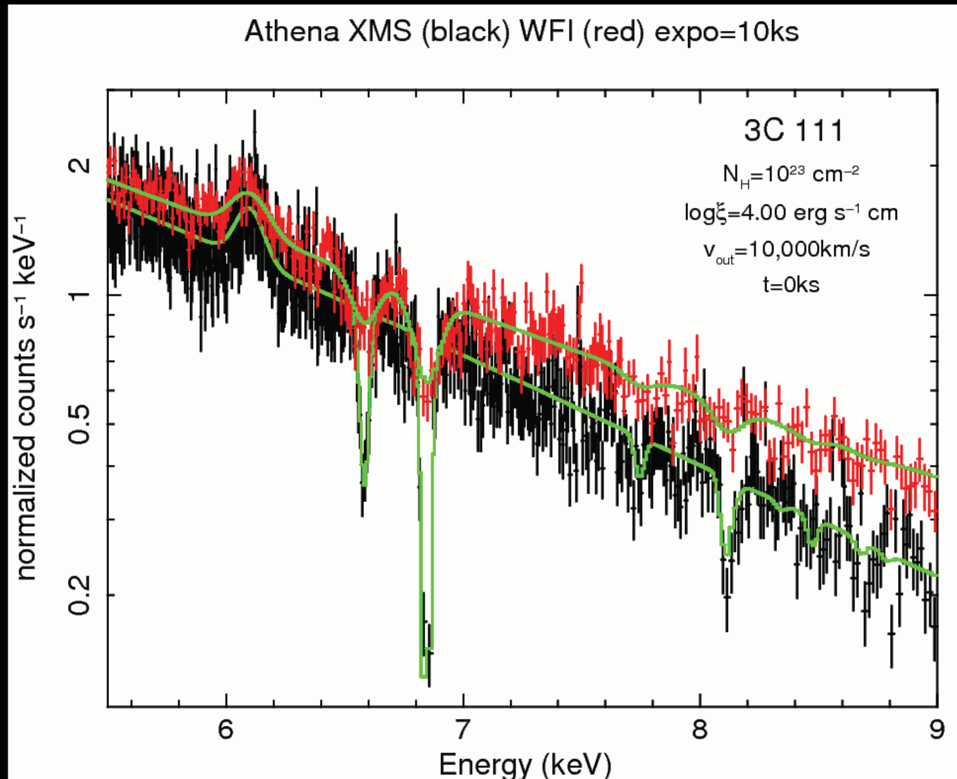
Future: XMS absorption spectroscopy

Absorption spectroscopy with calorimeter resolution from 0.1 keV up to 8-10 keV will revolutionize the field

First probes of absorption line profiles (P-Cygni?)



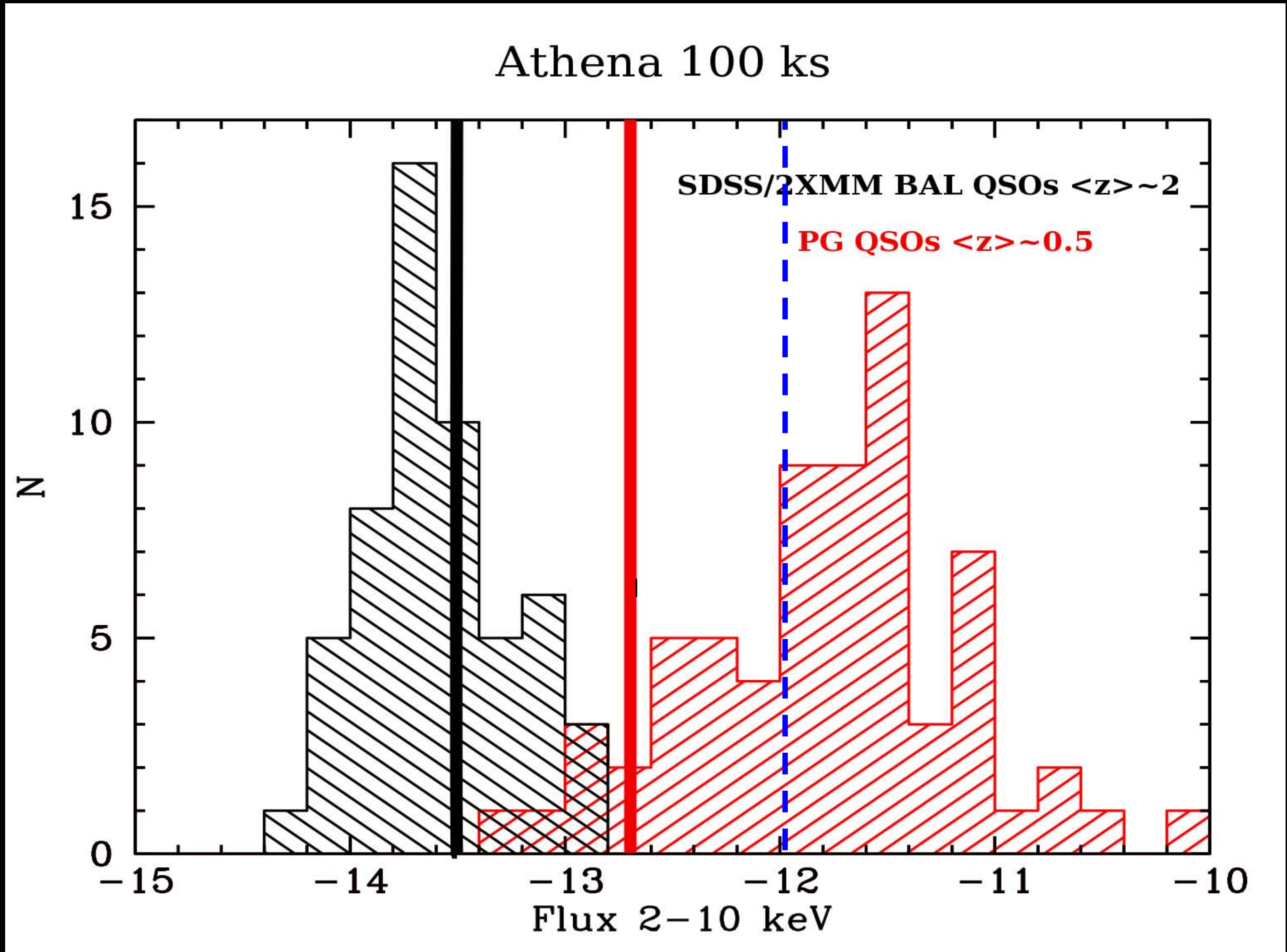
Probe of flow dynamics on short time-scales



Important to probe unambiguously the geometry and location of the outflow, and therefore the total mass outflow and the kinetic

Future: Study WAs and UFOs in QSOs up to z~2

Minimum 2-10 keV flux to constrain (N_W, ξ) within (20%, 10%) in a 100 ks observation



QUANTIFY AGN FEEDBACK UP TO z~2

Conclusions

- Athena could be the next generation L-class X-ray observatory
- Will address broad science (from BHs to LSS), but Feedback is core science for Athena
- A great mission to study all possible “modes” of AGN feedbacks, and for probing winds/outflows/UFOs
- The way to go to understand wind/outflow models and quantify their feedback (up to z=2-3)
- Stiff competition (Juice & New Grav. Wave Obs)
  $\Rightarrow$ *Community support is essential and stay tuned till february*

Sign up as an Athena supporter here:
https://lists.mpe.mpg.de/mailman/listinfo/athena-supporters

Thank you very much for your attention