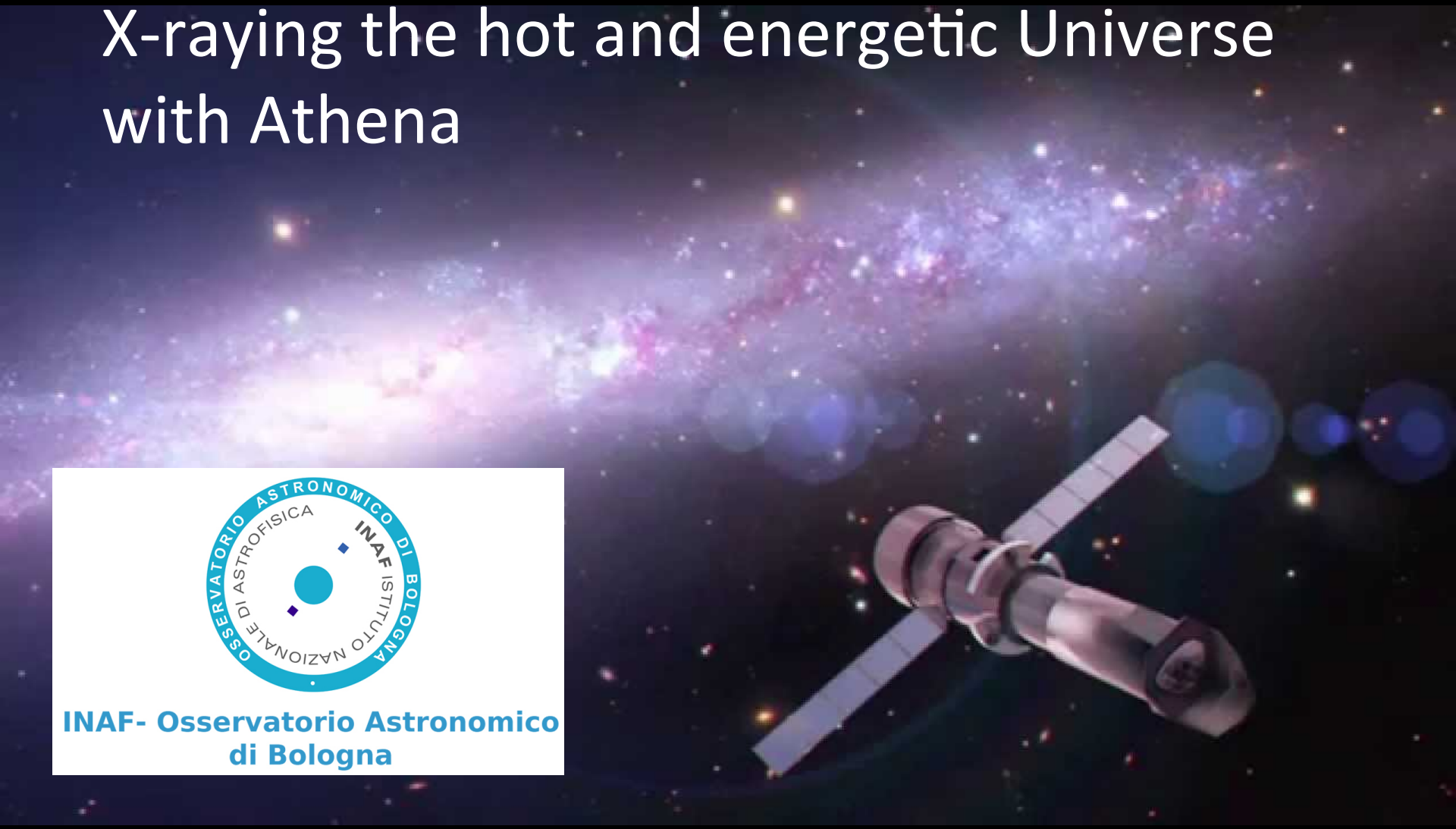
X-raying the hot and energetic Universe with Athena

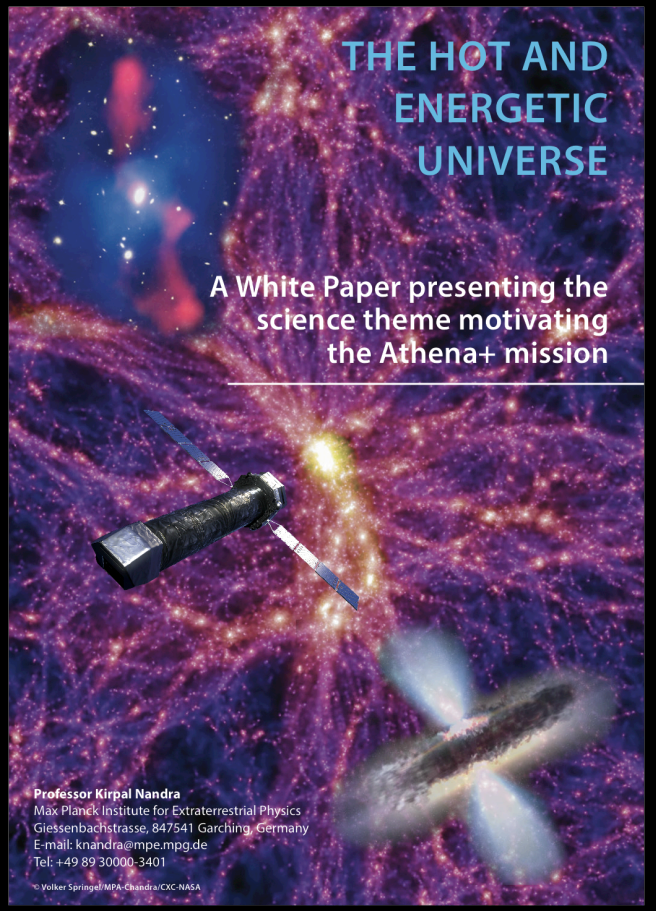


INAF- Osservatorio Astronomico di Bologna

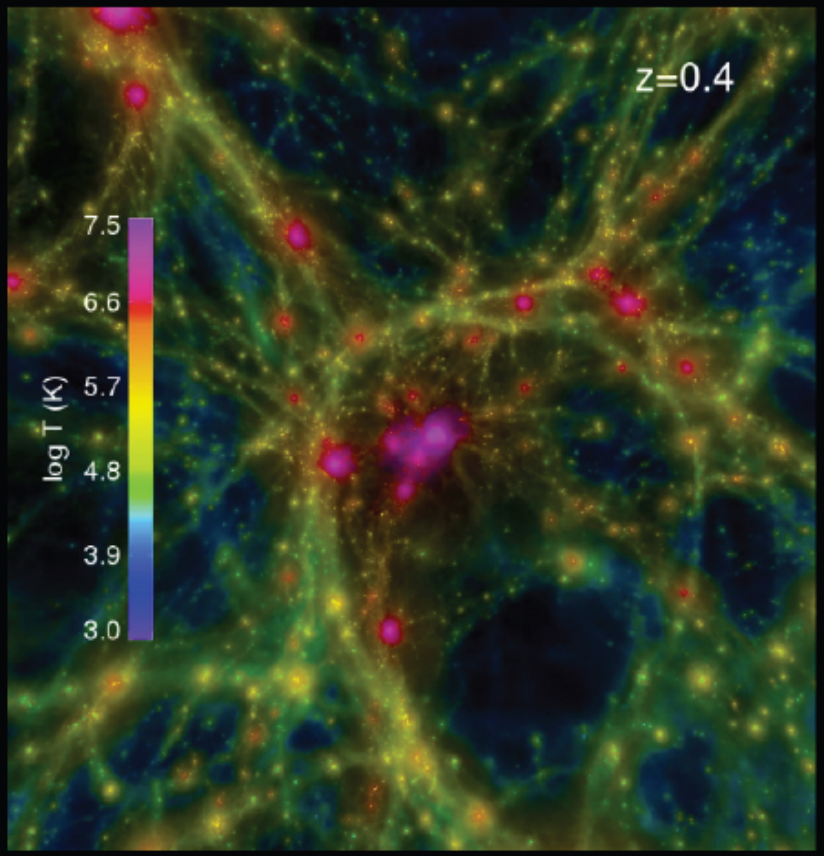
Andrea Comastri INAF-Osservatorio Astronomico di Bologna
on behalf of ATHENA WGs and Italian SSC

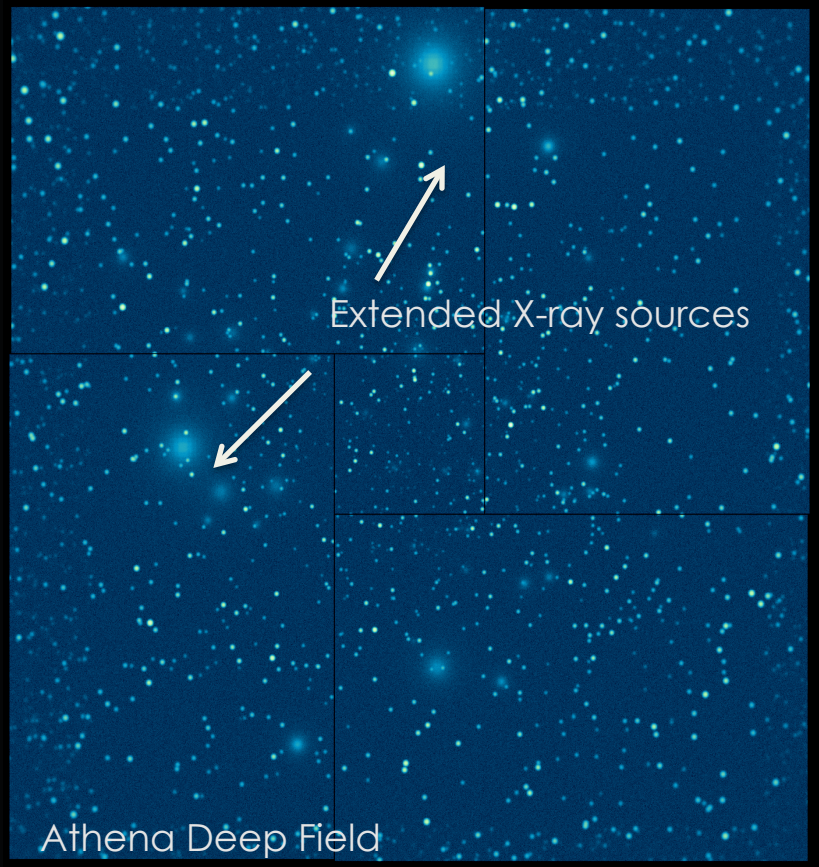
The Hot and Energetic Universe

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



How does ordinary matter assemble into the large scale structures we see today?





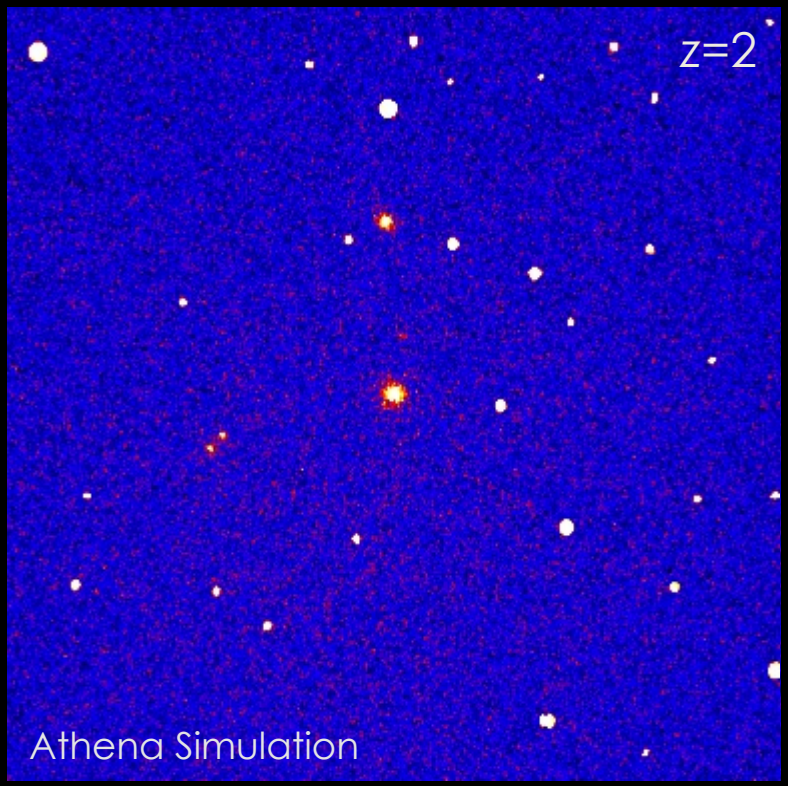
Oppenheimer et al. 2009

Pointecouteau, Reiprich et al., 2013 arXiv1306.2319

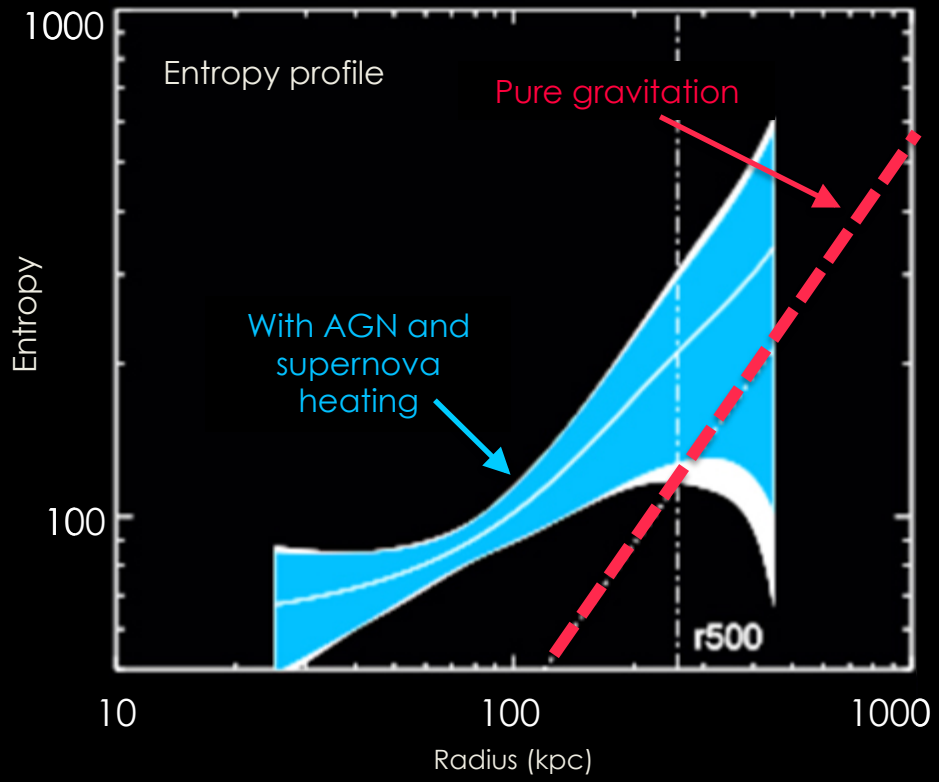
ATHENA

The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot intra-cluster medium generated?



Pointecouteau, Reiprich et al., 2013 arXiv1306.2319



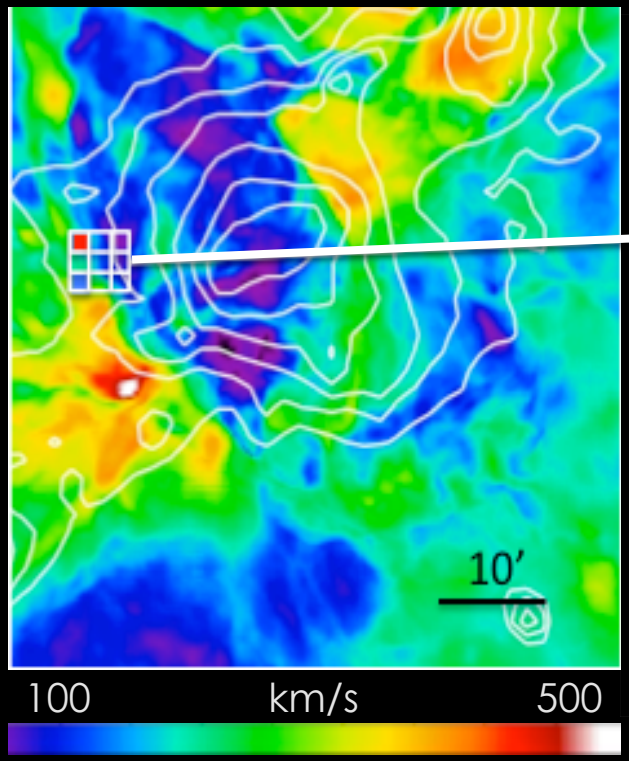
How does ordinary matter assemble into the large-scale structures that we see today?

ATHENA

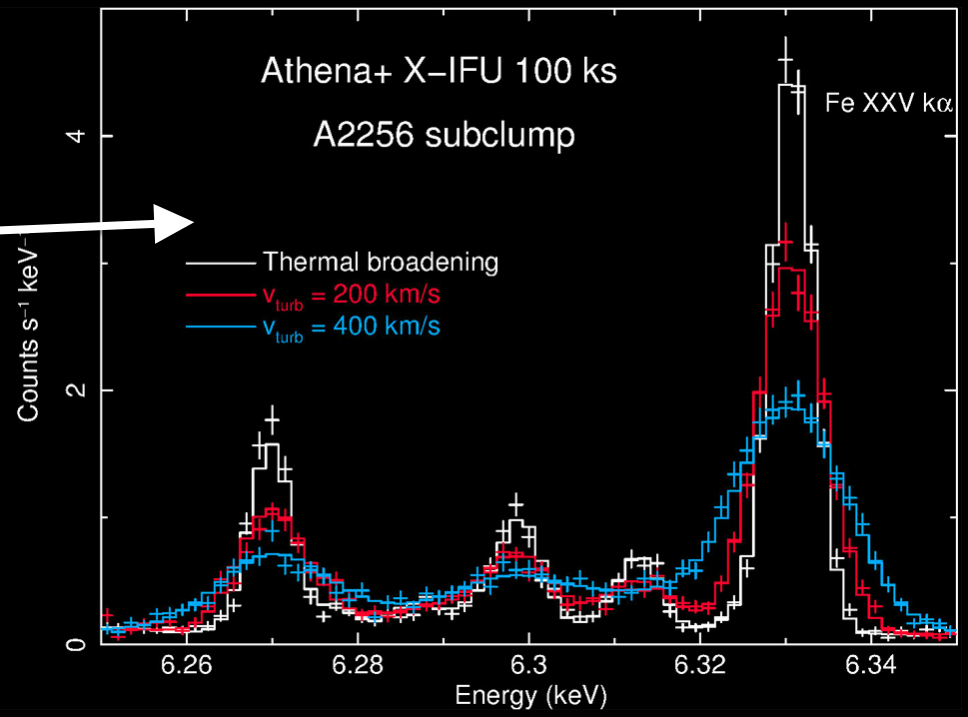
The formation and evolution of clusters and groups of galaxies

How and when was the energy contained in the hot intra-cluster medium generated?

Simulated Velocity map



Ettori, Pratt, et al., 2013 arXiv1306.2322

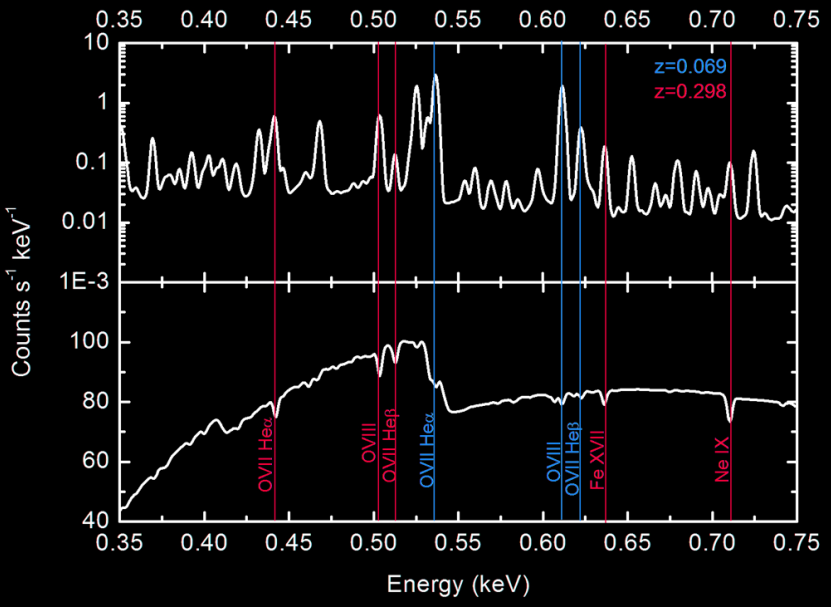


How does ordinary matter assemble into the large-scale structures that we see today?

ATHENA

The Warm-Hot intergalactic medium (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?



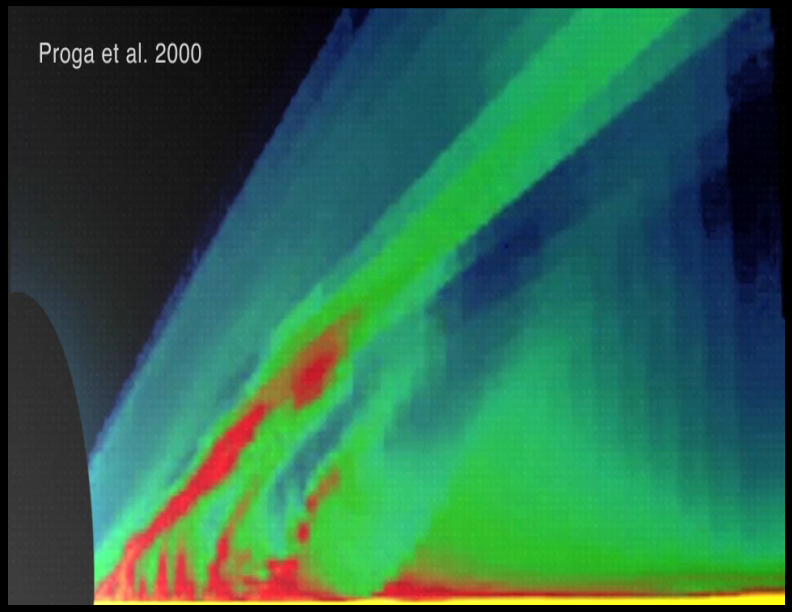
Kaastra, Finoguenov et al., 2013 arXiv1306.2324

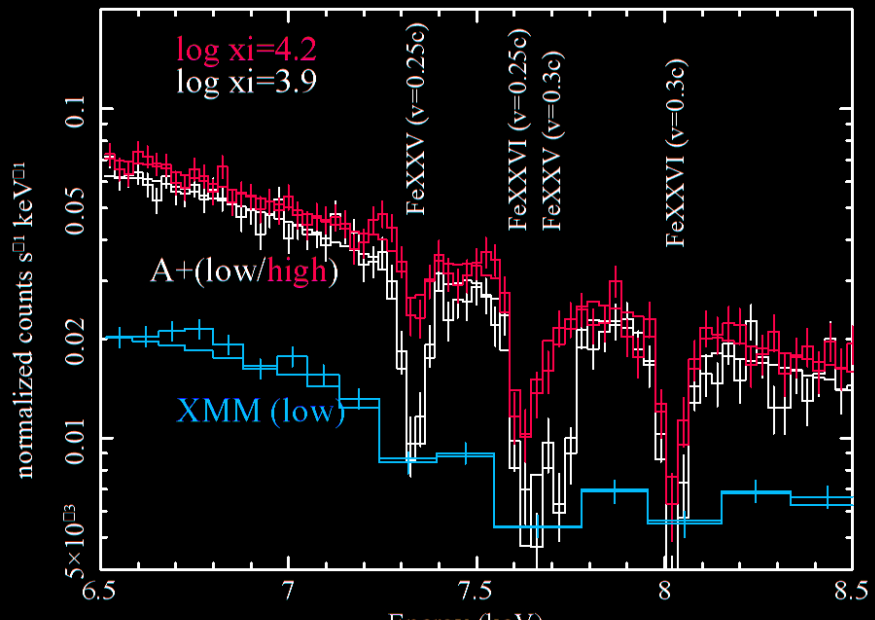
How does ordinary matter assemble into the large-scale structures that we see today?

How do black holes grow and shape the Universe?

Cosmic feedback: the origin of black hole winds

How do black holes launch winds and outflows?
How much energy do they carry out to larger scales?

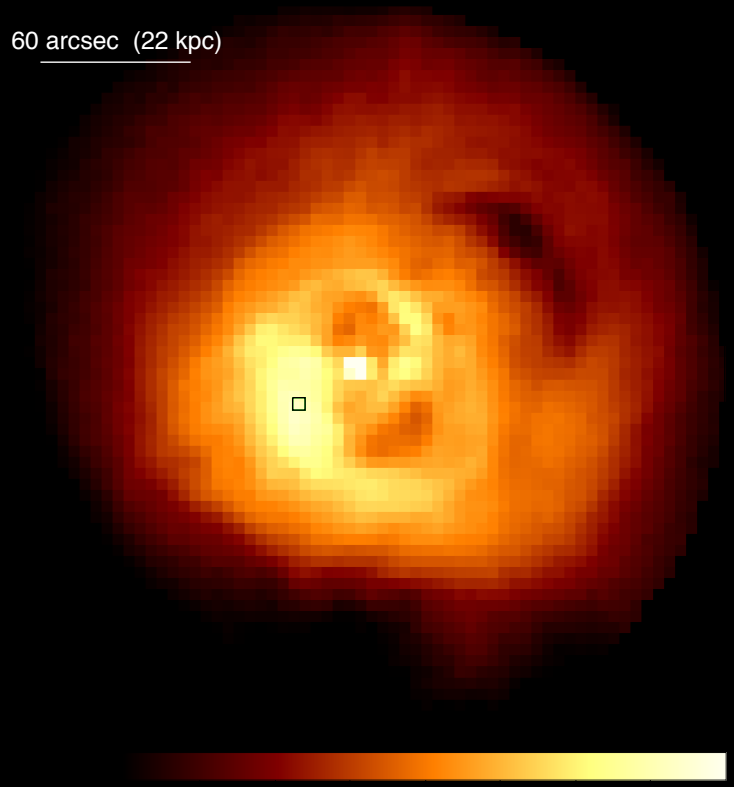


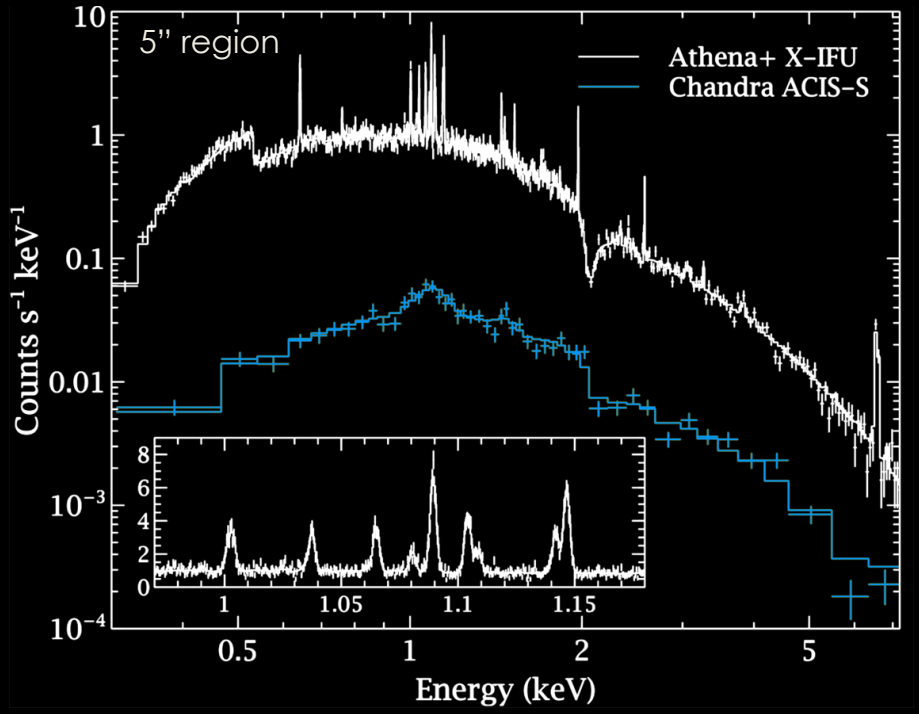


Cappi, Done et al., 2013 arXiv1306.2330
Dovciak, Matt et al., 2013 arXiv1306.2331

Cosmic feedback: the impact on galaxy cluster scales

How do jets from Active Galactic Nuclei dissipate their mechanical energy in the hot intracluster medium, and how does this regulate gas cooling and black hole fuelling?





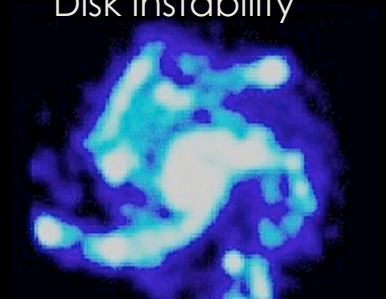
Croston, Sanders et al., 2013 arXiv1306.2323

ATHENA

Cosmic feedback: black hole and galaxy co-evolution

How much black hole accretion occurs in the most obscured environments?
How does this relate to the evolution of the host galaxy?

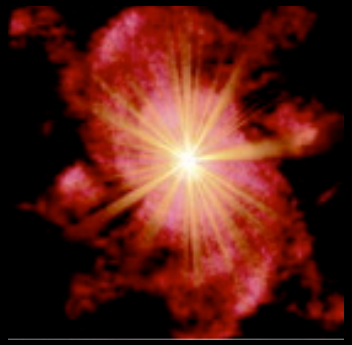
Disk instability



Ceverino et al. 2010

Obscured BH growth

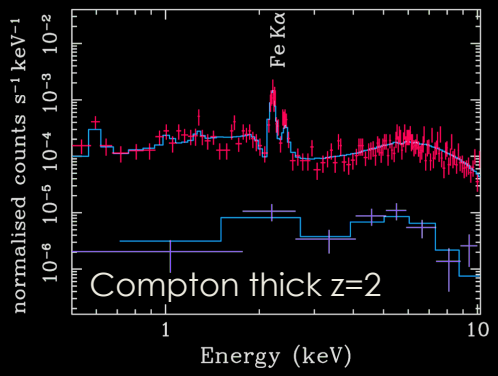
Feedback phase

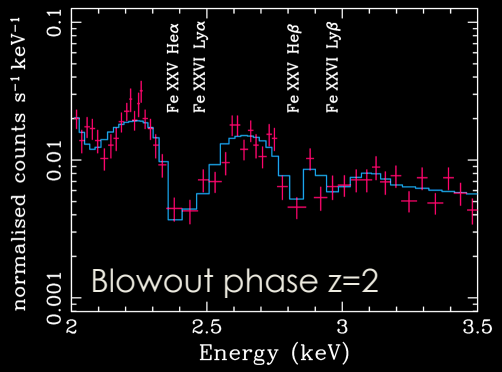


Quiescent remnant

Merger

Hopkins et al.2006





Georgakakis, Carrera et al., 2013 arXiv1306.2328

How do black holes grow and shape the Universe?

Accretion time needed by a BH to reach a given final mass:

$$M(t) = M_0 \, \mathrm{e}^{f_{\mathrm{Edd}} \frac{t}{\tau} \frac{1-\epsilon}{\epsilon}}$$

$$t_{\mathrm{acc}} = 0.45 \ \mathrm{Gyr} \ \frac{\epsilon}{1-\epsilon} \ f_{\mathrm{Edd}}^{-1} \ \ln(M_{\mathrm{fin}}/M_{\mathrm{in}})$$

$M_{final}=10^9$ M⊙

$M_{initial}=10$ M⊙ (10^5 M⊙)

$f_{EDD}=1$

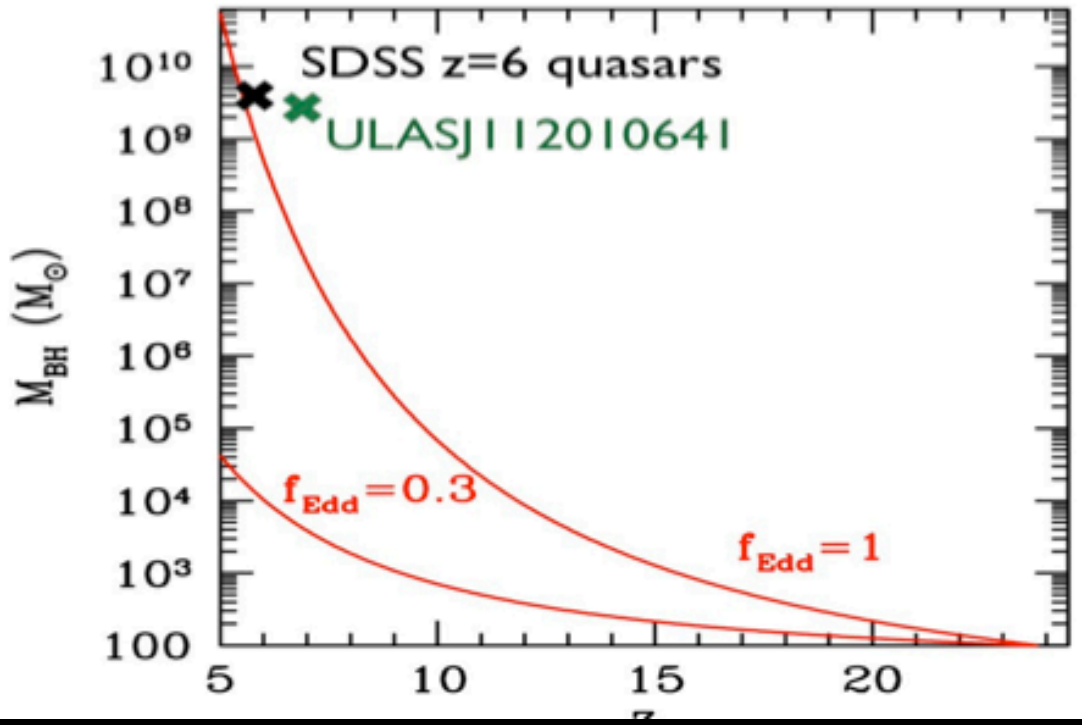
ε=0.1

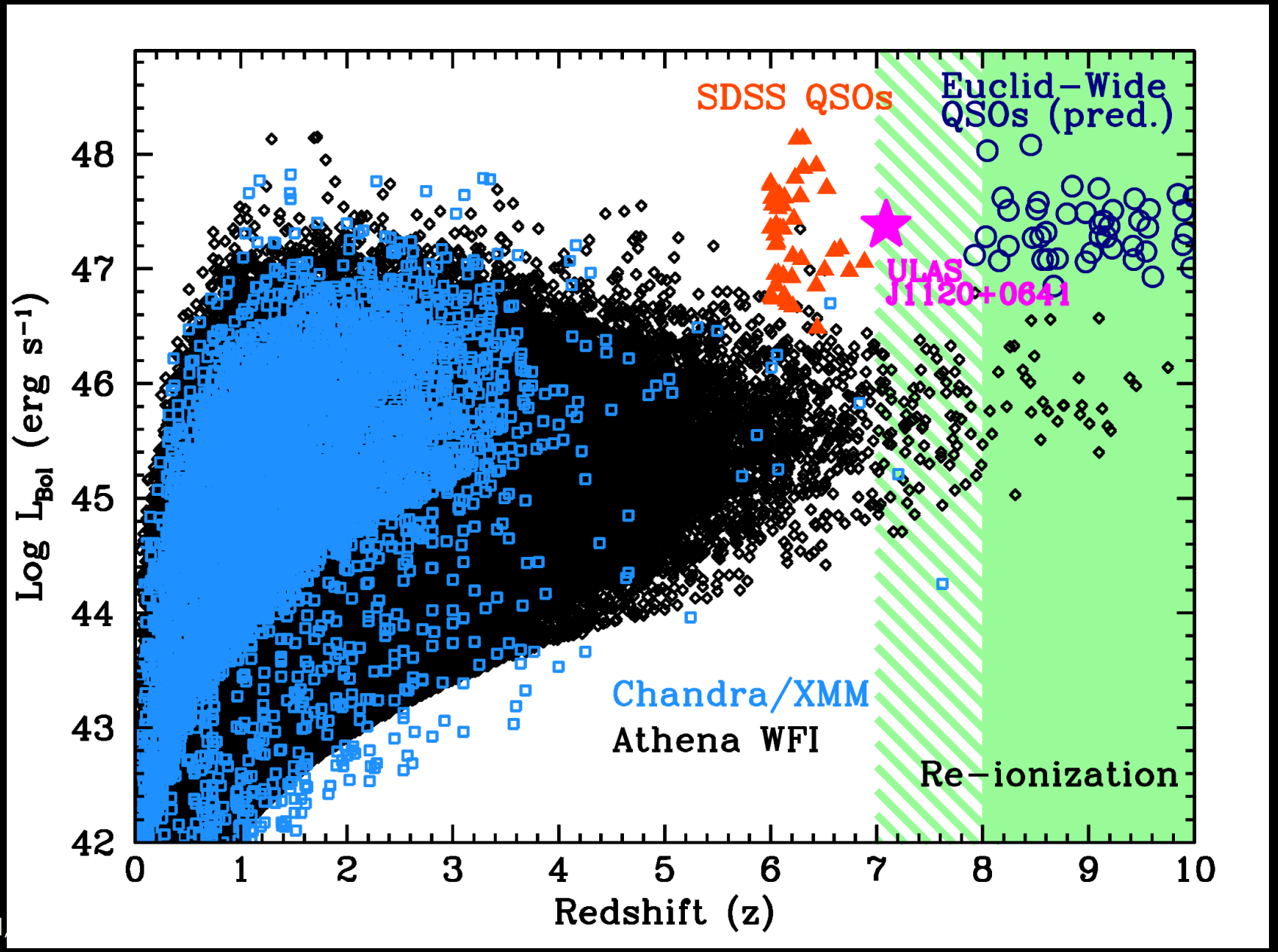
➪ $t_{acc}=0.4$ Gyrs (0.2 Gyrs)

If $f_{EDD}=0.3$ – 1.2-0.6 Gyrs

$t_H(z=7)=0.75$ Gyrs

$t_H(z=6)=0.9$ Gyrs



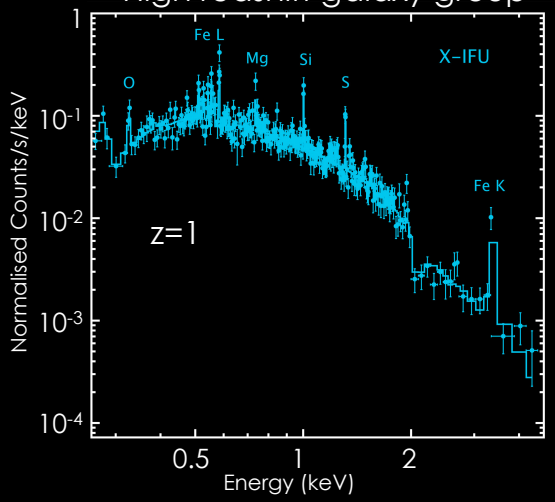

SDSS QSOs
Euclid–Wide
QSOs (pred.)
ULAS
J1120+0641
Chandra/XMM
Athena WFI
Re–ionization
Log L_{Bol} (erg s^{-1})
Redshift (z)
42
43
44
45
46
47
48
0
1
2
3
4
5
6
7
8
9
10

Aird,

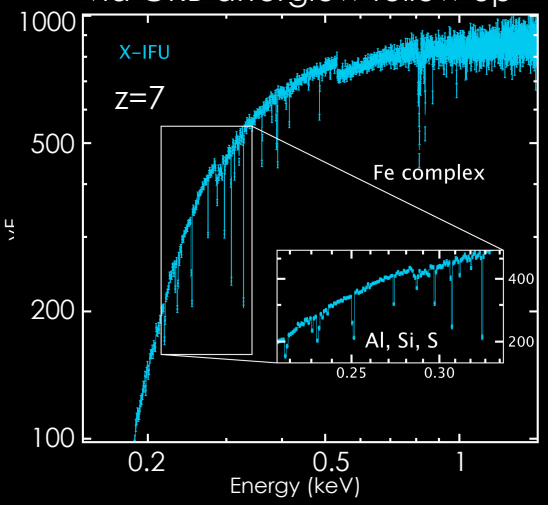
ATHENA

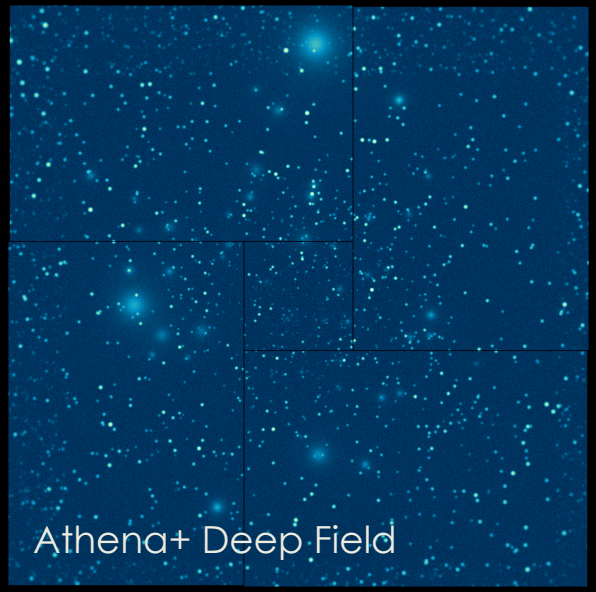
Athena:
Exploring the Hot and Energetic Universe

High redshift galaxy group

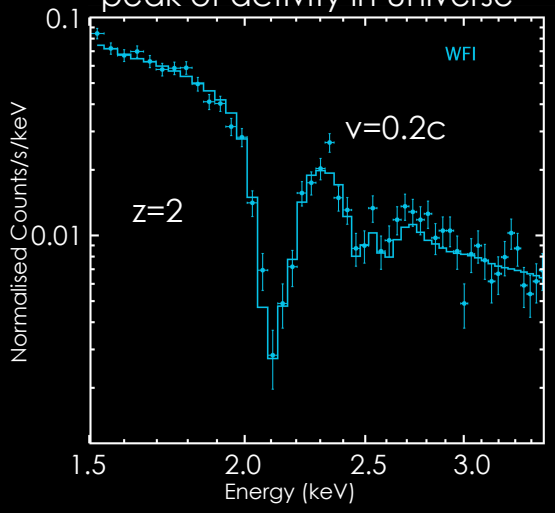


Primordial stellar populations via GRB afterglow follow up



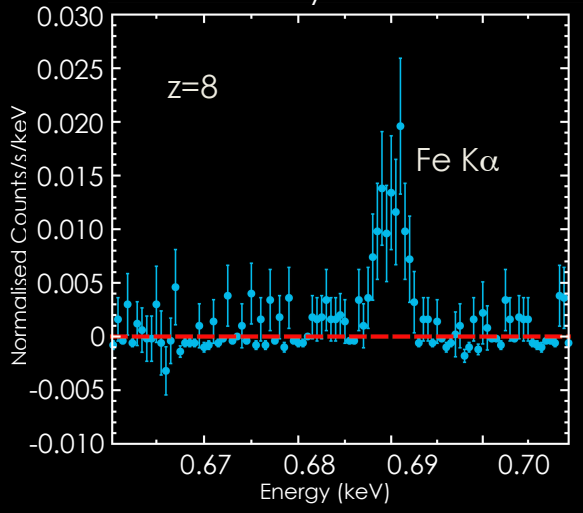


Black hole feedback at peak of activity in Universe



Nandra, Barret, Barcons, Fabian, den Herder, Piro, Watson et al. 2013 arXiv 1306.2307

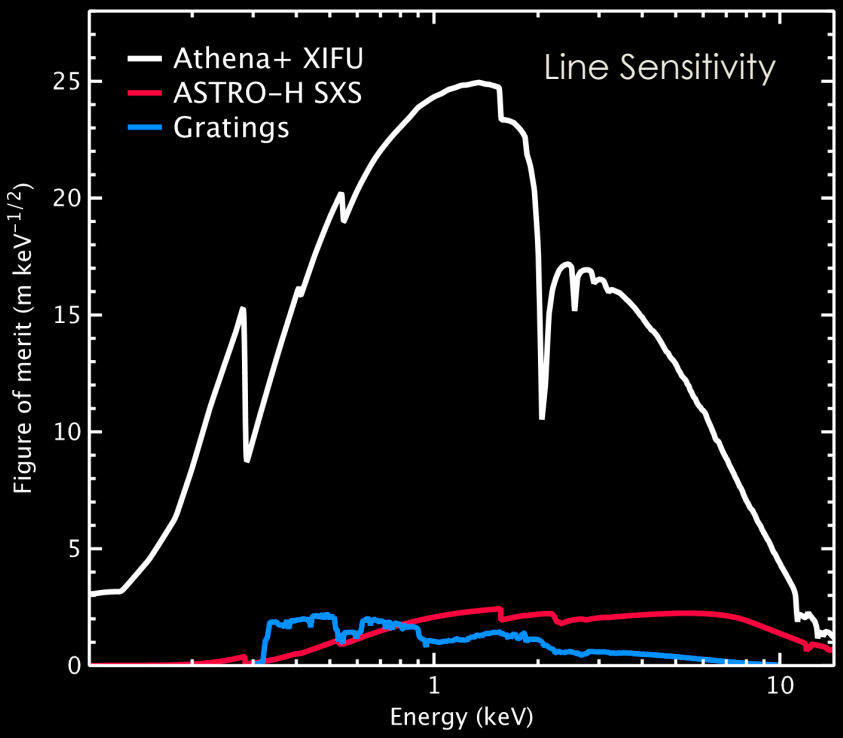
Obscured black hole in the early Universe



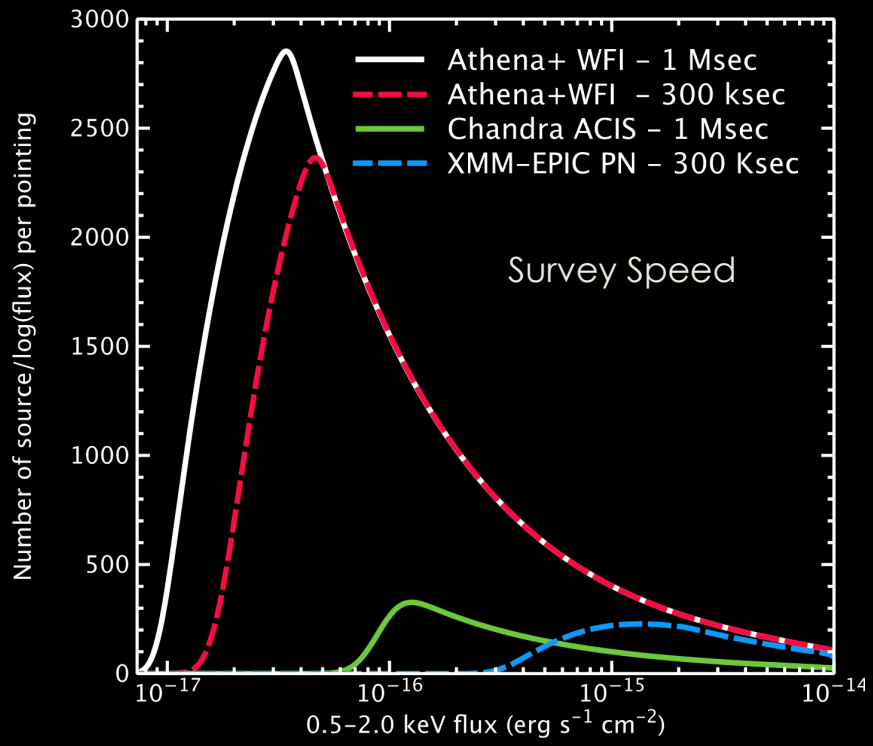
ATHENA

A Deep Universe X-ray Observatory

Athena+ has vastly improved capabilities compared to current or planned facilities, and will provide **transformational** science on virtually all areas of astrophysics

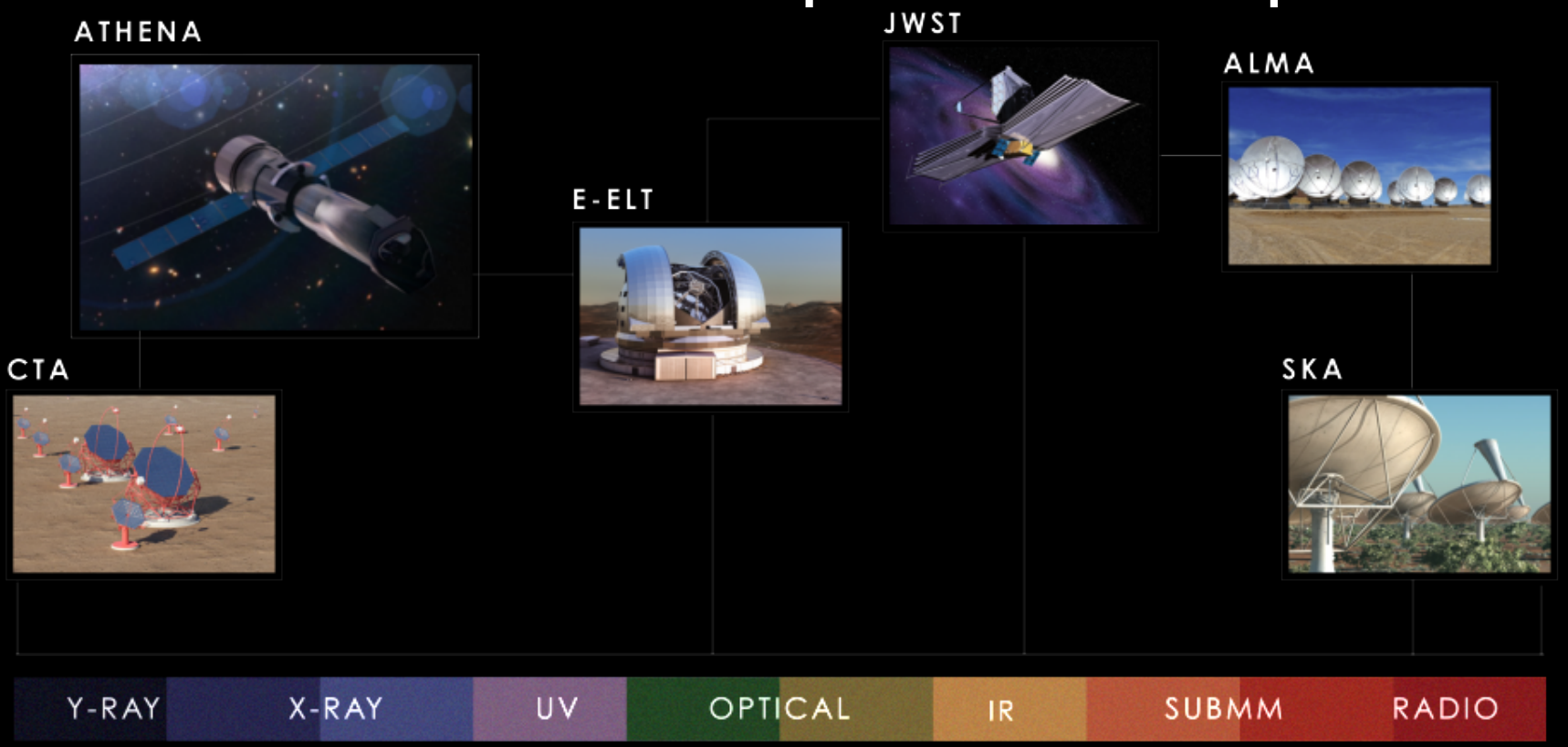


X-ray spectroscopy at the peak of the activity of the Universe



Deep survey capability into the dark ages and epoch of reionization

Athena in context in the ~2030 European landscape



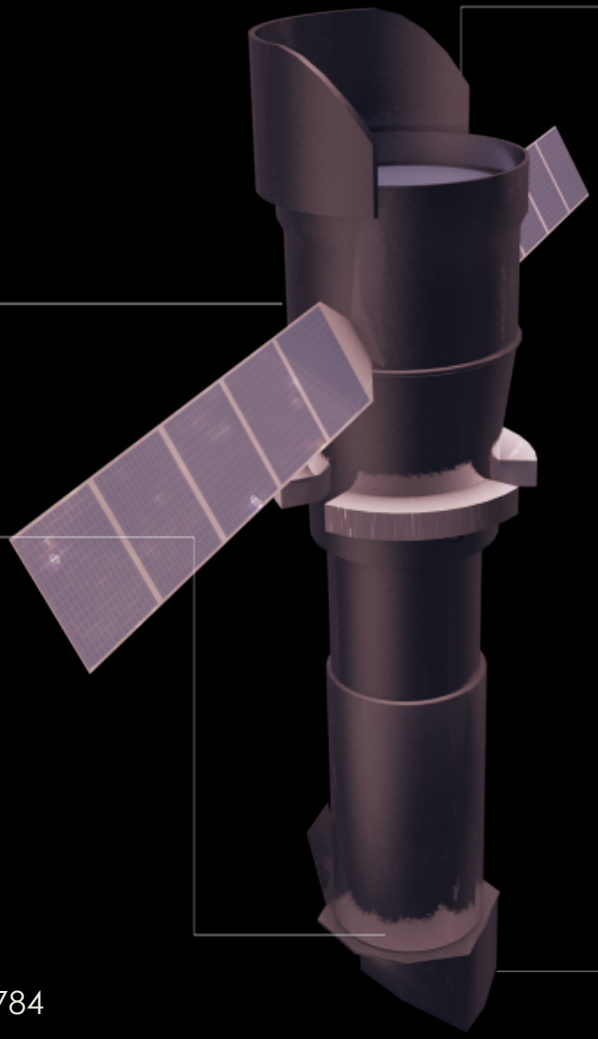
Athena is a crucial part of the suite of large observatories needed to reach the science objectives of astronomy in the coming decades

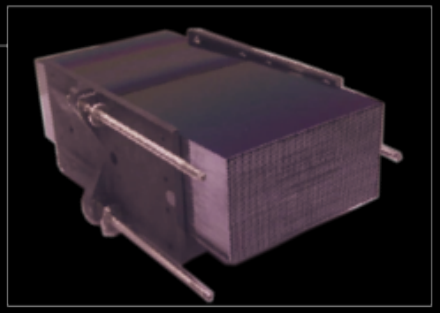
ATHENA

The Athena Observatory

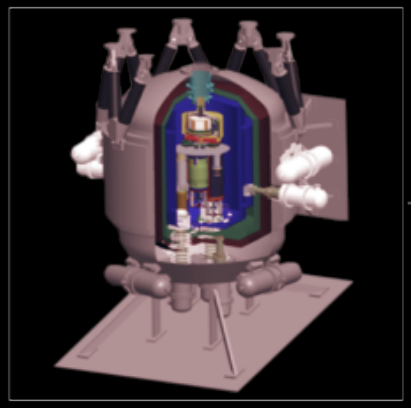
Willingale et al, 2013
arXiv1308.6785

L2 orbit Ariane V
Mass < 5100 kg
Power 2500 W
5 year mission

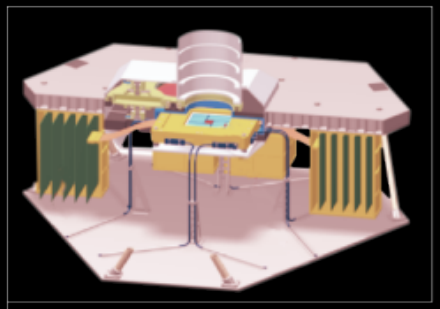




Silicon Pore Optics:
2 m^2 at 1 keV
5 arcsec HEW
Focal length: 12 m
Sensitivity: 3 10^{-17} erg cm^{-2} s^{-1}



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



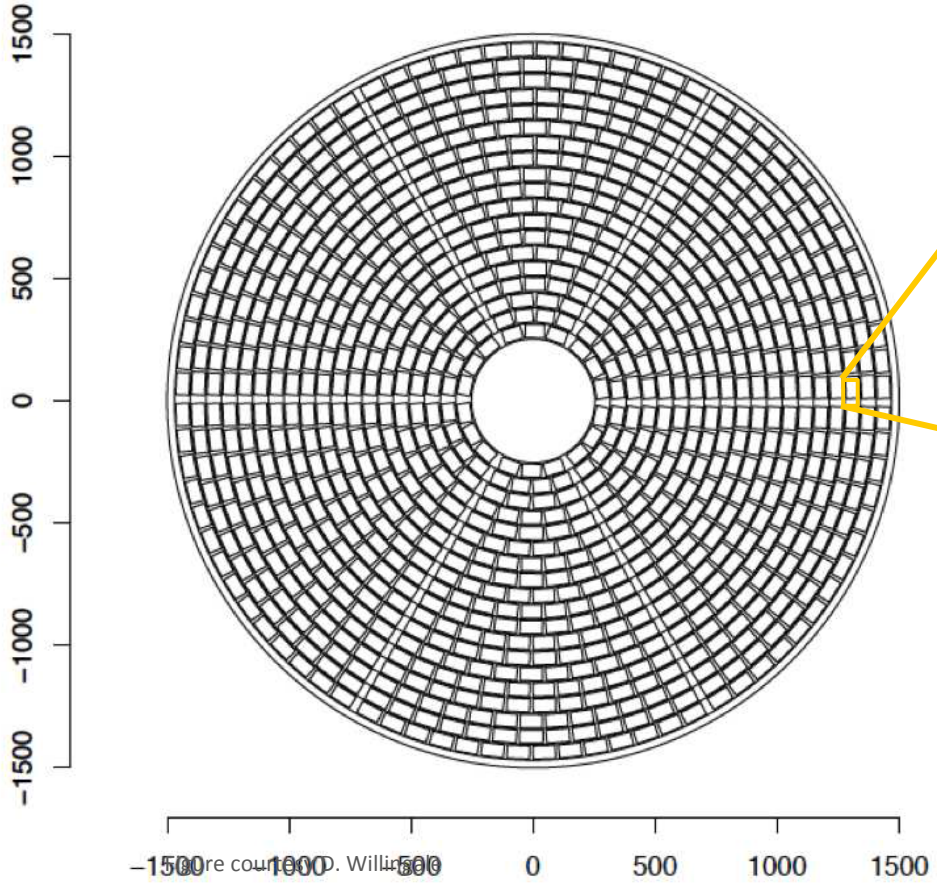
Wide Field Imager:
ΔE: 125 eV
Field of View: 40 arcmin
High countrate capability

Barret et al., 2013 arXiv:1308.6784

Rau et al. 2013 arXiv1307.1709

Optics

- ESA responsibility



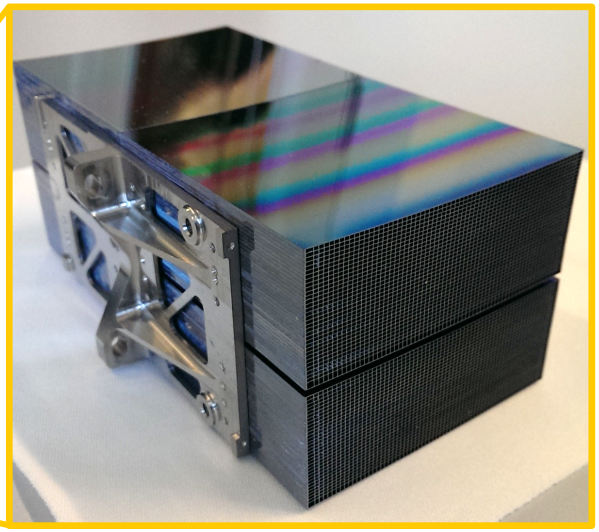


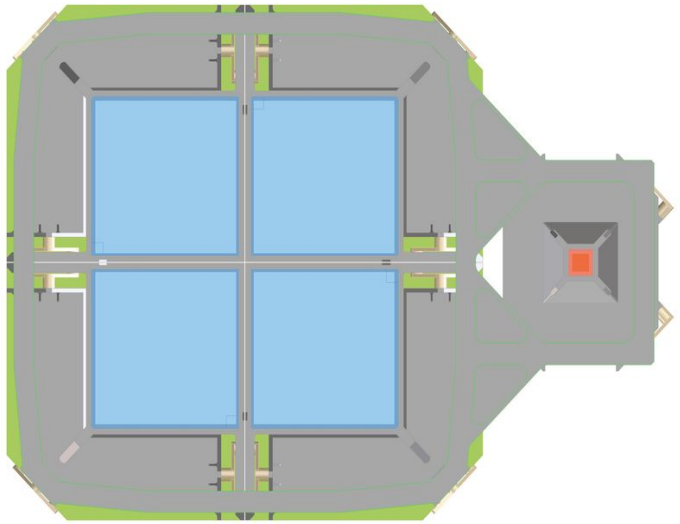
Figure courtesy D. Willingale

ATHENA+

Wide Field Imager

WFI consortium lead: Germany

FoV = 40 arcmin ↔ Size = 140 mm



4 large DEPFET sensor chips

512 x 512 pixels with 130 µm x 130 µm

sensitive area → 67 x 67 mm^2

Time resolution: **1.28 ms**

1 fast timing DEPFET sensor

64 x 64 pixels with 130 µm x 130 µm

sensitive area → 8.3 x 8.3 mm^2

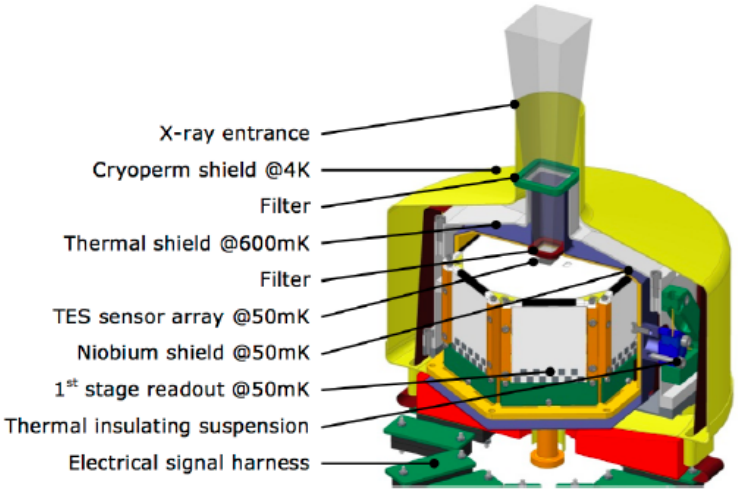
Time resolution: **160 µs** (or **80 µs** with 2-line readout option)

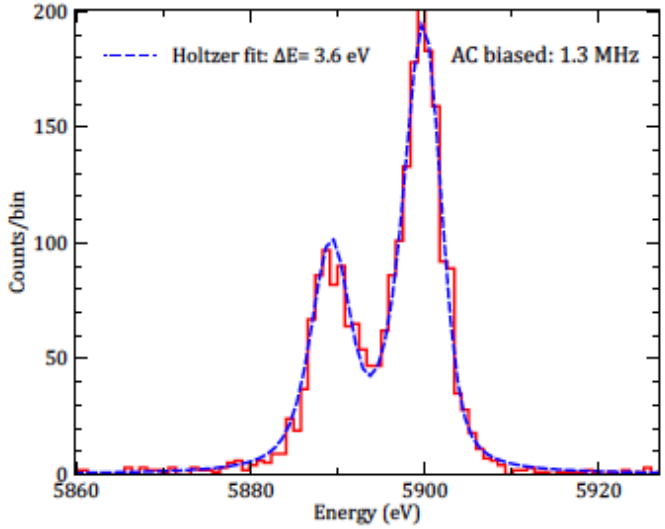
Window mode: 8+8 lines (36 arcsec ≈ 7 x PSF): **20 µs** (or **10 µs** with 2-line readout option)

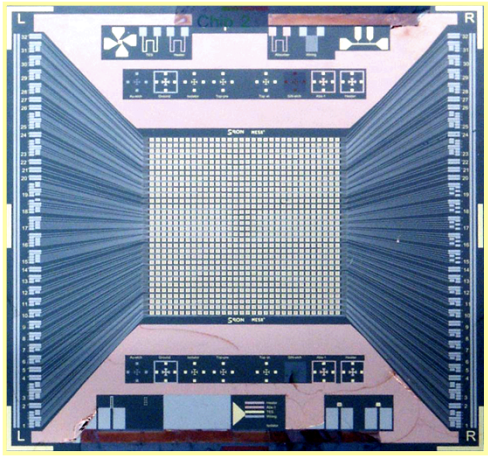
ATHENA+

X-Ray Integral Field Unit

- ✓ XIFU consortium lead: France (PI), Italy & Holland (CoPI)
- ✓ Transition Edge Sensor microcalorimeter in cryo (50 mK)
- ✓ 4-kpixel array
- ✓ Large TES-based CryoAC for
- ✓ Low instrumental background







A T H E N A

Programmatics

- ESA led missions, but international collaboration allowed (<20%)
- NASA and JAXA are partners
- ESA responsible of mission systems, spacecraft, launcher, mirror, operations and SOC
- Instruments and Science Ground Segment elements to be provided by the Member States < ~ 400 M€
- ESA Cost at Completion ~ 1 B€

Schedule

✓ Hot&Energetic Univ. Theme selected for ESA L2	Nov. 2013
✓ Athena Mission selected	Jun. 2014
✓ Phase A and B1	on going
✓ Implementation Phase	2019
✓ Launch	2028
✓ Operations:	5 +5 years

A T H E N A +

Italy in ATHENA

Science, Mission and Instruments with a leading role of Italian scientists and industry.

XIFU CoPI + synergical participation to WFI

Roles & Community: 1 in the ESA Study Team, 9 Italian co-chairs of Mission &Science WGs + 160 Italian members

Italian Key institutions are:

INAF: IAPS(RM), IASF-MI, IASF-Bo, IASF-Pa, OABrera, OABo, OATo, OAPa, OaTs, OAArcetri, OARM, OANa

Univ. &INFN Genova, Univ Rm1,Rm2Rm3, Univ. Bo, Univ. Pa, Un.Mi

CNR, IFN-RM

Industrial role from mission prime-ship, subsystems, instrument cutting-edge technologies, mirror assembly (TAS,CGS,FBK, Mediolario,..)

Italian contributions formalized at the ESA-Leading Funding Agencies meeting in Otc. 2014