Athena@OAS-Bologna: A Summary

Cappi M., Lanzuisi G. and Fioretti V. on behalf of:

L. Amati, N. Auricchio, L. Bassani, A. Bulgarelli, A. Comastri, M. Dadina, A. DeRosa, S. Ettori, F. Gianotti, P. Grandi, M. Malaspina, A. Malizia, N. Masetti, L. Nicastro, E. Palazzi, J. Stephen, A. Tacchini, E. Torresi, M. Trifoglio, L. Valenziano

Outline

- Background (past experience, logic, etc.)
- Athena in a nutshell
- Context (national & international)
- Italian and OAS contributions (Athena-level, XIFU, WFI, +?)
- Programmatics (at OAS and at INAF level)
- Conclusions of Athena @ OAS-Bologna
- Two examples of important OAS contributions:
  - Science sim for WFI (by G. Lanzuisi)
  - Geant4 sim for SPOs, XIFU, WFI and Hitomi (by V. Fioretti)

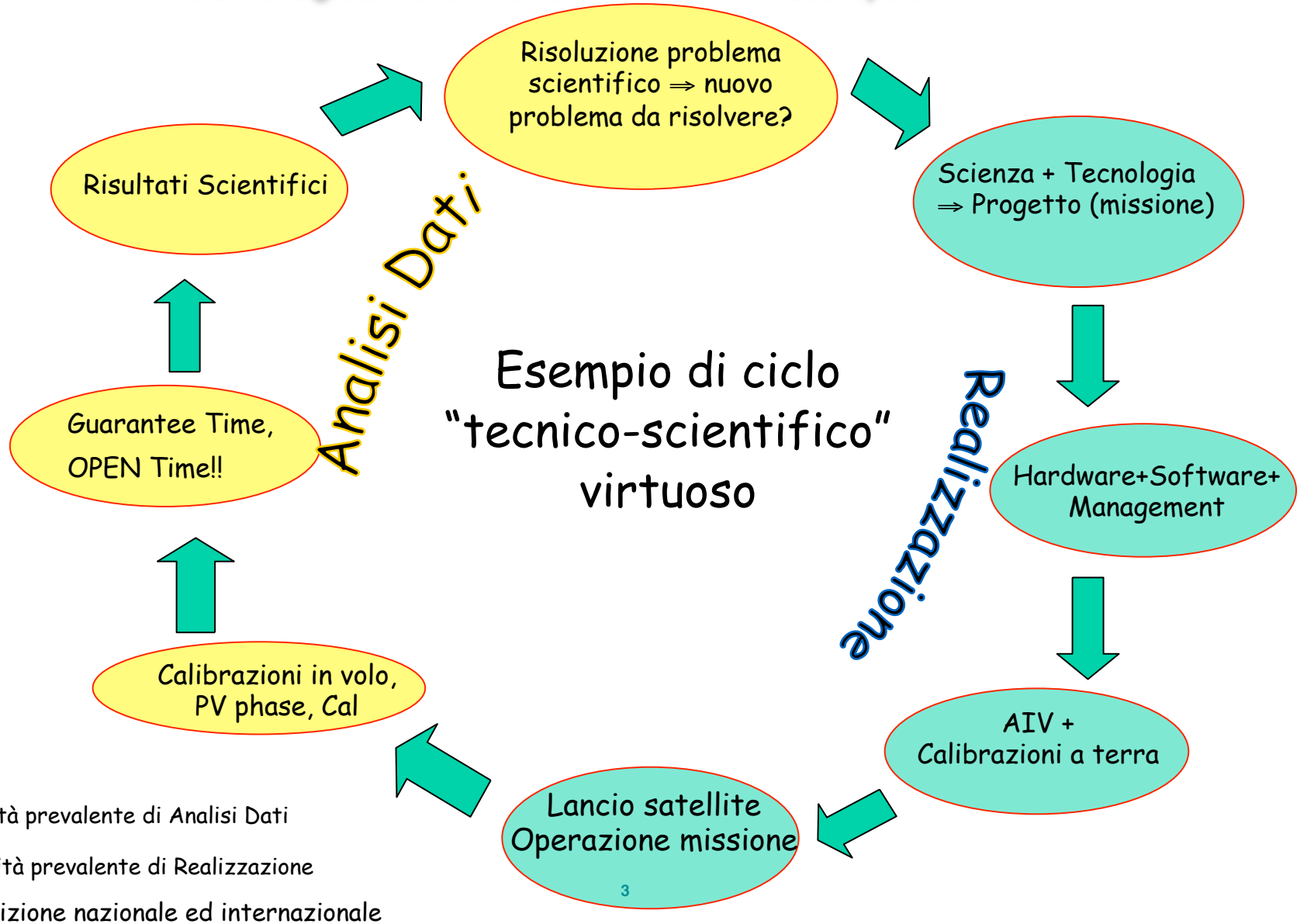
Background: Past experience

Team experience was build over past (scientific, technological and managerial) experiences in:

- BeppoSAX
- XMM-Newton (+ Chandra)
- Integral
- Swift
- Agile
- Planck
- Euclid
- Fermi

- Future @ Bo:
  - Athena@Bo
  - Theseus @ Bo (if selected as M5, see Amati's talk) + Hermes ?
  - CTA @ Bo (See Bulgarelli's talk)

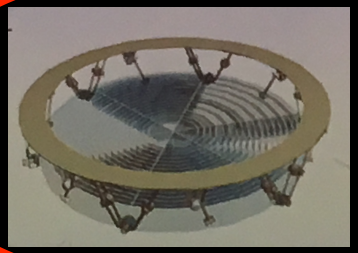
Background: Logic/key to maximize scientific and technological return is to have a "virtuous cycle"

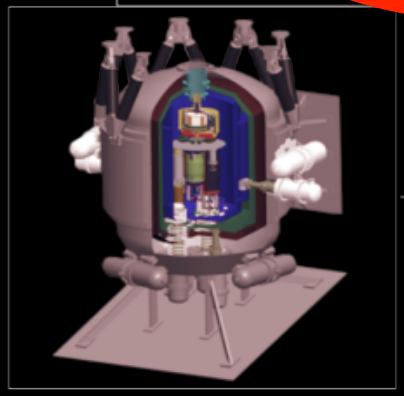


Athena in a Nutshell

Willingale et al. 2018

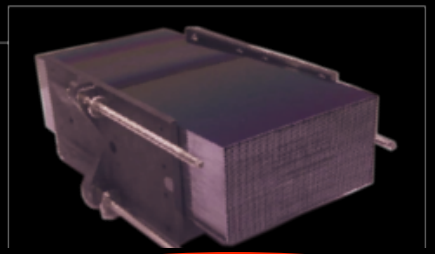
L2 orbit Ariane 64
Mass < 7000 kg
Power 2500 W
4 years mission
5 year mission



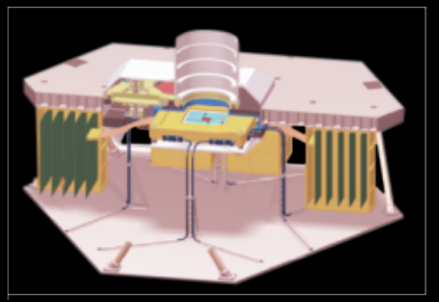


X-ray Integral Field Unit:
ΔE: 2.5 eV
Field of View: 5 arcmin
Operating temp: 50 mk

Barret et al., 2018 arXiv: 1807.06092



Silicon Pore Optics:
1.5 m^2 at 1 keV
5 arcsec HEW (6"@R<20')
Focal length: 12 m
Sensitivity: 3 10^{-17} erg cm^{-2} s^{-1}



Wide Field Imager:
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

Meidinger et al. 2017 arXiv: 1702.01079

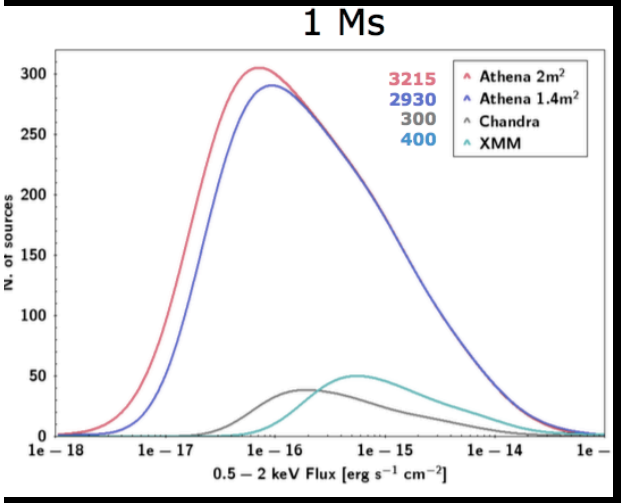
Launch ~2031, Hexapod switch mechanism, Ariane 6.4, L2 (TBC)

Athena Performance in a nutshell

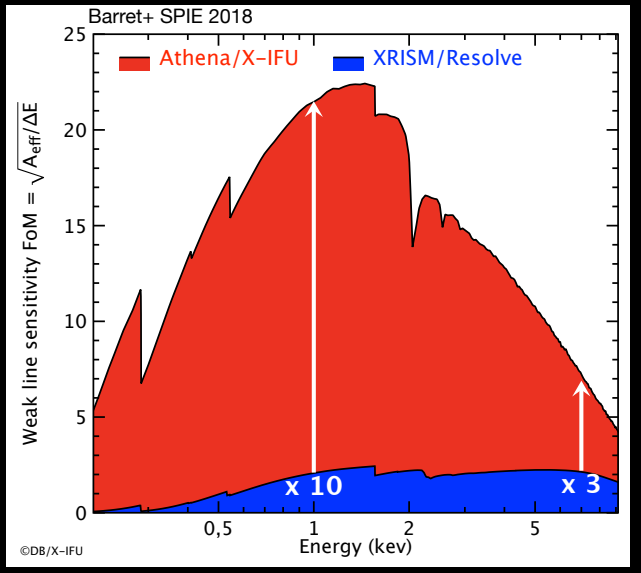
Key performance parameters

survey speed, weak line sensitivity (and bright sources capabilities) and ToO capabilities

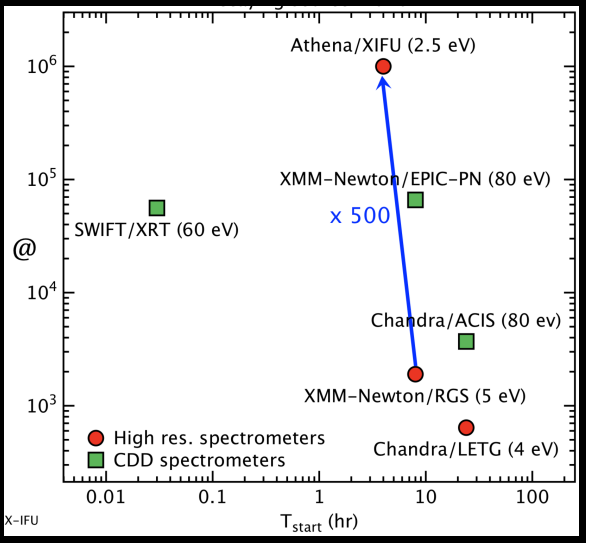
Survey Speed/grasp



Throughput/Line Sensitivity



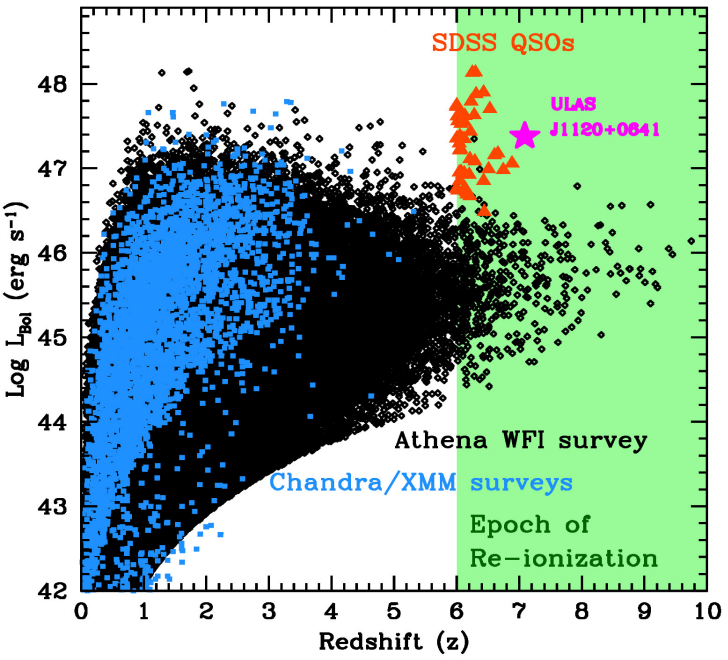
ToO capabilities



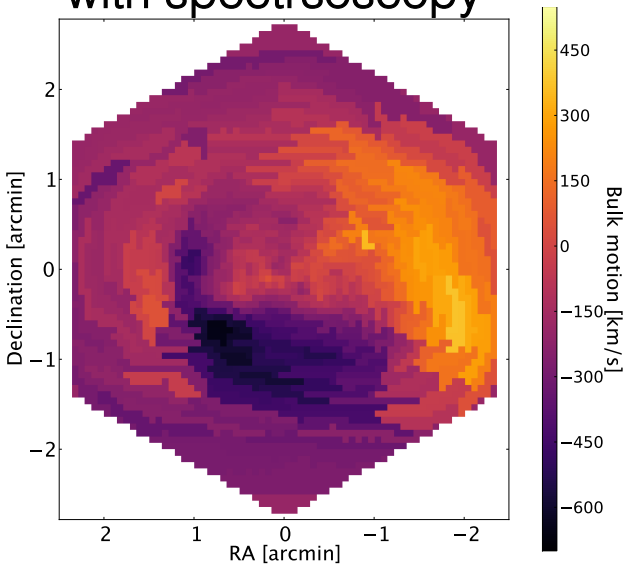
A fantastic machine to discover, repoint, and understand the physics of the Energetic Universe

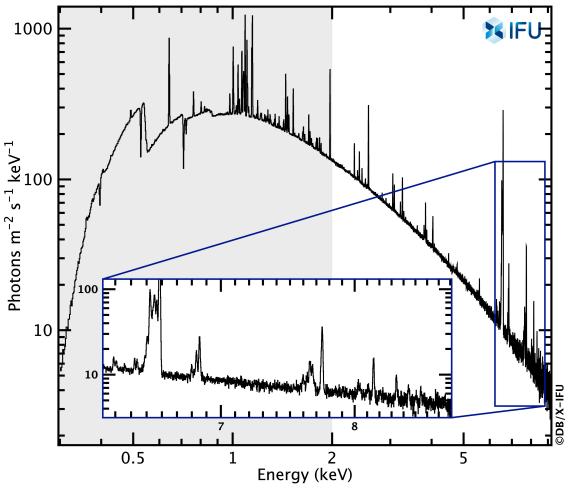
Athena Science in a nutshell

Discover with WFI survey speed/grasp

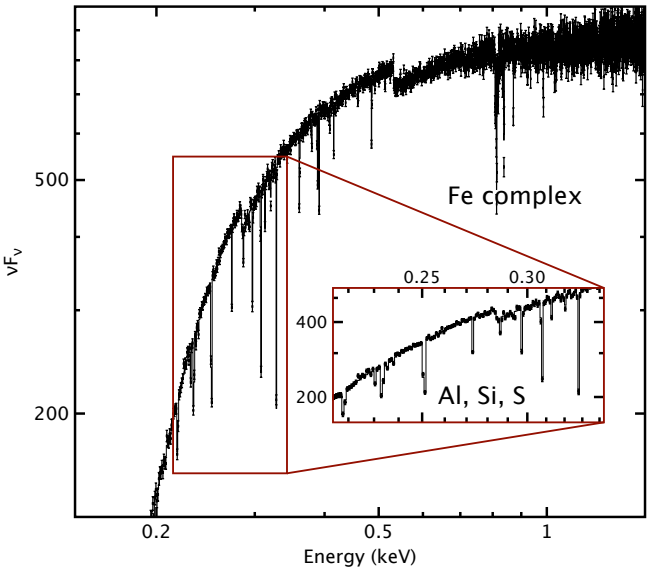


Point X-IFU to probe physics with spectrsoscopy





Re-point X-IFU to probe GRBs/ToOs



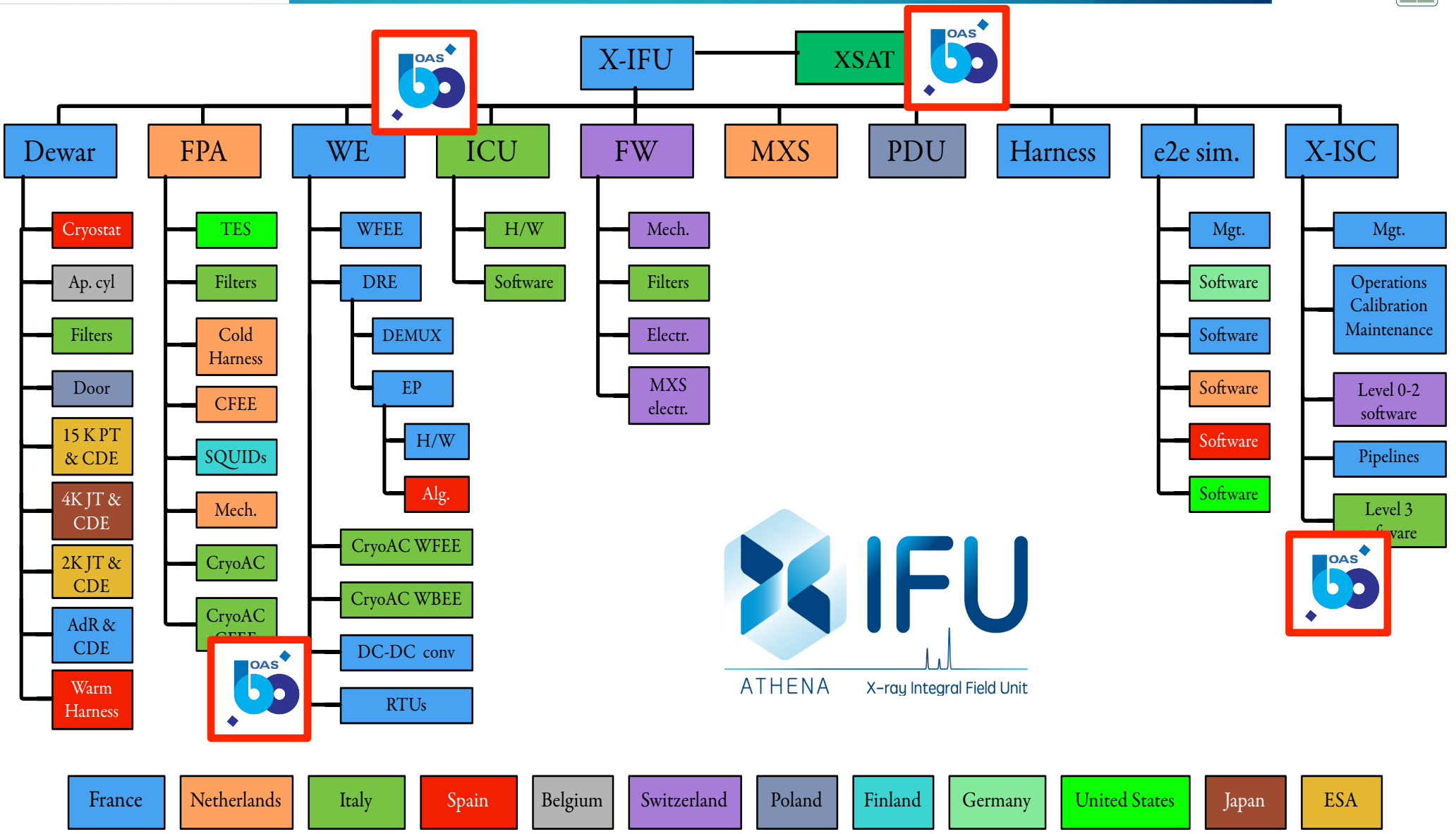
Context: International and National

✓ Hot&Energetic Universe Theme selected for ESA L2	Nov. 2013
✓ Athena Mission selected	Jun. 2014
✓ Phase A and B1	on going
✓ IPRR of WFI , and ICC formalized	Nov. 2018
✓ IPRR of XIFU	Mar. 2019
✓ Mission Adoption Review	2021
✓ Start of Implementation Phase	2021
✓ Launch	2030-31
✓ Operations:	4.5+ years

Programmatics:

- ESA led mission (CaC < 1.05 B€), NASA and JAXA are partners (<30%)
- ESA responsible of mission systems, spacecraft, launcher, mirror, operations and SOC
- Instruments and Science Ground Segment elements to be provided by the Member States (>= ~ 600 M€)

XIFU and OAS WBS



Italian and OAS Responsabilities

- **Athena-general level:**
  - ***Science (ASST, SWGs, TPs):*** 1 in the ESA Study Team (L. Piro), 1 co-chair of SWG2 (**M. Cappi**), 9 Italian co-chairs of Mission & Science WGs (**A. Comastri, S. Ettori**, etc.) + 160 Italian members
  - ***GS, Science Innovation Center*** (led by OaR, TBC, but also **OAS**)
  - *Mirror calibration facility* (led by OABrera) - TBC

- **XIFU-related (consortium) responsabilities:**
  - ***Management***: co-PI (L. Piro), co-Is: **M. Cappi, L. Valenziano**
  - ***Science***: members of **XSAT** (chair: **M. Cappi**, members: **M. Dadina, S. Ettori**, P. Mazzotta, F. Nicastro, S. Sciortino), plus active TP members (e.g. **M. Roncarelli**)
  - ***CryoAnticoincidence***, front-end electronics, digital and Data proc. (IAPS, Uni.Ge, CNR/IFN, IASF-Mi)
  - ***Background simulations*** and instrument design (IAPS/INAF, OAS, IASF-Pa, Mi) (**V. Fioretti, A. Bulgarelli**)
  - Optical/IR blocking ***filters*** (Univ.Pa &Oss.Pa/INAF)
  - ***Instrument Control Unit*** (OAS-Bo, Oss.To, IAPS) (PI: **L. Valenziano, N. Auricchio, J. Stephen, M. Dadina**)
  - Contribution to ***instrument calibrations on ground and in-flight*** (IAPS/INAF+) under assessment

- **WFI-related (consortium) activities:**
  - ***Management***: co-I **A. Comastri**
  - ***Science***: **G. Lanzuisi, A. Comastri**
  - Optical/IR blocking ***filters*** (Univ.Pa &Oss.Pa/INAF)
  - ***Background reduction simulations, SPOs, diverter*** (IASF-Mi, **OAS**) (**V. Fioretti**)

- **N.B: Italian (and OAS) contribution is crucial for science (Bkg. reduction, Area at low E=> filters) and lead role in Instrument Design and Control (Bkg. Simu;, ICU).**

Activities: Athena @ OAS-Bologna

- **Athena-general level:**
  - ***Science (SWGs, TPs):*** 1 co-chair of SWG (Energetic Universe: **M. Cappi**), 2 co-chairs of TPs (TP1.2: S. **Ettori**; 2.1: A. **Comastri**), several (>30) members of TPs @ Bo (IASF-Bo, OABo, IRA, DiFA)
  - ***GS, Science Innovation Center*** (led by OaR, but likely also **OAS**) (TBD)
  - *Mirror calibration facility (TBD)*

- **XIFU-related (consortium) responsabilities:**
  - ***Management***: 2 co-Is: **M. Cappi, L. Valenziano**
  - ***Science***: members of **XSAT** (chair: **M. Cappi**, members: **M. Dadina, S. Ettori**, P. Mazzotta, F. Nicastro, S. Sciortino), plus active TP members (e.g. **Roncarelli**)
  - ***Background simulations*** and instrument design (IAPS/INAF, OAS, IASF-Pa, Mi) (**V. Fioretti, A. Bulgarelli**)
  - ***Instrument Control Unit*** (OAS-Bologna, Oss.To, IAPS) (PI: **L. Valenziano, N. Auricchio, M. Dadina**)
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- **WFI-related (consortium) activities:**
  - ***Management***: 1 co-I **A. Comastri**
  - ***Science***: **G. Lanzuisi, A. Comastri**
  - ***Background reduction simulations, SPOs, diverter*** (IASF-Mi, **OAS**) (**V. Fioretti**)

- **N.B: OAS contribution is crucial for science (Bkg. reduction, Area at low E=> filters) and lead role in Instrument Design and Control (Bkg. Simu;, ICU). Potential role (TBD) in the future in GS Innovation center and/or calibrations on-ground/in-flight.**

Programmatics @ OAS

Athena-general:

- **SWGs/TPs**: missioni coperte da ASI, ~10 missioni/anno
- **GEANT4 sim**: contratti ESA (ITTs: Arembes, Exacrad), 1 AdR/anno

XIFU-related:

- **XSAT activities:** missioni coperte da ASI (~15 missioni/anno)
  Science simulations? (qualche mese AdR/anno)
- **ICU**: attività coperte come spin-off delle attività Euclid, missioni parzialmente coperte da ASI/Athena (~10 missioni/anno).
  (1 borsa di studio/anno)
  N.B: CaC dell'ordine di 10 Meuro (per ASI).

WFI-related:

- **Science activities**: missioni coperte da ASI, (~5 missioni/anno)
  + qualche mese AdR/anno

<u>Totale @ Bo:</u>

Personale: staff ~4 FTEs/y for ~15 persons (staff), 2 FTEs/y (non-staff)

Cost: 40 keuro/y (missions) + 60-80 keuro/y (personale)

Programmatics @ INAF level

- **ASI**:
  - About 500 Keuro/year since 2016
  - 2-year (2018-19) Athena contract for 1.4Meuro currently frozen for unclear reasons(!?)
  - Replaced by Premiale (ADAM) just approved for 0.5Meuro 2018-19
  - New Athena contract to be discussed soon

- **INAF**:
  - Mostly manpower (20-30 FTEs)
  - 150keuro directly from INAF to cover lack of funding from ASI for (only) 2018-19.

- **ESA**:
  - AREMBES (end mid 2019)
  - EXACRAD (end mid 2019)

- **EU**:
  - AHEAD (partially, and partially finished). AHEAD-2 prop, OAS should be up higher
  - Other proposals failed

Conclusions of Athena@OAS-Bologna

- Athena is THE large X-ray Observatory for the next 20 years.
- Athena offers a unique opportunity of a strong Italian role and large scientific, technological and industrial return to a vast national community, and to OAS!
- Also unique opportunity in view of a full engagement in XRISM (for next 10 years)
- Complement the suite of major class facilities at other n's
- Athena science is **already** driving present research providing:
  - guidance for the formation of the new generations of researchers (Laurea and PhD thesis!)
  - Pathfinder experiments with present facilities (XMM, Chandra, etc.) and theoretical studies

→Need strong political and financial support!!

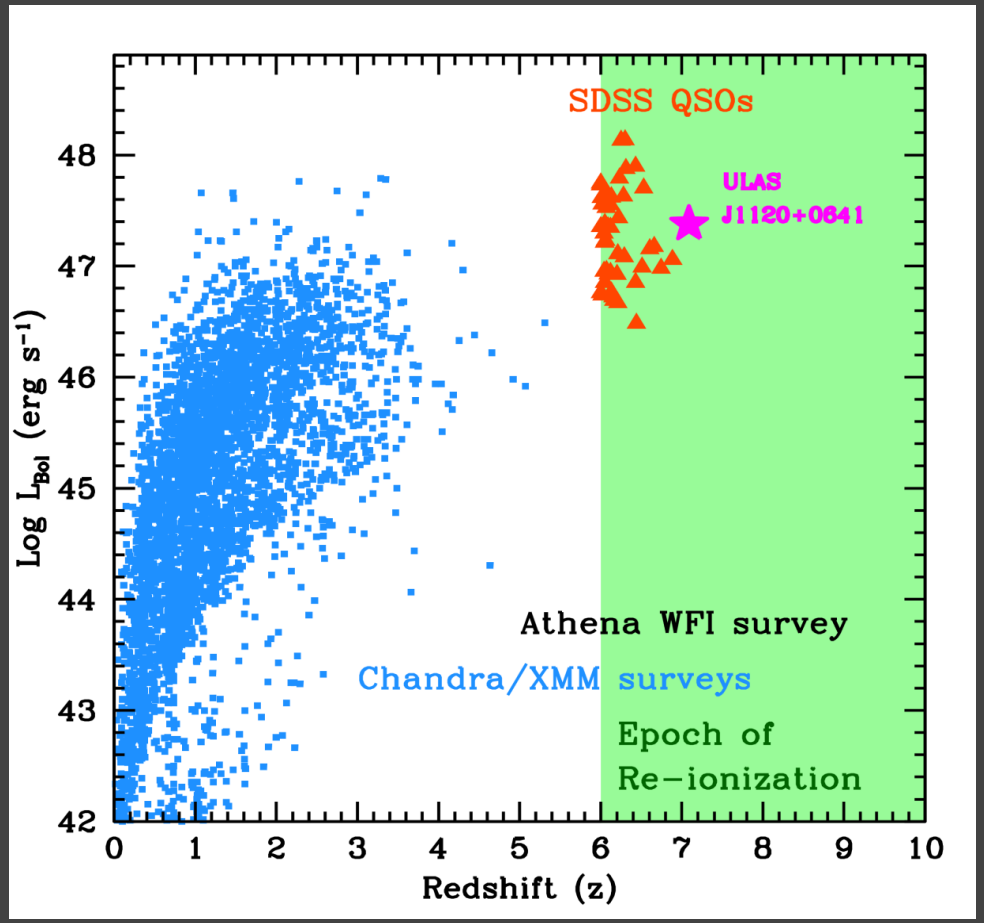
→ Opportunità @ OAS da cogliere e da sostenere!

Athena-WFI Survey: formation and growth of the earliest SMBH

G. Lanzuisi, A. Comastri, R. Gilli,
J. Aird, M. Brusa, N. Cappelluti, C. Vignali, F. Vito, I Matute…

Athena-WFI survey

Known z>6 AGN are extremely luminous/rare QSOs from Opt/IR surveys



z>6-7 QSOs with $M_{BH}>10^8\ M_\odot$

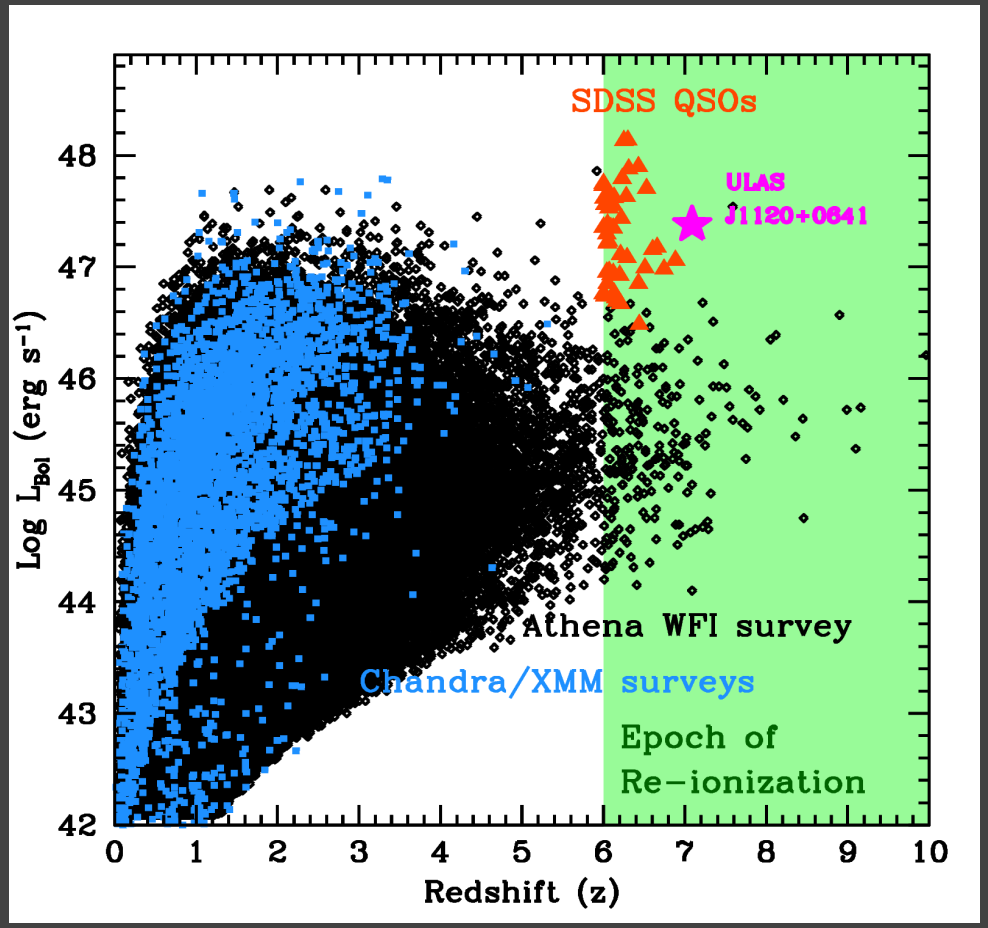
Continuos Edd-limited accretion needed for ~1Gyr?

Heavy vs. light seeds?

Athena-WFI survey

Known z>6 AGN are extremely luminous/rare QSOs from Opt/IR surveys

Goal: populate the z>6 Lum-z plane with hundreds of moderate luminosity AGN (L_X=43-45)



z>6-7 QSOs with $M_{BH}>10^8\ M_\odot$

Continuos Edd-limited accretion needed for ~1Gyr?

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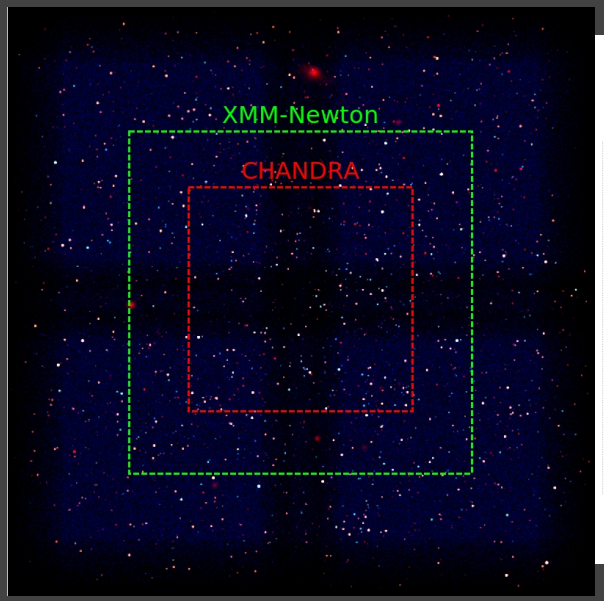
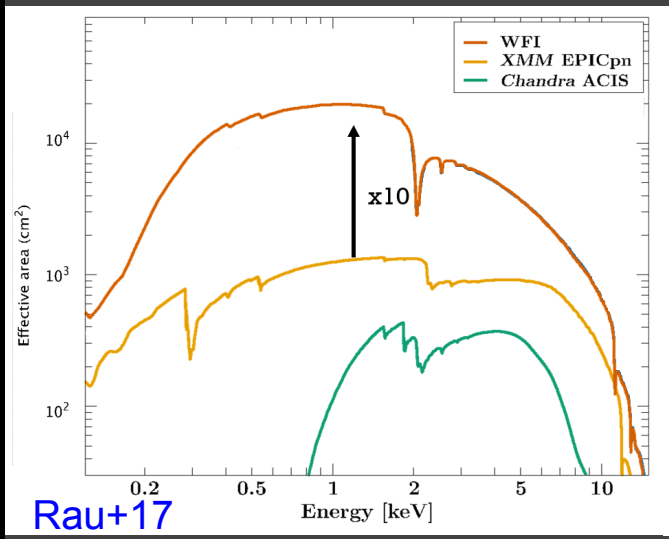
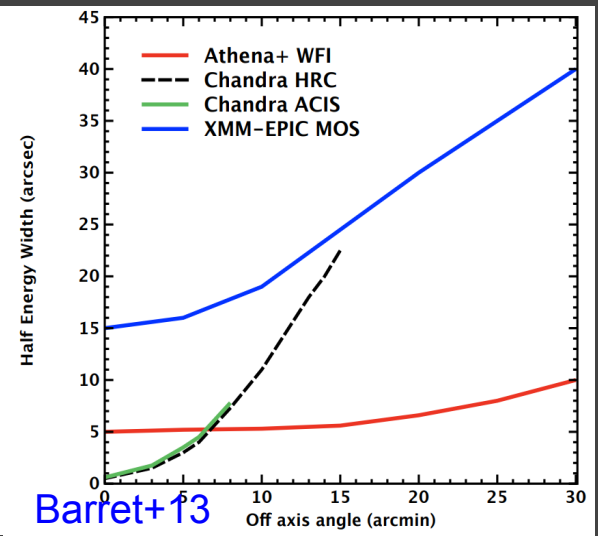
Athena-WFI survey capabilities

Large field-of-view (40’ x 40’)
+
Large collecting area (1.4m^2@1kev)
+
Good quality (~5”) PSF over
large fraction of FOV







Athena-WFI survey capabilities

Large field-of-view (40' x 40')
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Large collecting area (1.4m^2@1kev)
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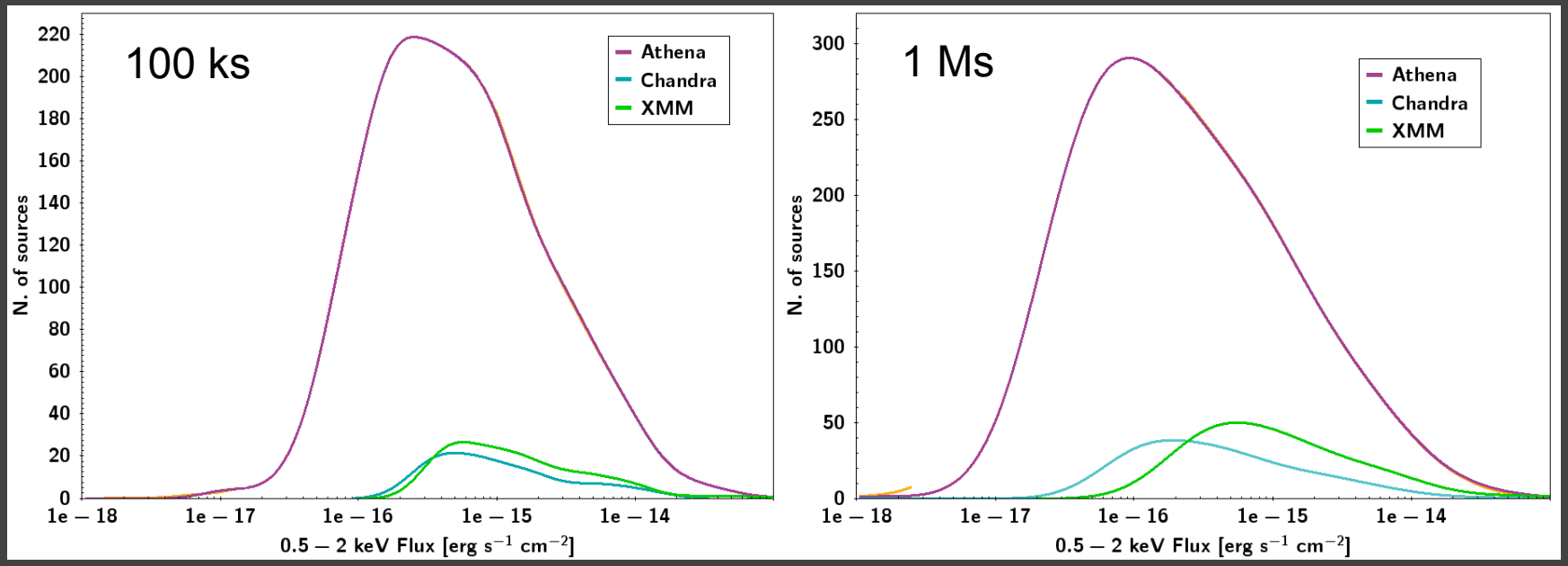
Good quality (~5") PSF over
large fraction of FOV

Powerfull survey machine! 100x Chandra/XMM



Athena-WFI survey

SciObj-211: Detect at least

Aim1: 10 AGN z=6-7 @L_X=43-43.5 erg/s → Flim 2.4×10^{-17} over 2.4 deg^2

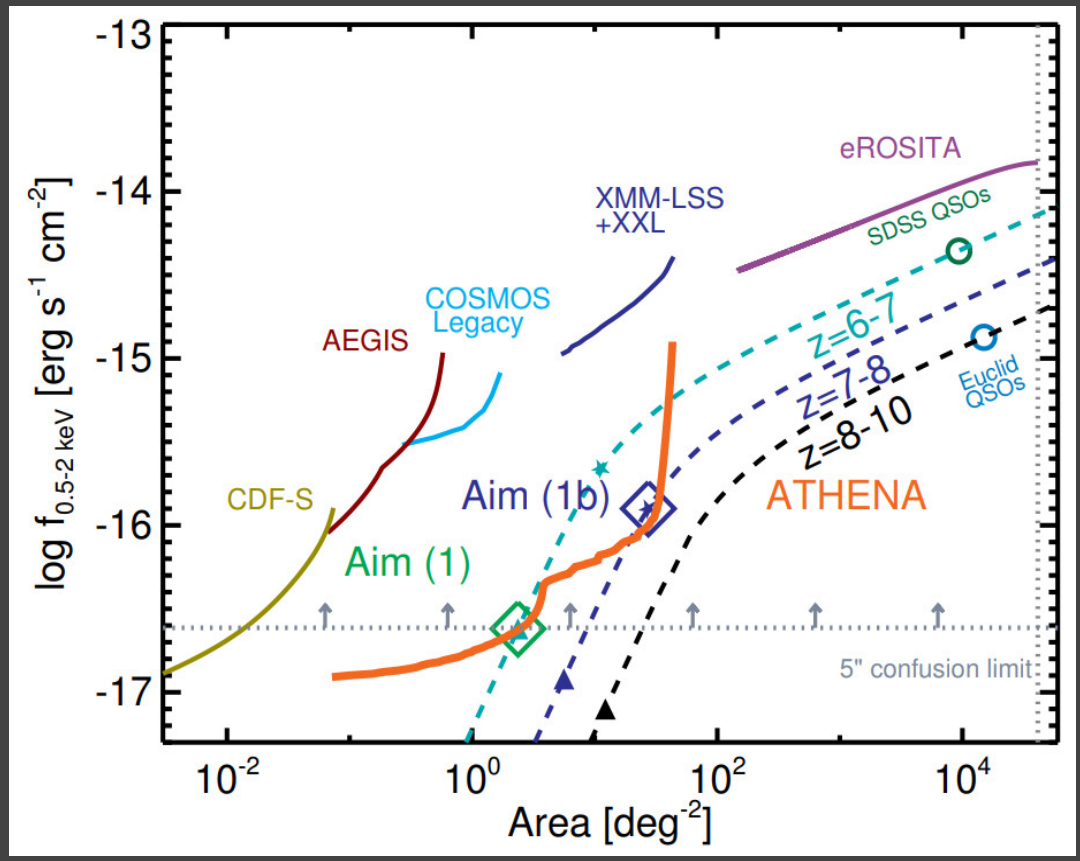
Aim1b: 10 AGN z=7-8 @L_X=43.5-44 erg/s → Flim 1.3×10^{-16} over 27.4 deg^2

Plus First Groups and CT AGN
→ Consolidated survey strategy:

Deep
12x1-1.5Ms

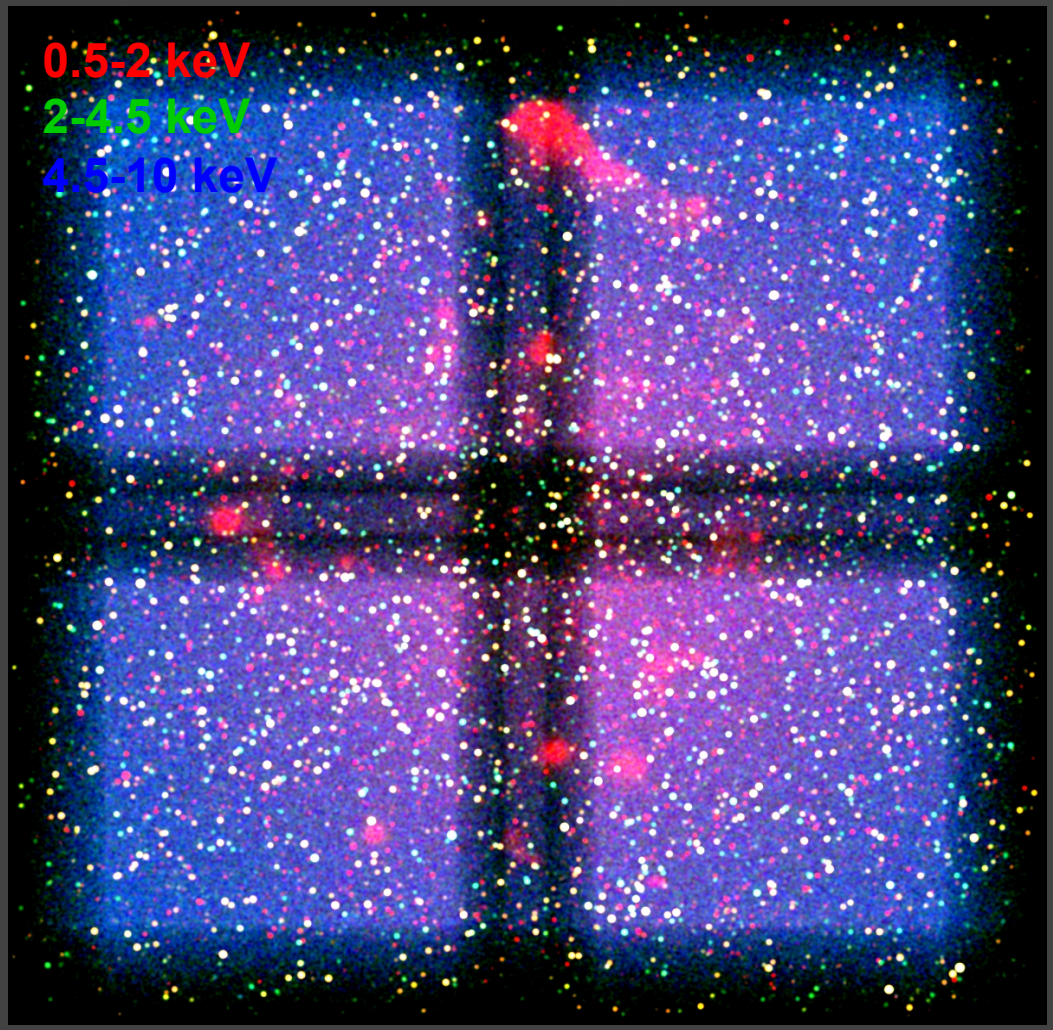
Shallow
108x90ks

Tot=23.62 Ms (~25% MOP)



Full SIXTE simulation of a deep field

Input: Mock catalogs from Gilli+07
~10^5 AGN in 10 deg^2, up to z=10, each with N_H, z, L_X….
~$2x10^5$ Galaxies at faint fluxes
+ Extended emission from CDFS (Finoguenov+15)



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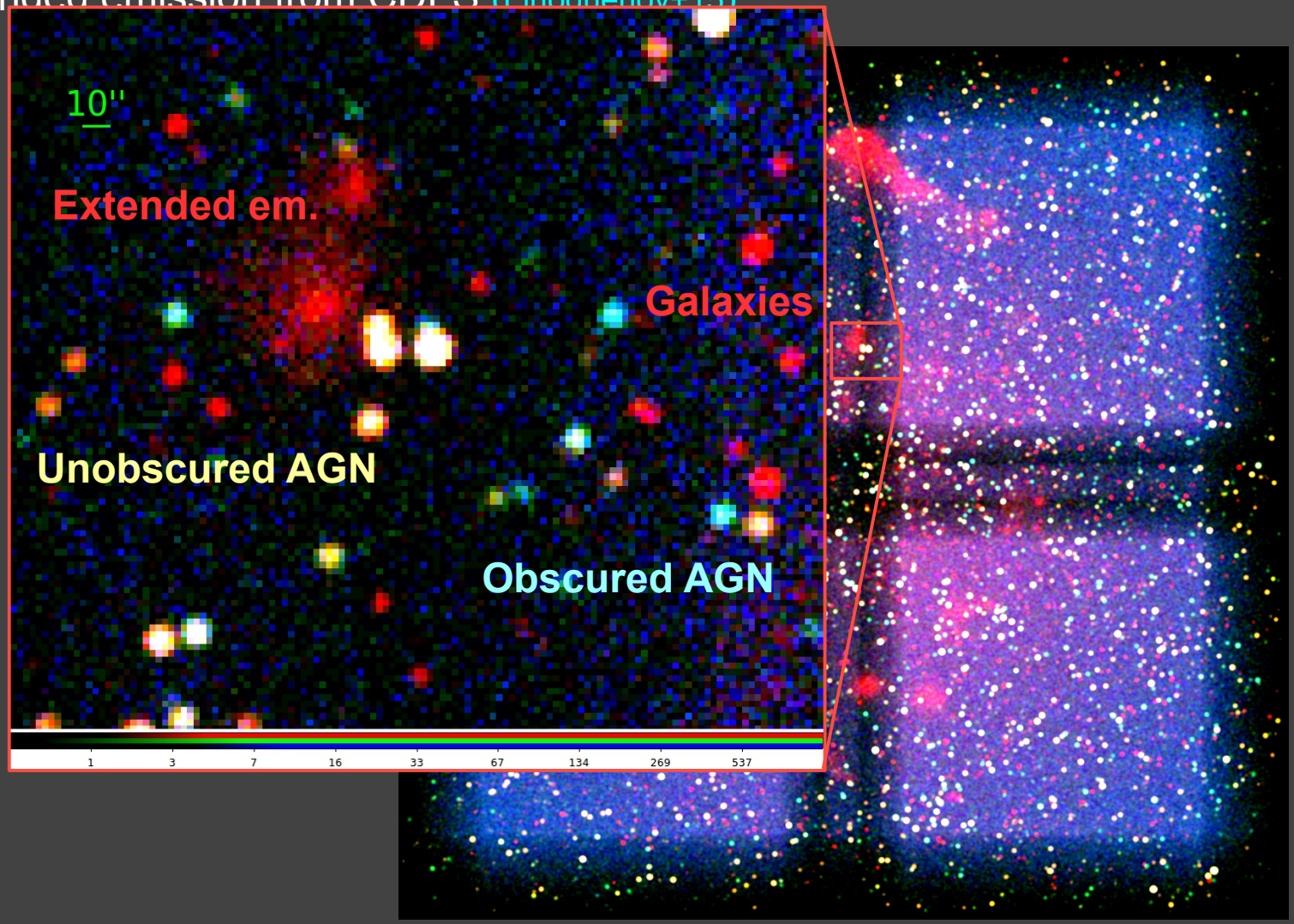

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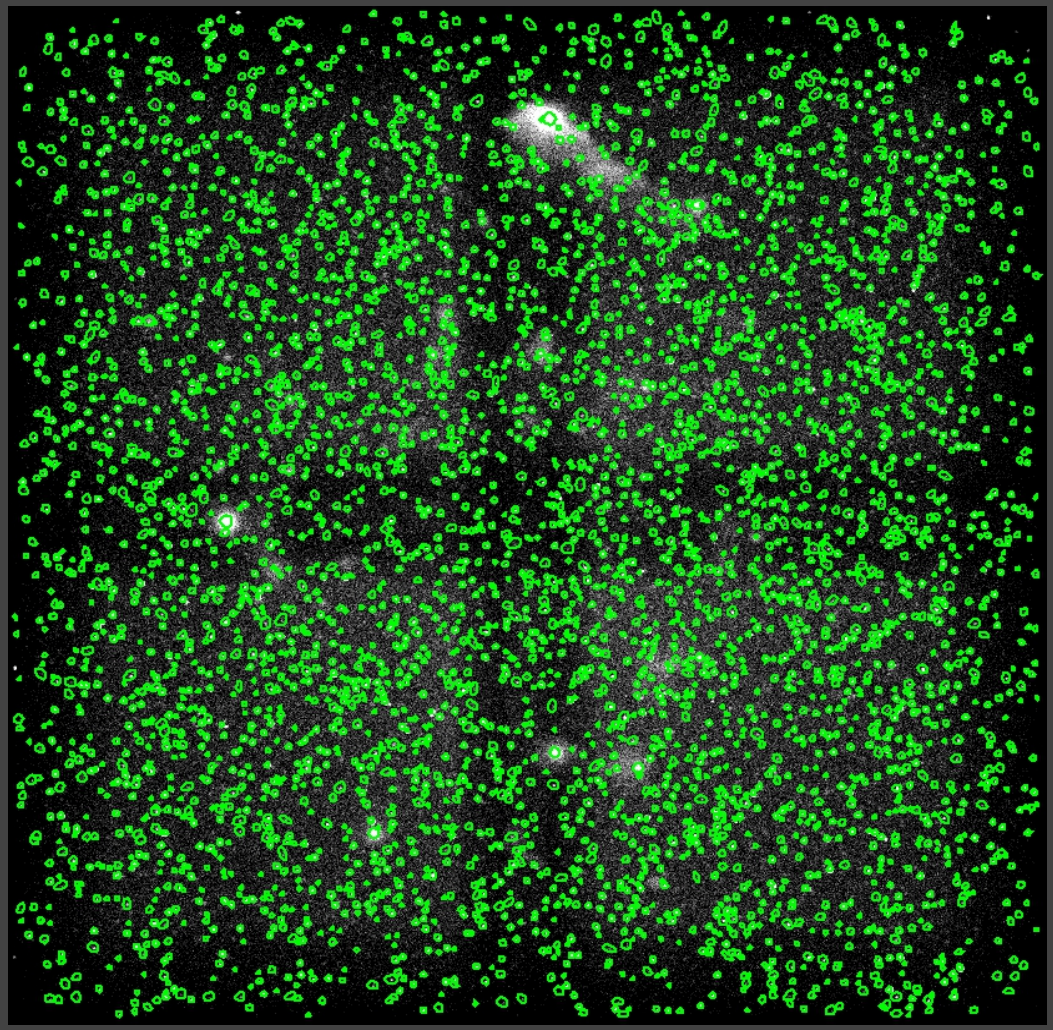
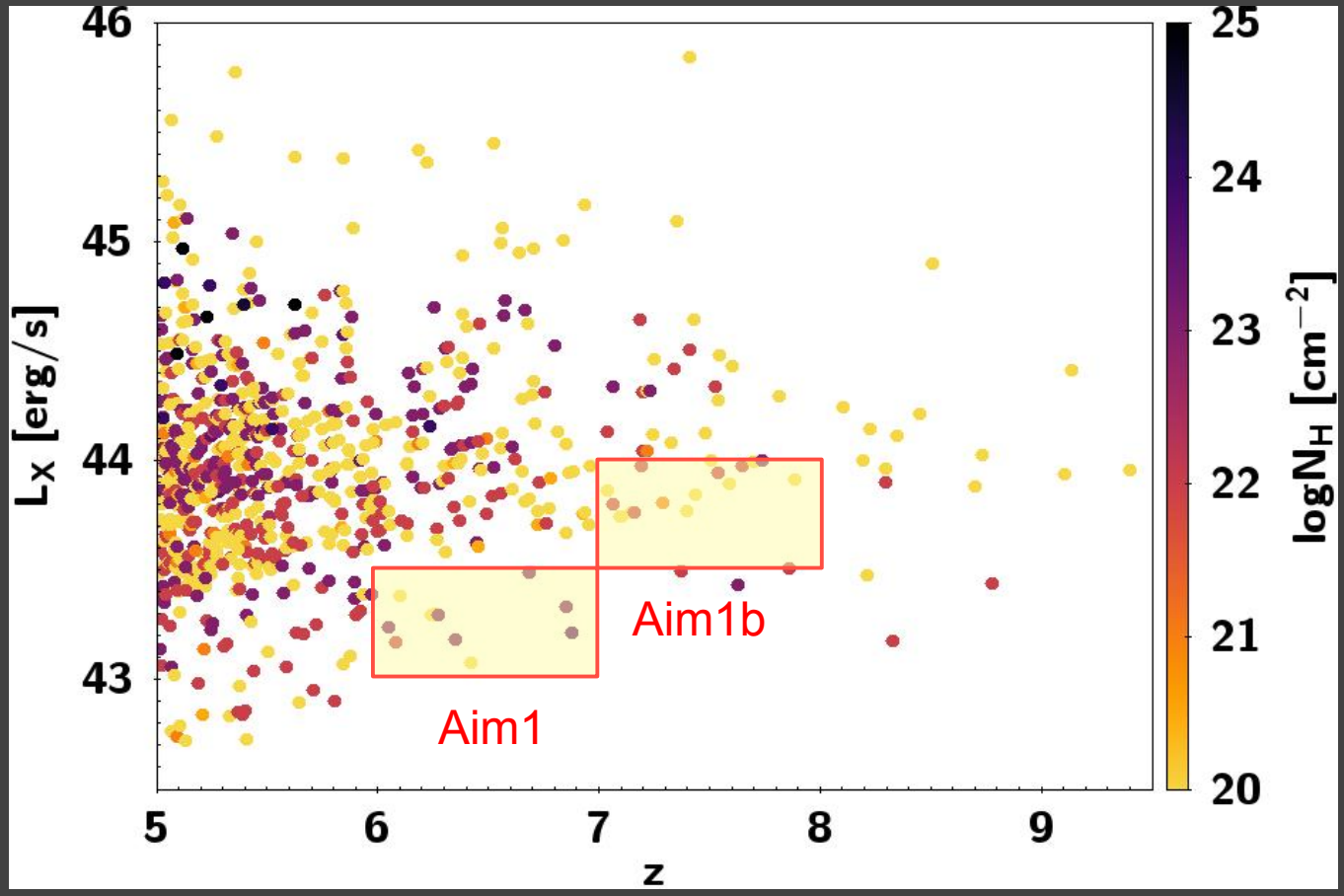


High z AGN

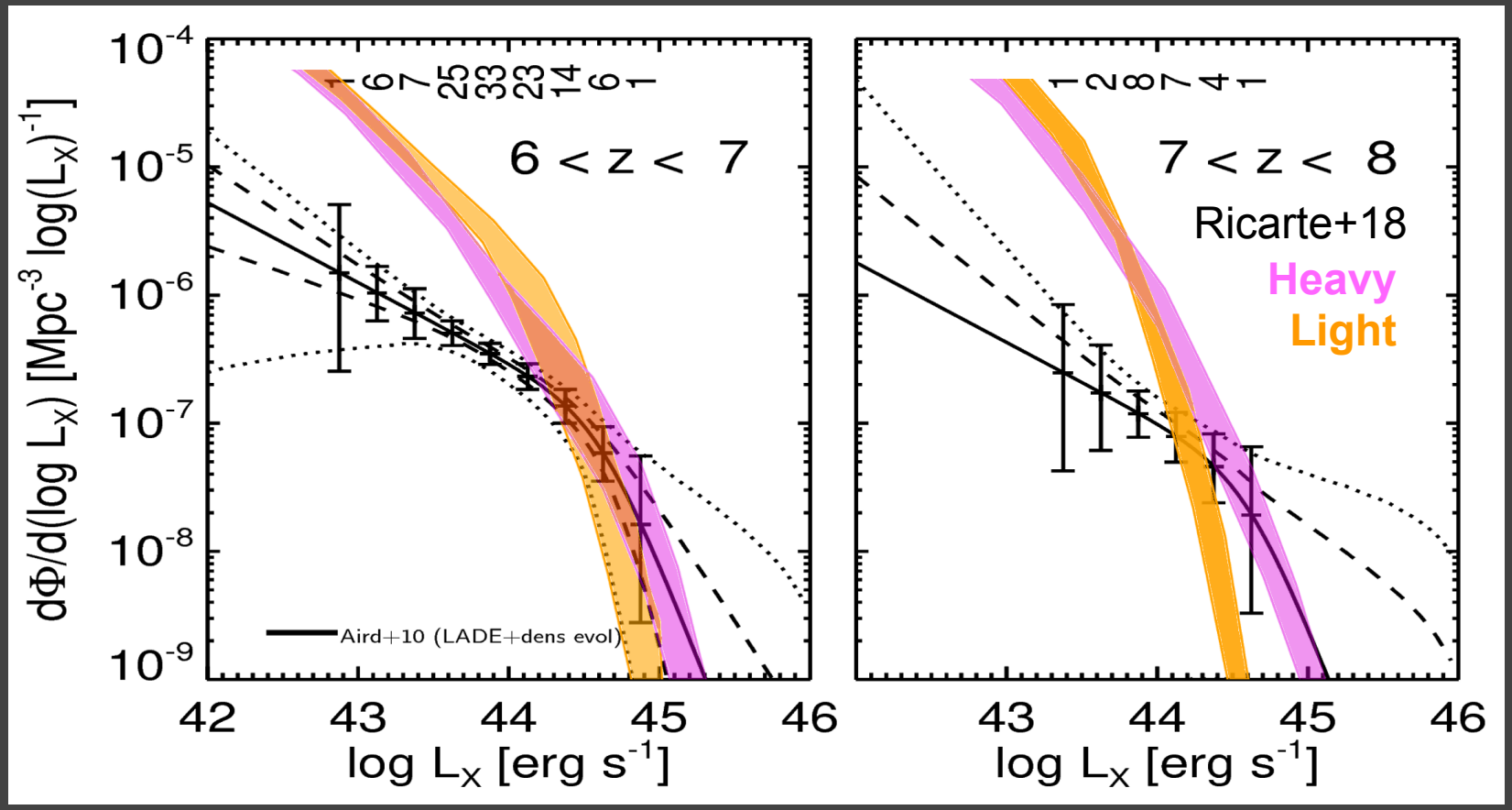
Over 2.4 deg^2 deep fields → ~10 AGN in the z=6-7 and L_X 43-43.5 bin

Over 27.4 deg^2 shallow fields → ~10 AGN in the z=7-8 and L_X 43.5-44 bin



high-z LF and BH seeds models

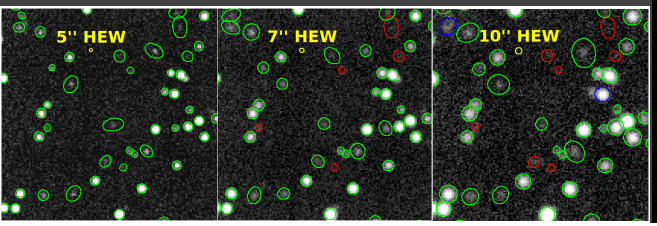
Realistic constraints on high z LF
huge impact on seed models! Unexplored L_X-z range

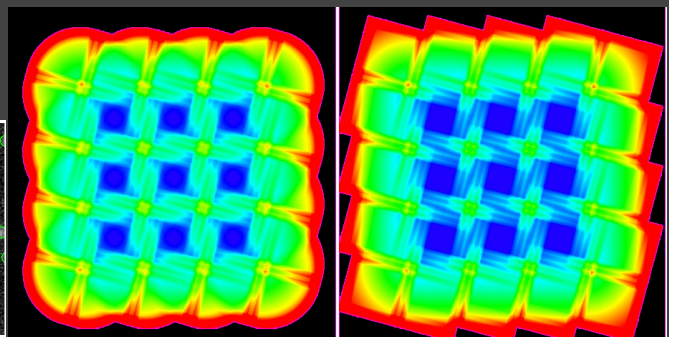


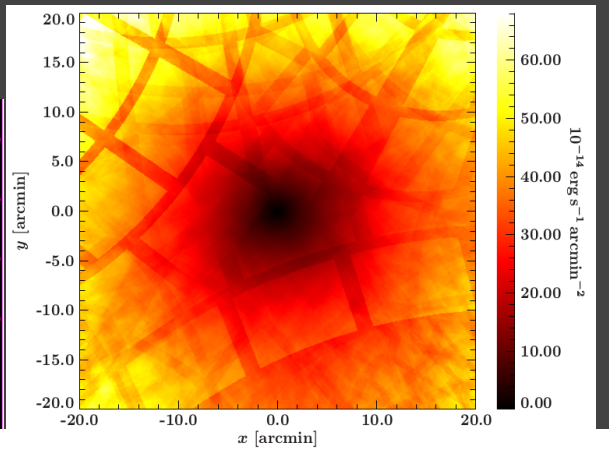
“Analytic” tools

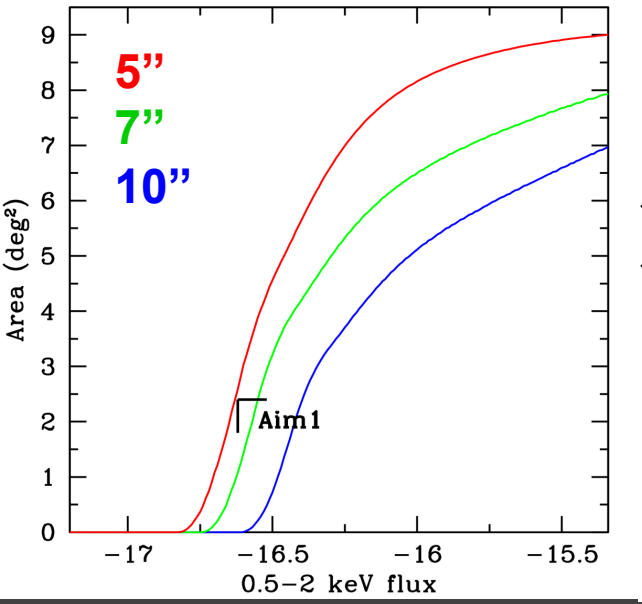
Exposure maps → bkg maps → sim. detection

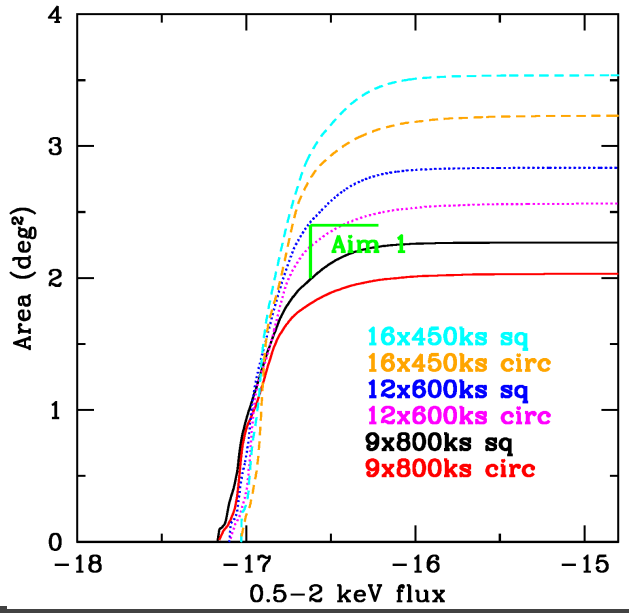
To test different specs/survey strategies

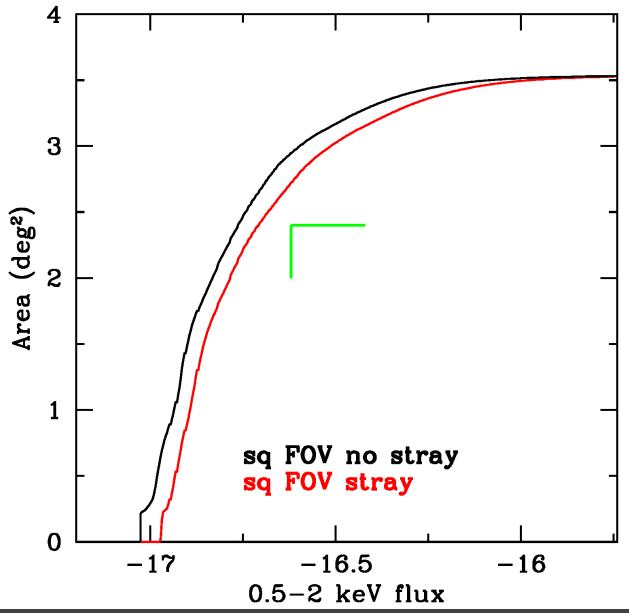










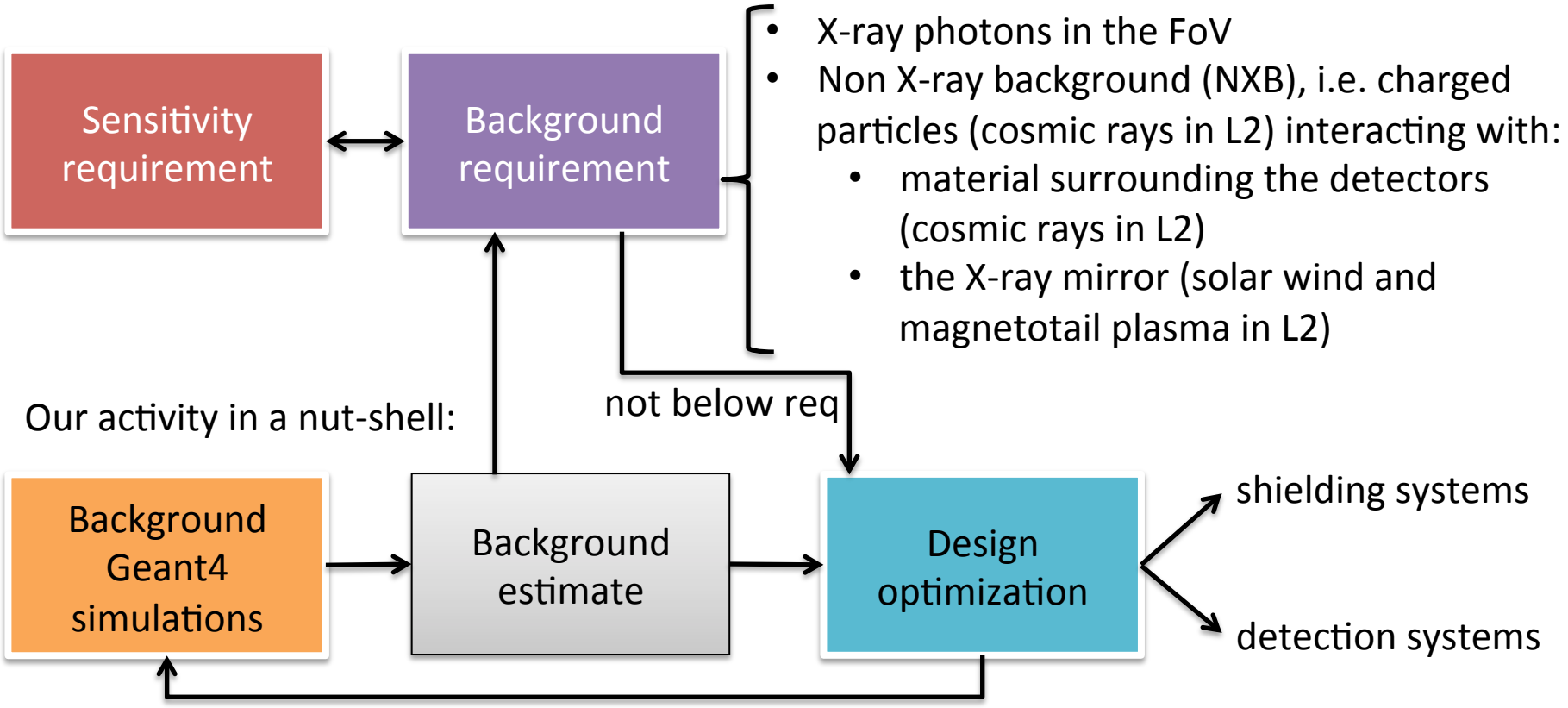


ATHENA Non X-ray Background: characterization and minimization

OAS contribution: V. Fioretti, A. Bulgarelli, M. Cappi, M. Dadina
in collaboration with: S. Lotti, C, Macculi, L. Piro (IAPS), S. Molendi, F. Gastaldello (IASF-Mi), T, Mineo, R. Amato (IASF-Pa)

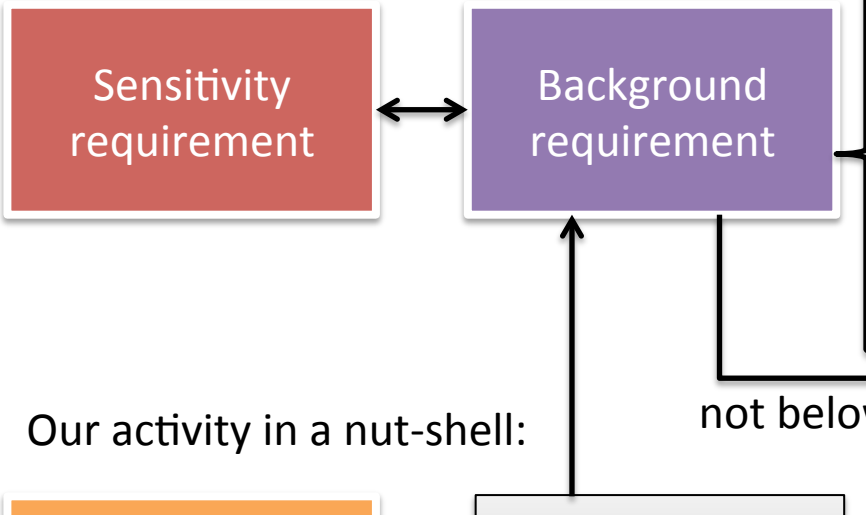
Many ATHENA observations will be pushed to the sensitivity limit:

- X-ray surveys of the high-z sky
- mapping the diffuse and faint thermal emission in clusters of galaxies
- mapping the dynamics and chemical composition of hot gas in diffuse sources



Many ATHENA observations will be pushed to the sensitivity limit:

- X-ray surveys of the high-z sky
- mapping the diffuse and faint thermal emission in clusters of galaxies
- mapping the dynamics and chemical composition of hot gas in diffuse sources



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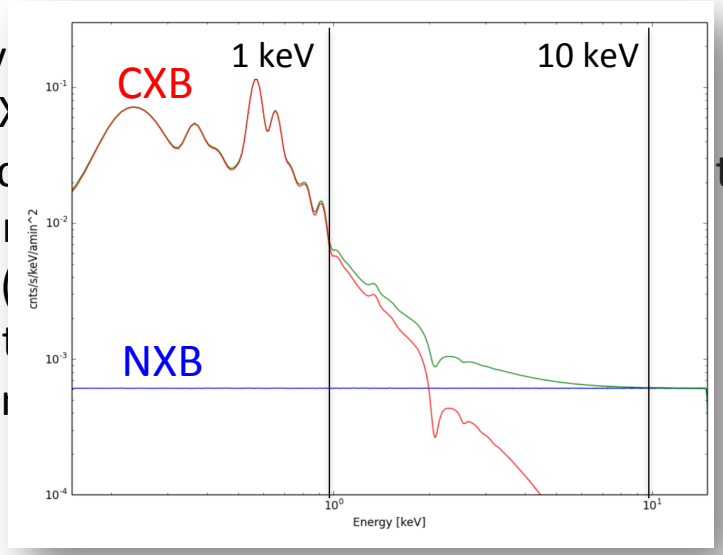

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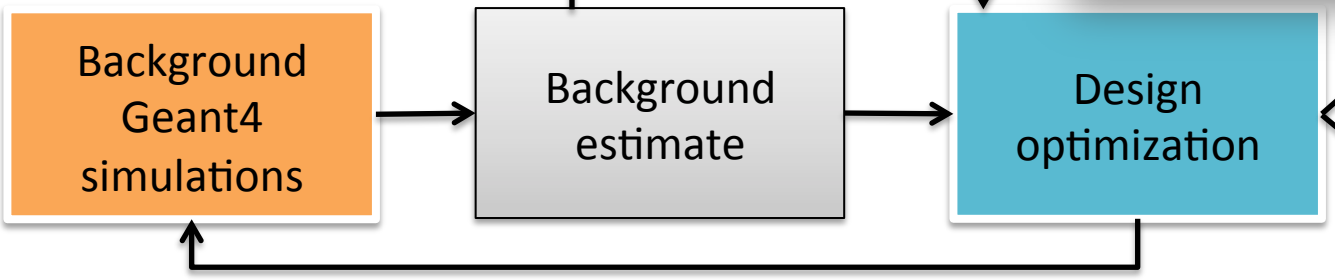
Our activity in a nut-shell:



shielding systems

detection systems

Geant4 is an open-source toolkit for the simulation of high energy particles with matter. Created by CERN for accelerators, it has been extended to lower (> tens of eVs) energies and it is now supported by a wide community. Geant4 is the tool of reference for the simulation of radiation effects in space by NASA, ESA and JAXA.

Geant4 simulations at OAS
(see also Campana's talk)

BoGEMMS*

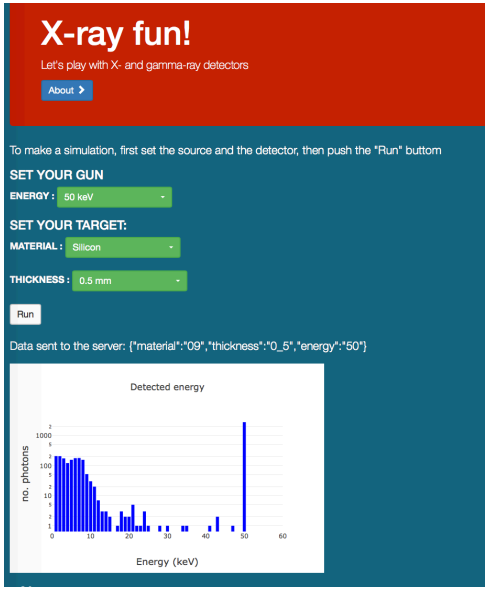
Bologna Geant4 Multi-Mission Simulator
(bulgarelli+2012, fioretti+2014)

An Astronomy-oriented Geant4-based framework for the simulation of missions/ experiments in the high energy domain. The ESA/AREMBES simulation framework used the BoGEMMS software as reference for the I/O formatting.
(V. Fioretti, A. Bulgarelli)

*Is it distributed to the community? We need funding!

"X-ray fun!" http://giove.iasfbo.inaf.it

A prototype web-application (an RdB funded project) for exploring the x-ray interaction with matter using BoGEMMS
(G. De Cesare, V. Fioretti, L. Nicastro, A. Zoli, M. Malaspina, F. Gianotti)



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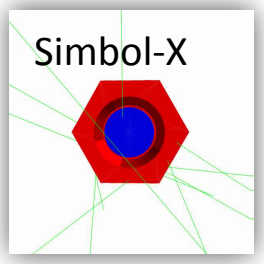
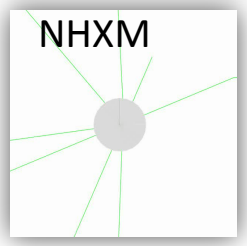
Geant4 simulations at OAS
(see also Campana's talk)

Old projects

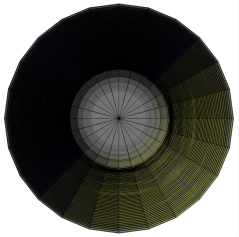
Simbol-X



NHXM

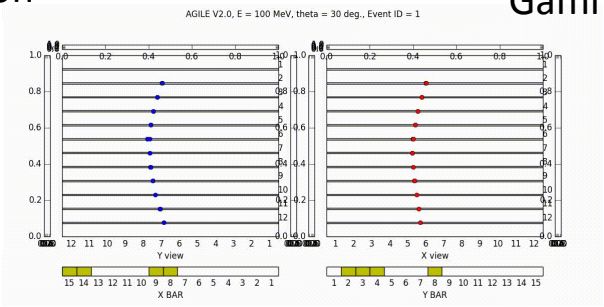


XMM-Newton



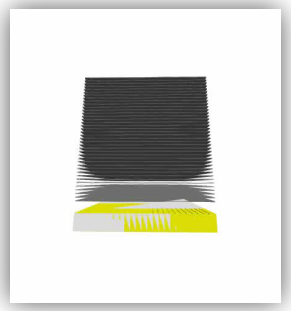
Soft proton scattering by XMM optics (fioretti+2016)

AGILE



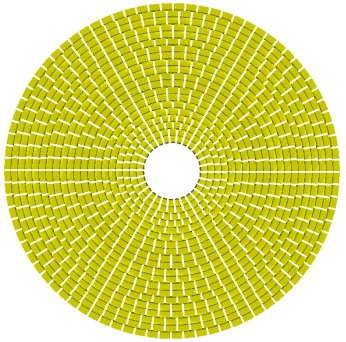
AGILESim: a BoGEMMS based AGILE/GRID simulator interfaced to the AGILE analysis pipeline. (fioretti+ in review). In coll. with M. Tavani (IAPS) and the AGILE team.

GammaLight/eASTROGAM



Simulation of the mission performance in the pair domain (G4 simulator + Kalman filter + analysis)
(V. Fioretti, A. Bulgarelli, A. Aboudan + eASTROGAM instrument team)

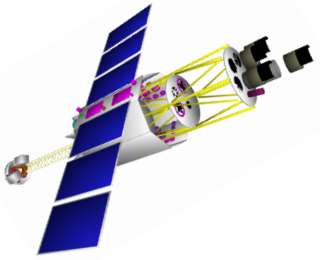
ATHENA and HITOMI (this talk)

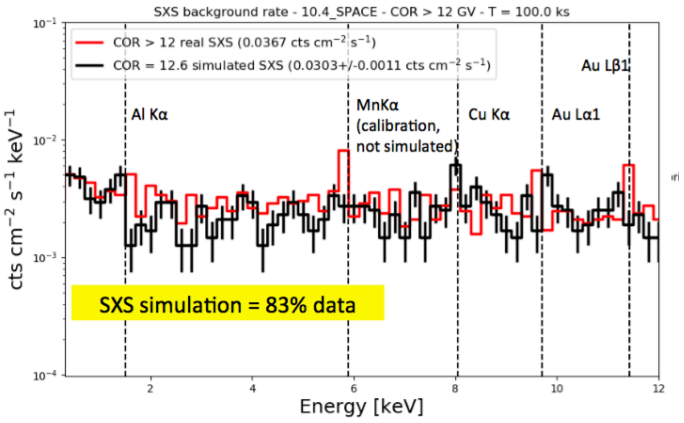


Validating the Geant4 simulation of the X-ray micro-calorimeters background: the case of ATHENA/X-IFU and HITOMI/SXS

OAS roles: members of X-IFU background group

1. [lead by OAS] definition of the algorithm for the simulation flux normalization in collaboration with ESA (fioretti+2018)
2. [lead by OAS] testing and verification of the Geant4 simulation secondary production (fioretti+2018)
3. [lead by IAPS] X-IFU NXB background simulation (lotti +2018, lotti+2016, macculi+2016)
4. [lead by OAS] HITOMI/SXS background simulation and **comparison with real data** (in collaboration with NASA/GSFC and JAXA)





Preliminary results presented at ATHENA science conference (poster) and Geant4 Space Users Workshop (Ozaki's talk)

All the results are included in the X-IFU I-PRR (instrument preliminary requirement review) submitted to CNES

ATHENA Soft protons induced background and a magnetic diverter for charged particles

OAS roles:

- AREMBES WP 3.3, 7, 7.2 (leader)
- EXACRAD WP 6.1 (leader)
- WFI background group (member)

Context:

Low energy protons (< 300 keV) are scattered by X-ray mirror towards the focal plane increasing the background. The shielding solution is a magnetic diverter in front of the focal plane.

Current results:

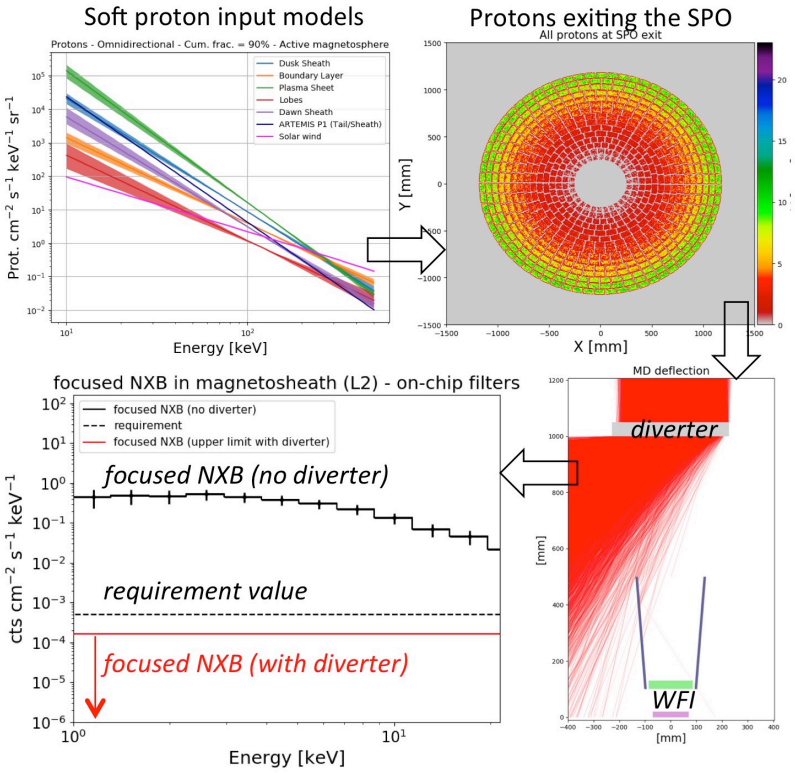
- validation of the physics process behind the proton scattering (fioretti+2017)
- Geant4 mass model of the full ATHENA Silicon Pore optics
- Simulation of the WFI soft proton induced background with and without a magnetic diverter (fioretti+2018)

On-going activity:

- under ESA AREMBES-SIMPOSIUM synergy, evaluation of the shielding efficiency of the current diverter prototype

Proposals

- a proton response matrix for XMM-Newton and ATHENA (letter of intent to the AHEAD-2 call)



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