

ATHENA

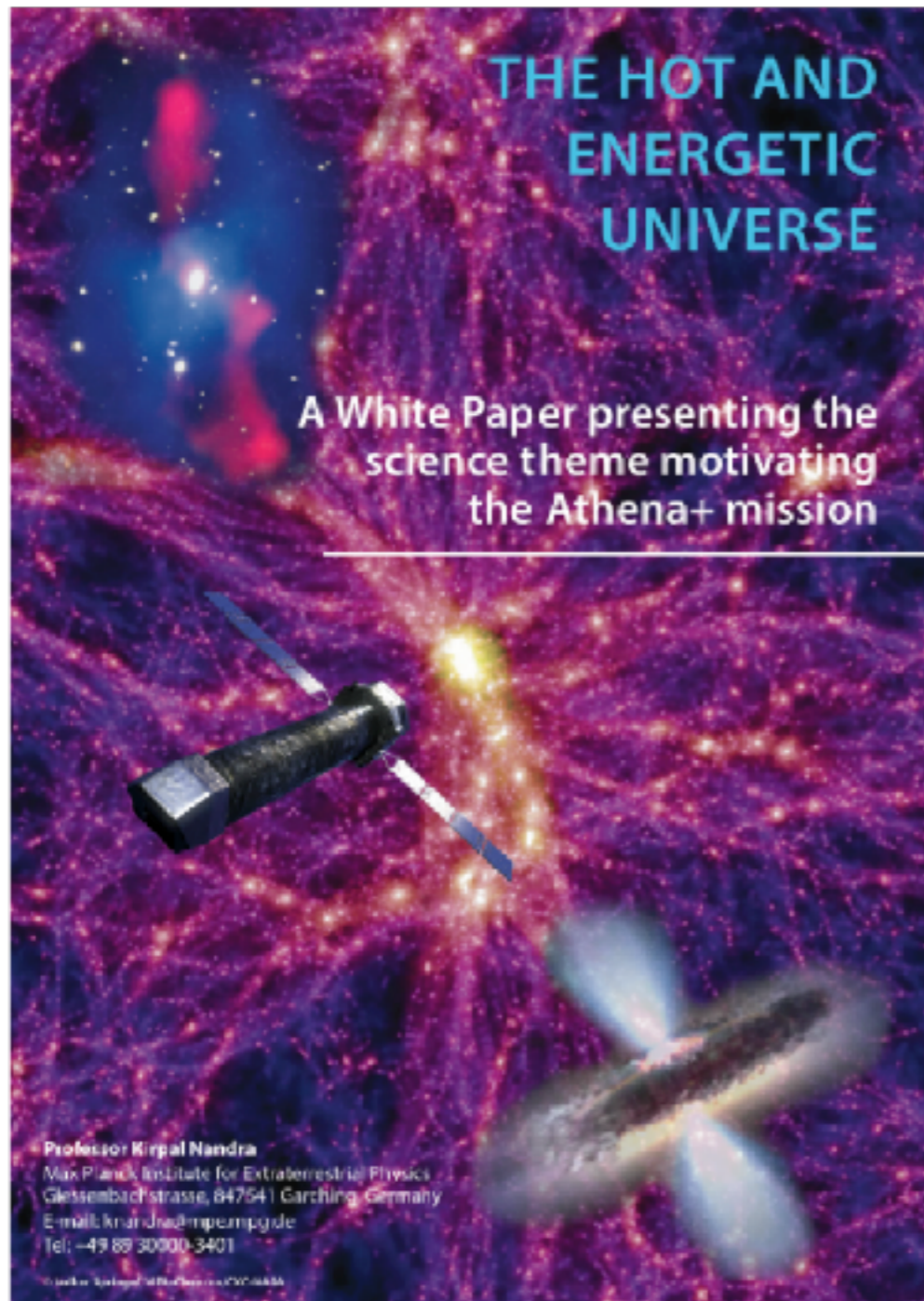
<http://www.the-athena-x-ray-observatory.eu>

Cluster science with Athena

Etienne Pointecouteau

SnowCluster, March 23rd 2018

The hot and energetic Universe

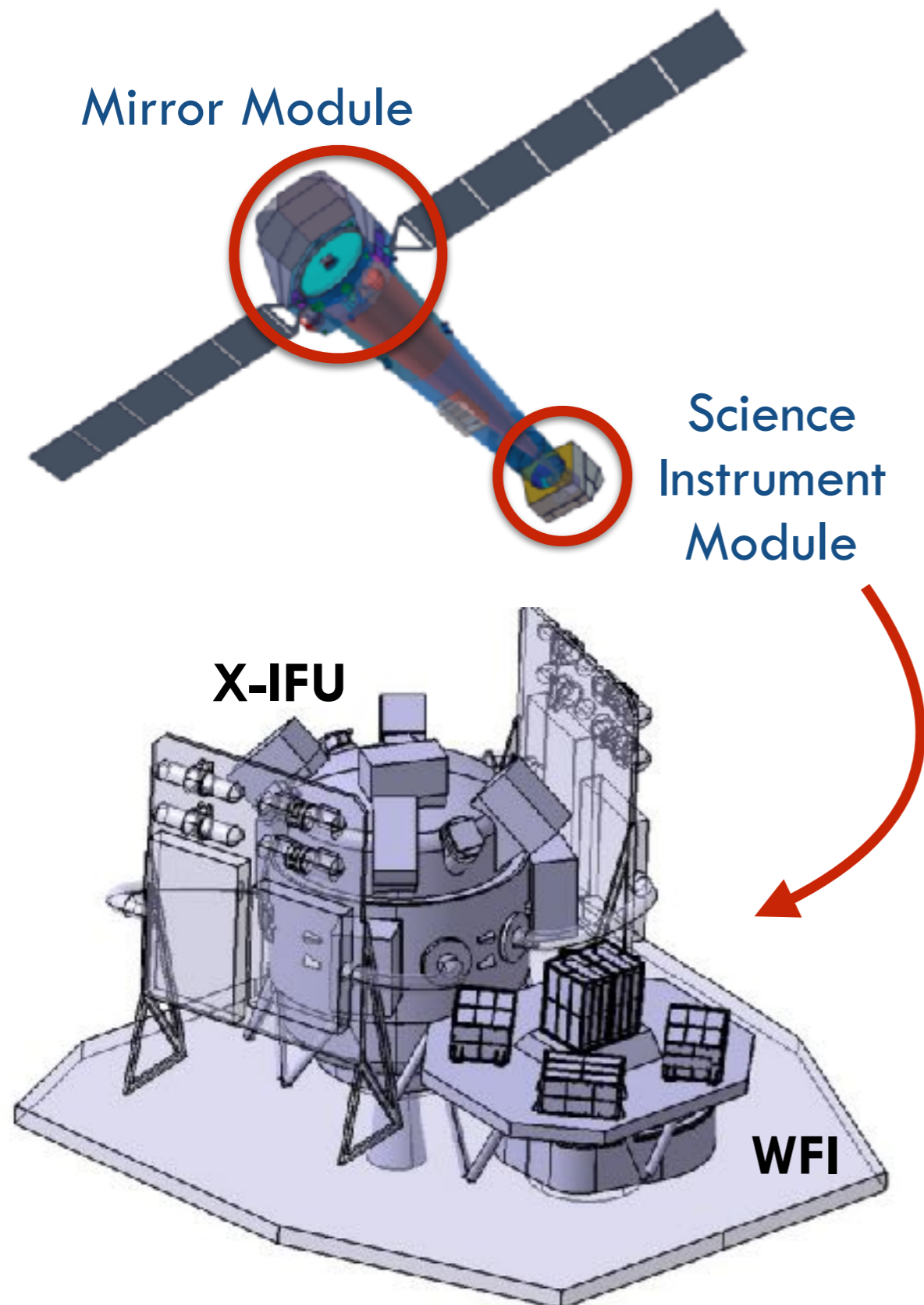


Nandra, Barret, Barcons et al. arXiv:1306.2307

- How does the ordinary matter assemble into the large-scale structures that we see today?
- How do black holes grow and influence the Universe?
- In addition:
 - ▶ Fast ToO capability to study transient sources
 - ▶ Observatory science across all corners of Astrophysics

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

ATHENA: Advanced Telescope for High ENergy Astrophysics

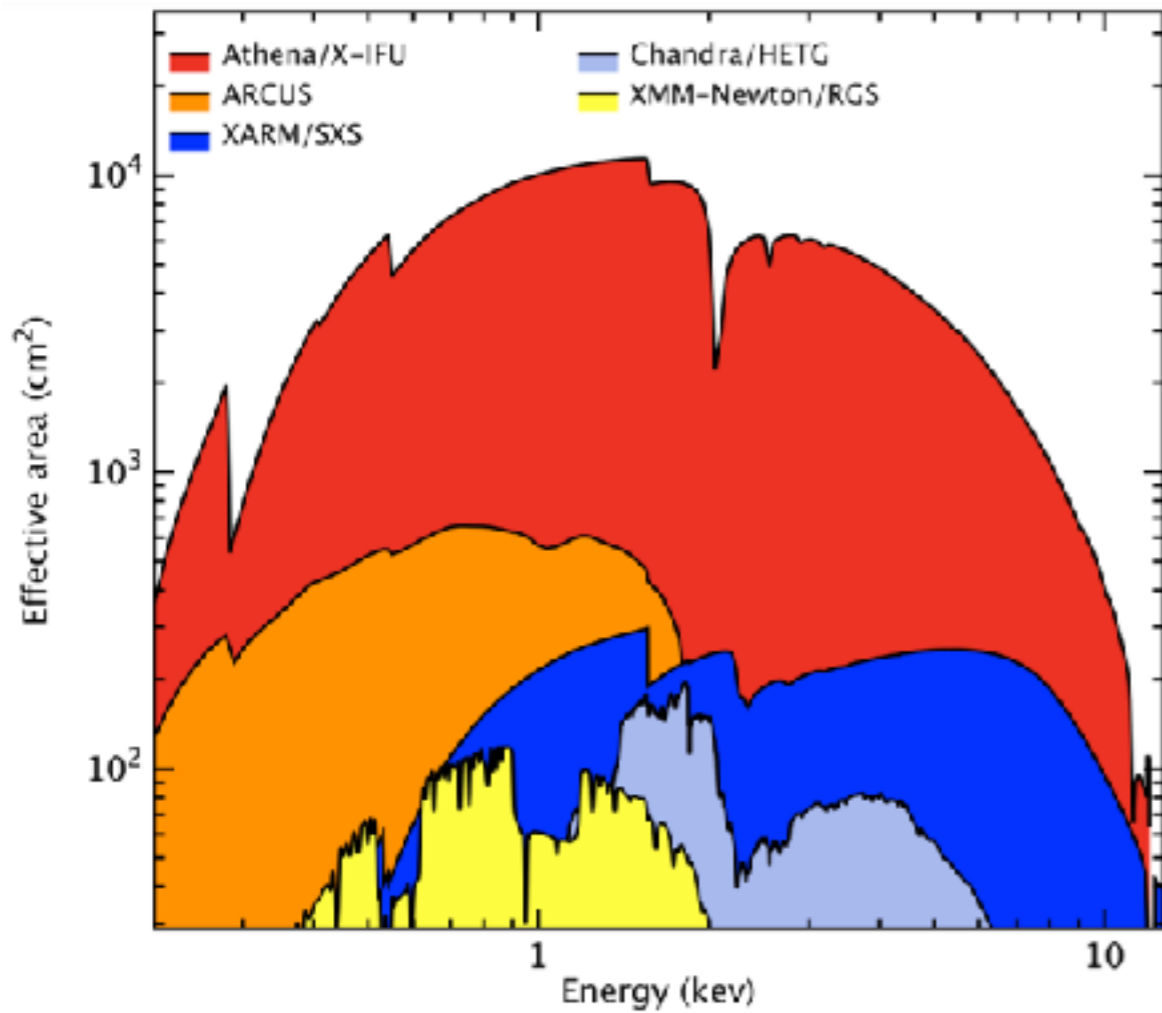


- 12 m focal length
- **1.4 m²** area @1 keV, **5'' HEW**
- Wide Field Imager (WFI)
 - ▶ Active Pixel Sensor Si detector
 - ▶ **40'x40' FoV**
 - ▶ 120-150 eV @6 keV
- X-ray Integral Field Unit (X-IFU)
 - ▶ Cryogenic imaging spectrometer
 - ▶ 5' diameter equivalent FoV
 - ▶ **2.5 eV @7 keV**
- **Launch 2030**, Ariane 6.4, L2 orbit
- **4 years** nominal life-time + extensions

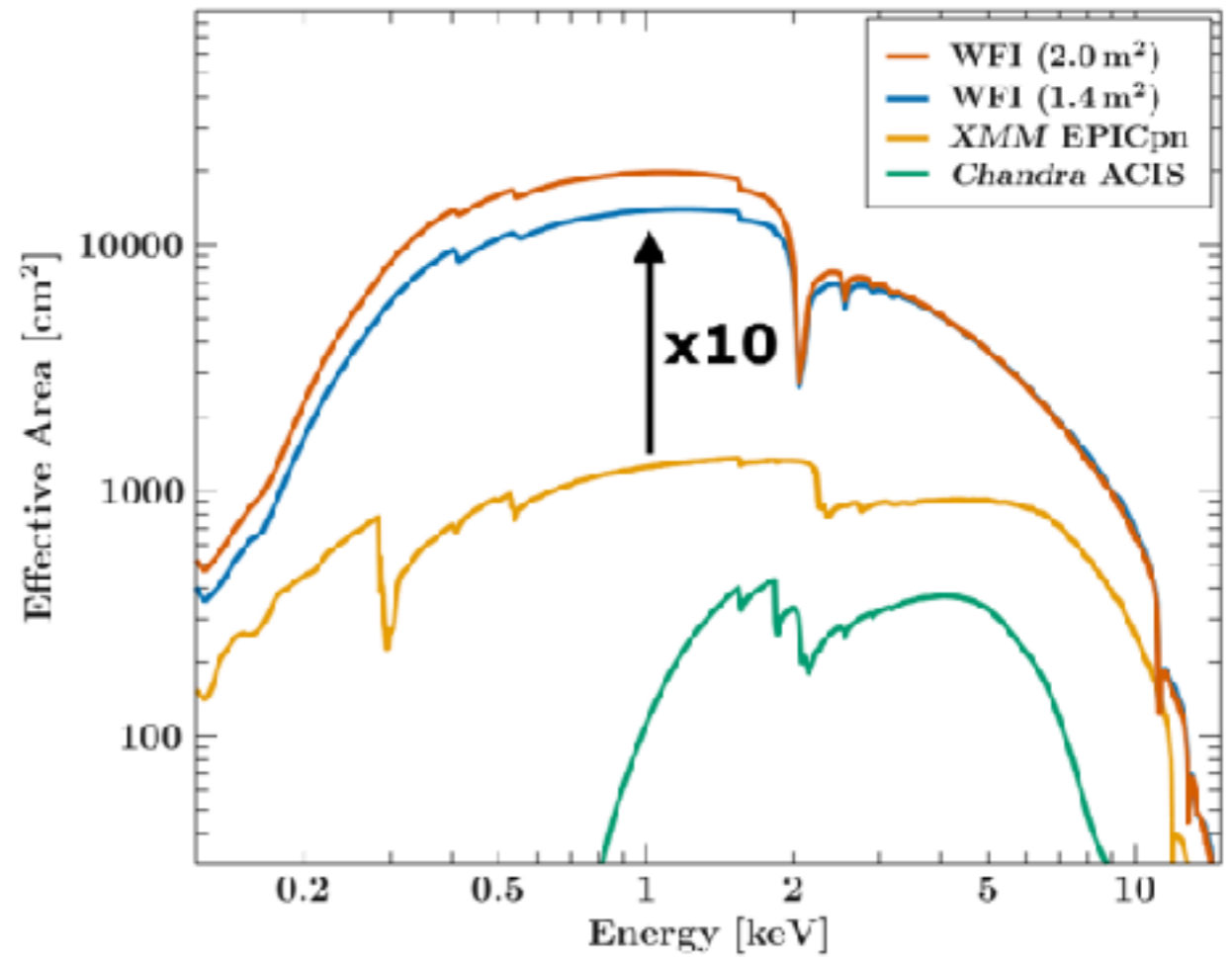
- Athena @ ESA
 - ▶ Cost cap = 1.05B€, encompasses the optics, payload, launch+
 - ▶ Phase A, i.e., accepted proposal in feasibility/definition phase
 - ▶ Main Milestone: Mission Adoption Review by ESA in 11/2021
- Athena optics
 - ▶ Silicon Pore Optics developed by ESA/Cosine are on a critical path
 - ▶ Maintain pressure on ESA to secure the effective area and the adequate spatial resolution
- Instruments (X-IFU and WFI)
 - ▶ Funded by national agencies + contributions by ESA, NASA, JAXA
 - ▶ Instruments (X-IFU and WFI) configuration as proposed

Effective area

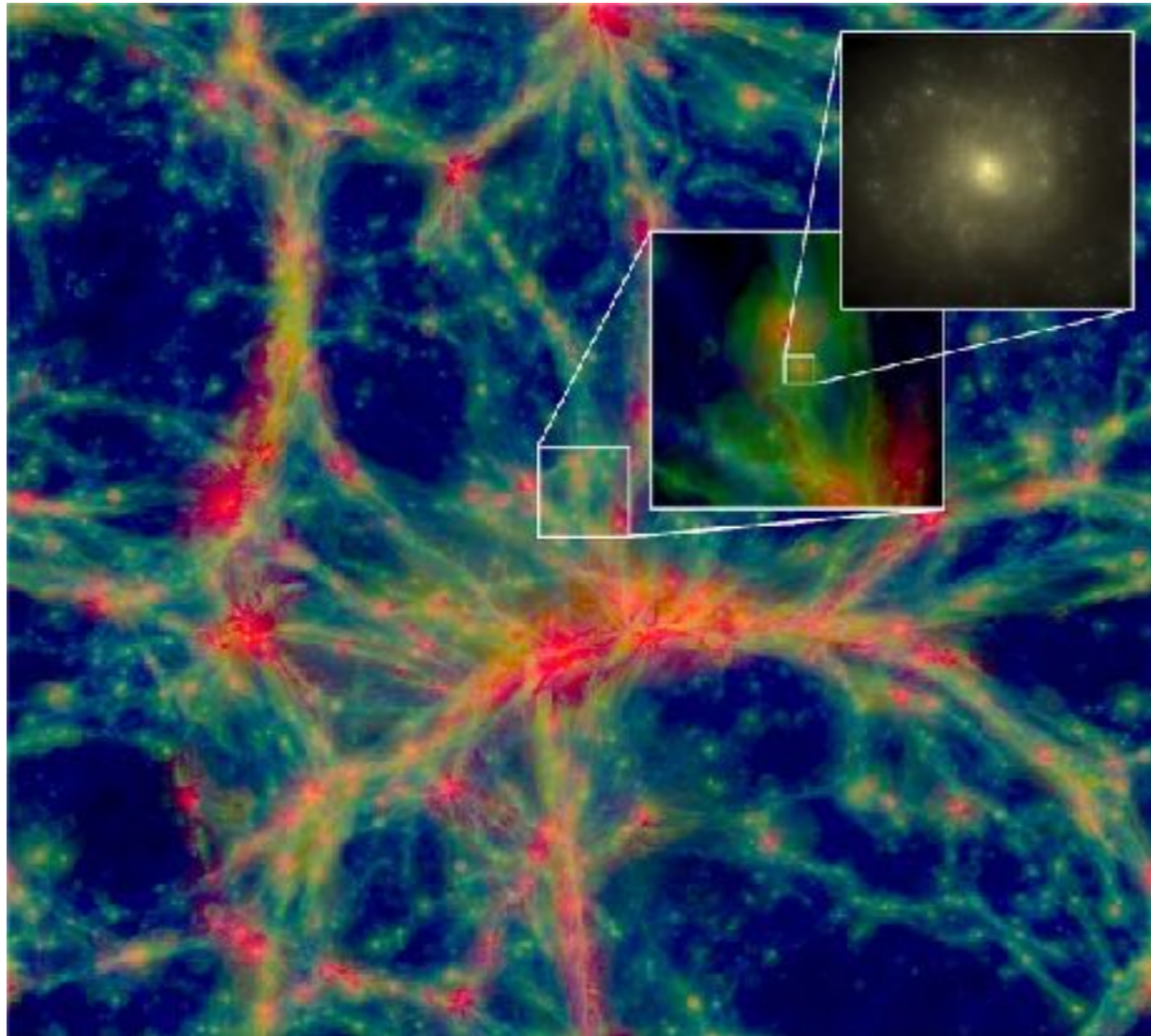
X-IFU



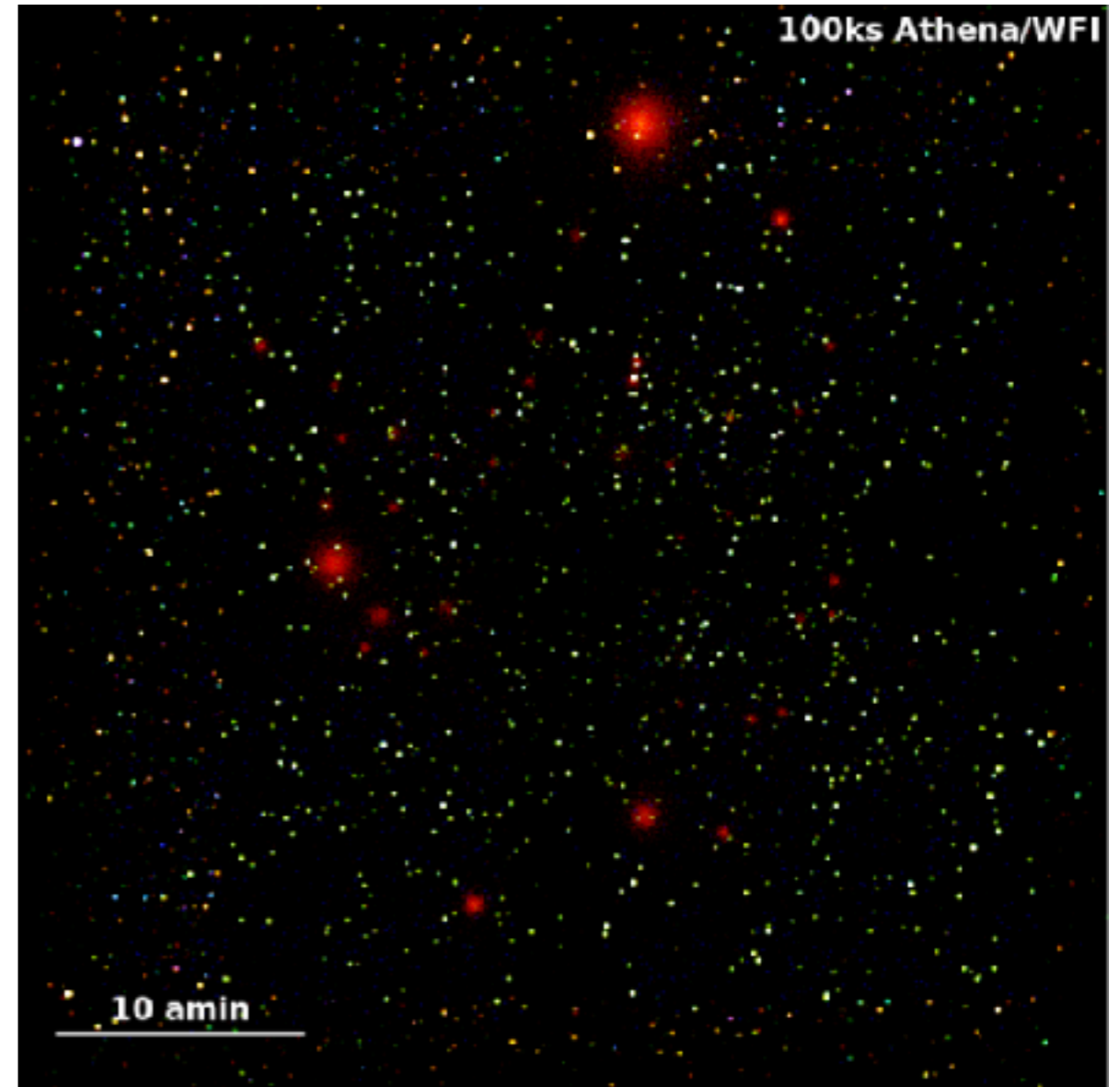
WFI



Assembly of the first massive halos



Schaye et al. 2015

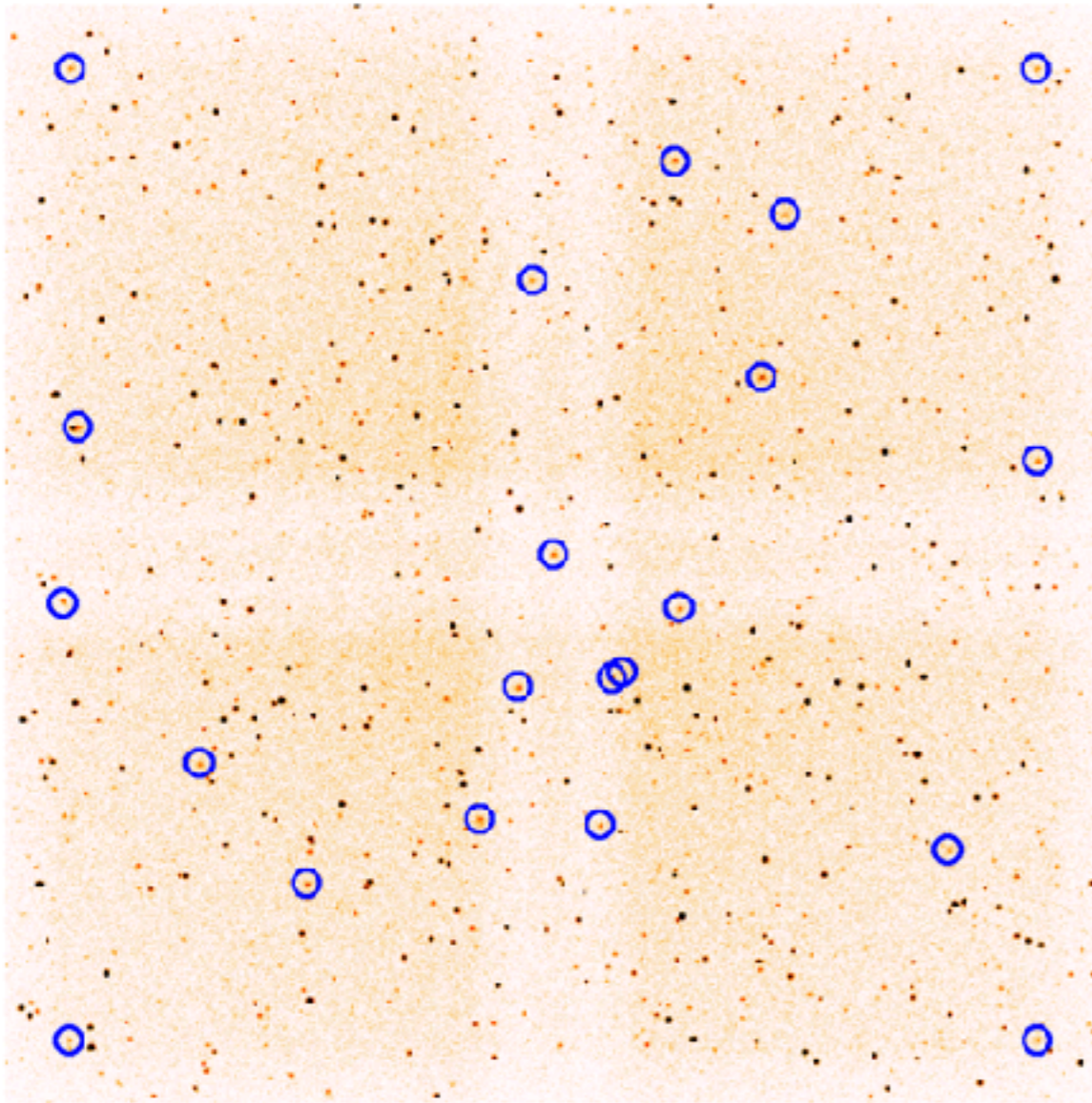


Athena/WFI 1 Ms simulation
MPE & WFI team

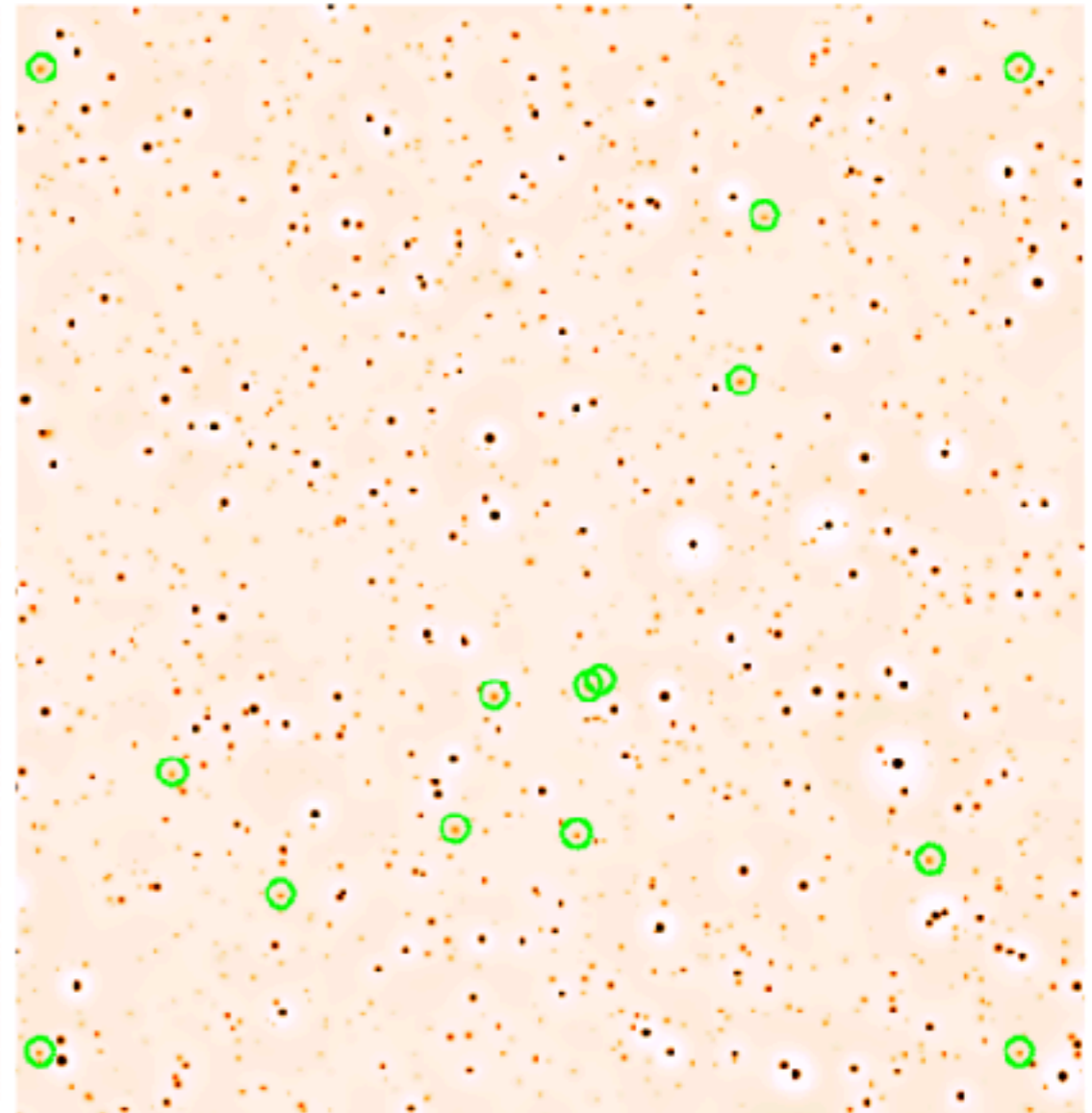
Assembly of the first massive halos

$z = 2.5 / 80 \text{ ks}$

Simulated



Detected

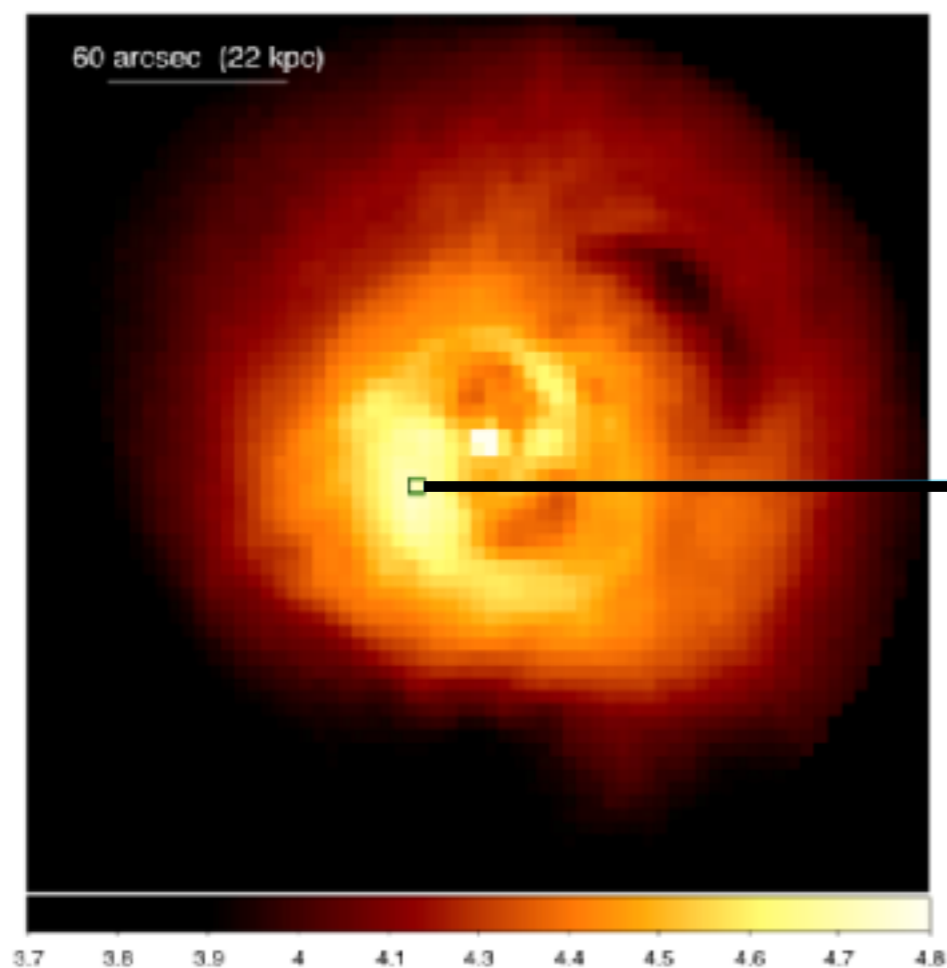


Courtesy of C. Zhang and F. Pacaud

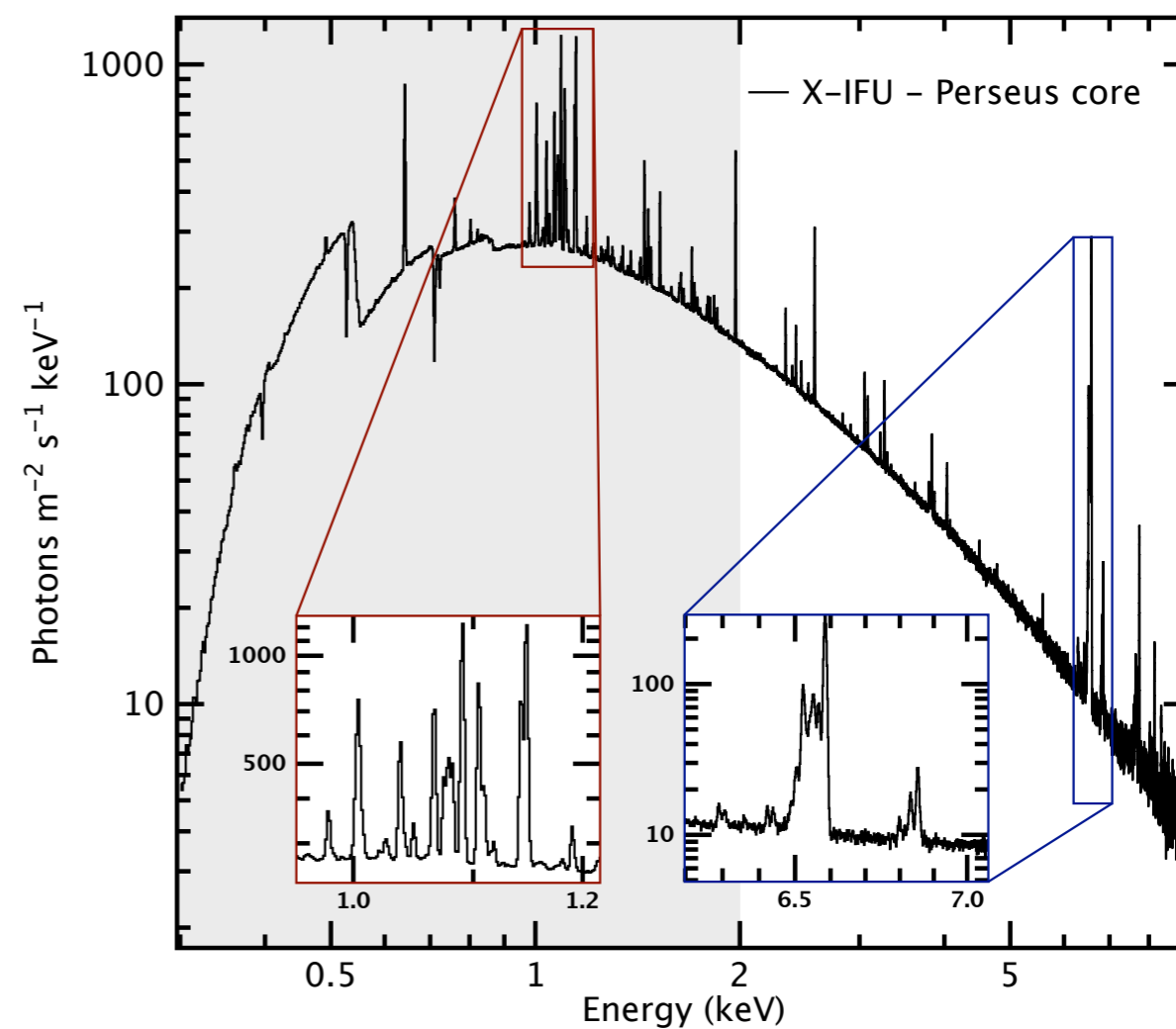
AGN feedback in clusters

- Energetics of central AGN feedback
- Gas dynamic and jet energy dissipation in clusters

Sanders , Croston et al. 2013



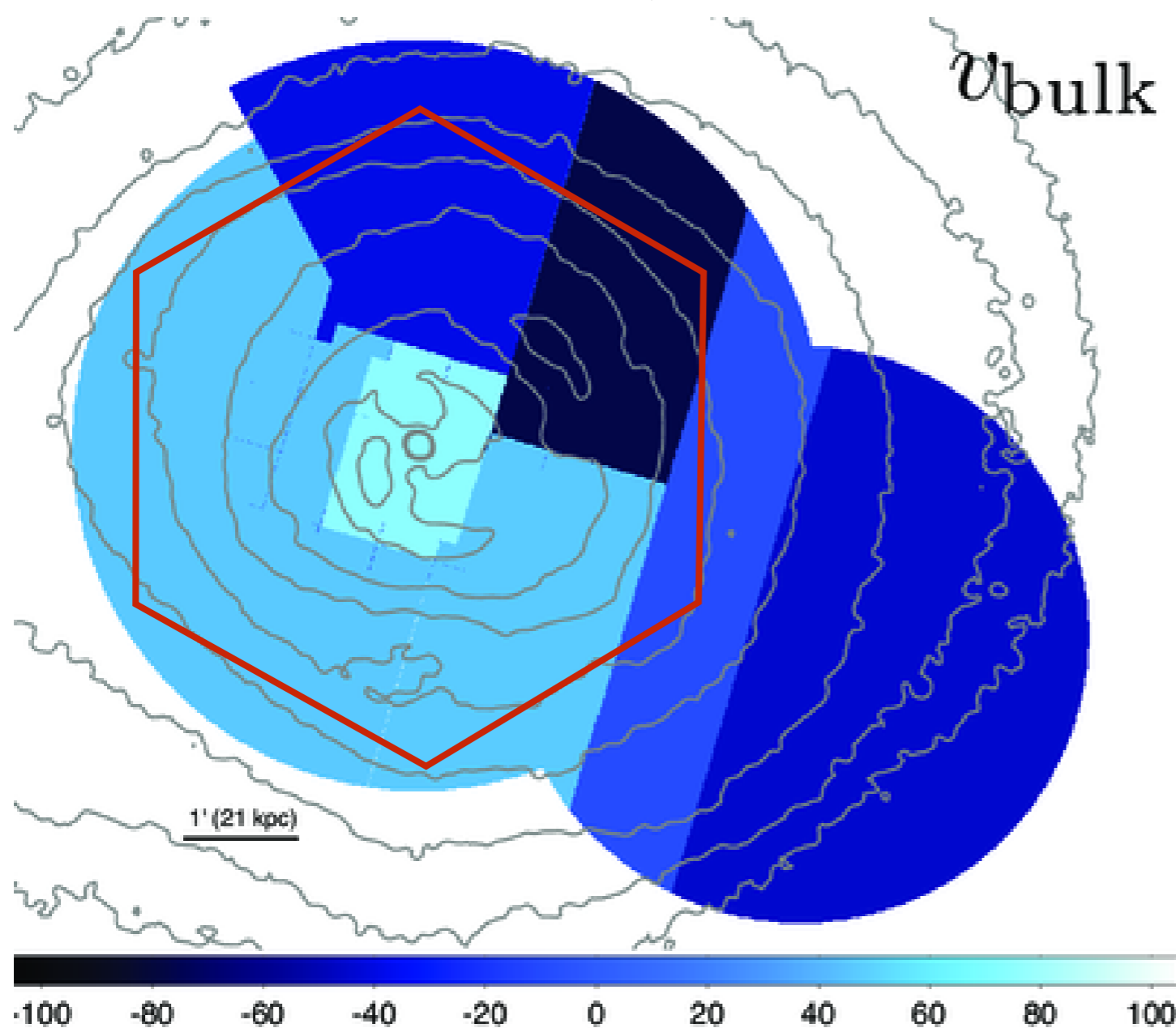
Barret et al .2016



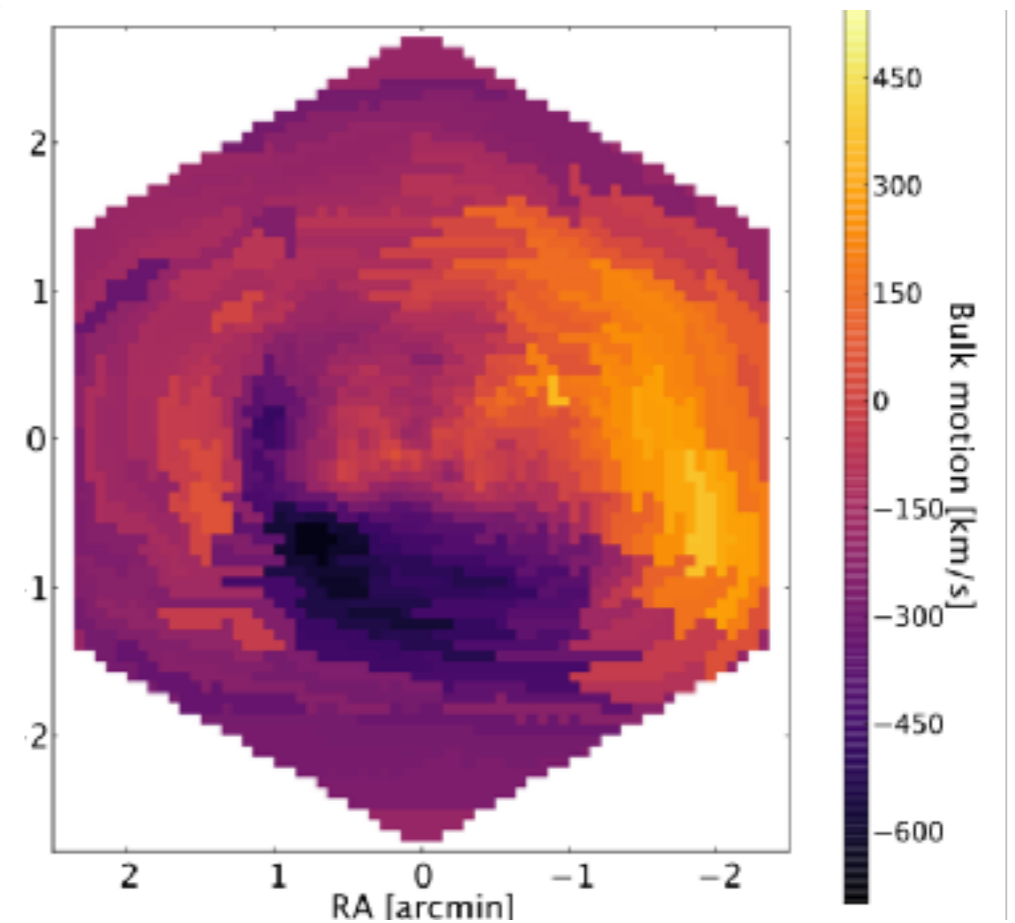
Dynamical assembly of clusters

- Simulated 'Perseus like' cluster (from Rasia, Biffi, Borgani, Dolag)
- 100ks X-IFU observation with SIXTE

Hitomi Collaboration - "V", 2017



Barret et al .2016

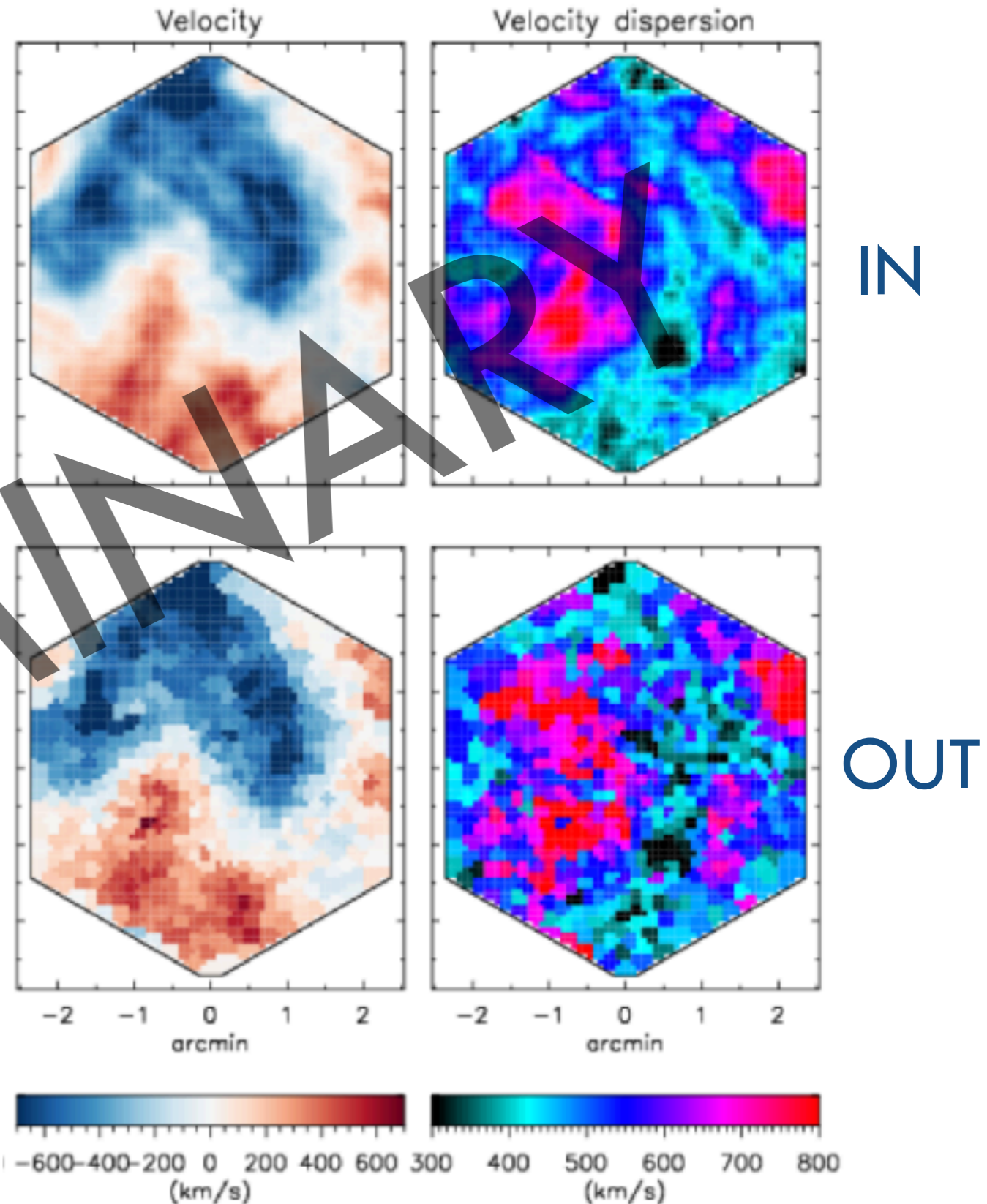




Dynamical assembly of clusters

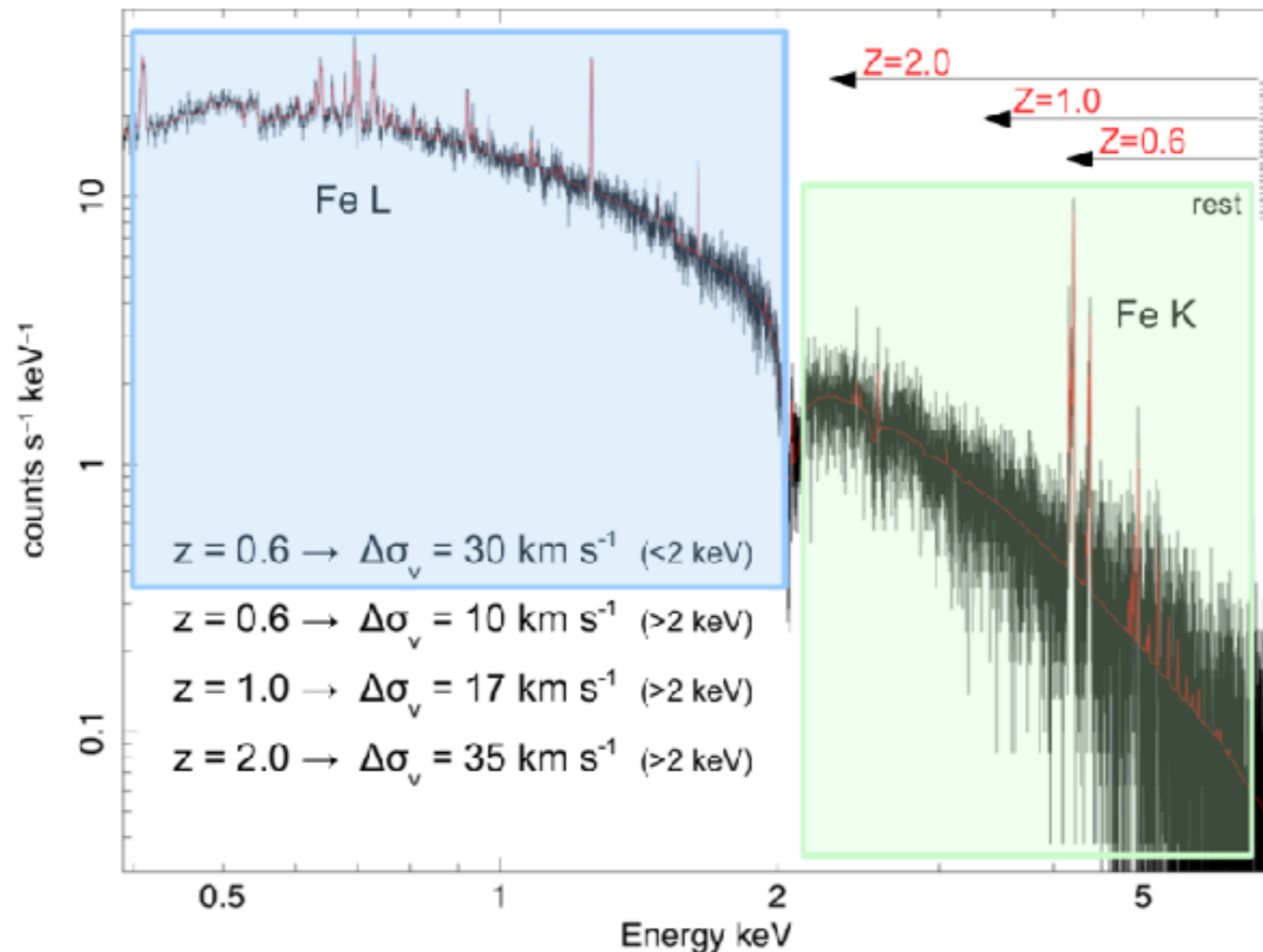
Roncarelli+ in prep

- Simulated Coma like ICM
 - ▶ from Gaspari & Churazov 2013
 - ▶ turbulence
 - ▶ thermal conduction
- X-IFU single pointing
 - ▶ SIXTE simulation of observation
 - ▶ bapec emission model
- Velocity measurement
 - ▶ bulk motion from line shift
 - ▶ turbulence from line broadening



Dynamical assembly of clusters

- Measuring velocities through line broadening
 - ▶ Phoenix cluster at $z \sim 0.6$
 - ▶ 1 arcmin diameter area, ~ 15 ksec, no instrumental noise
 - ▶ Statistical errors only



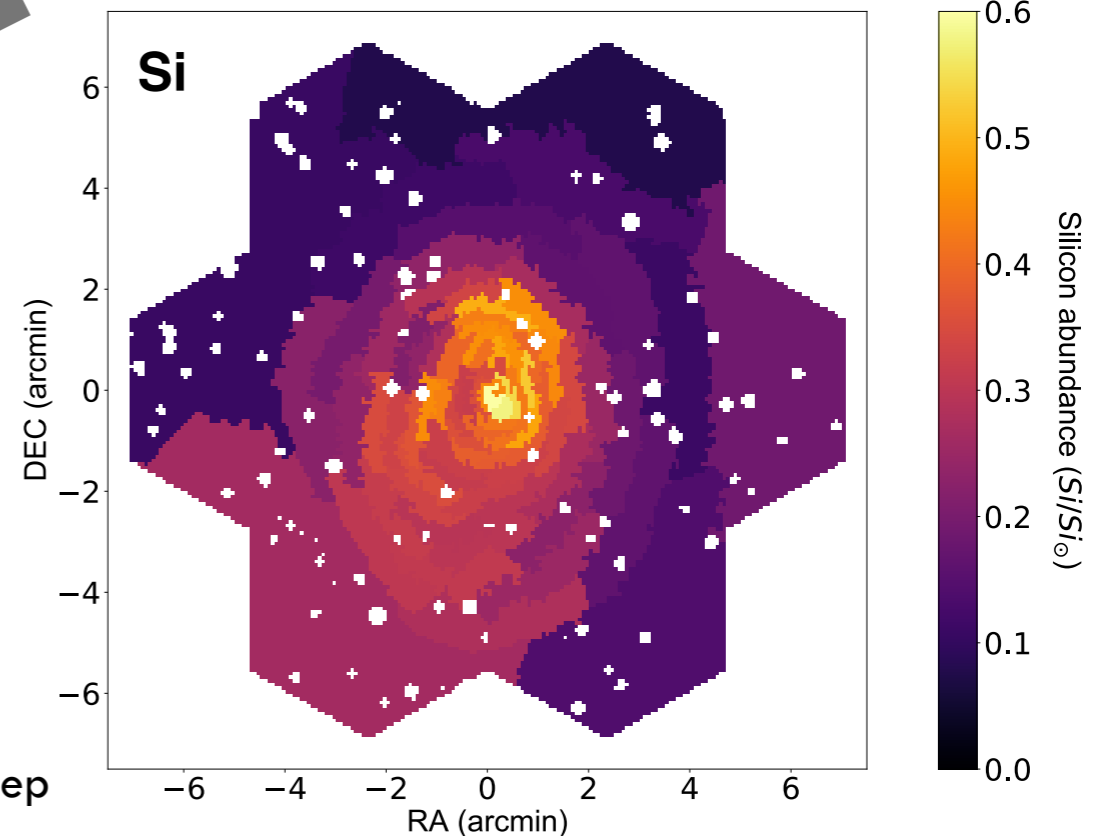
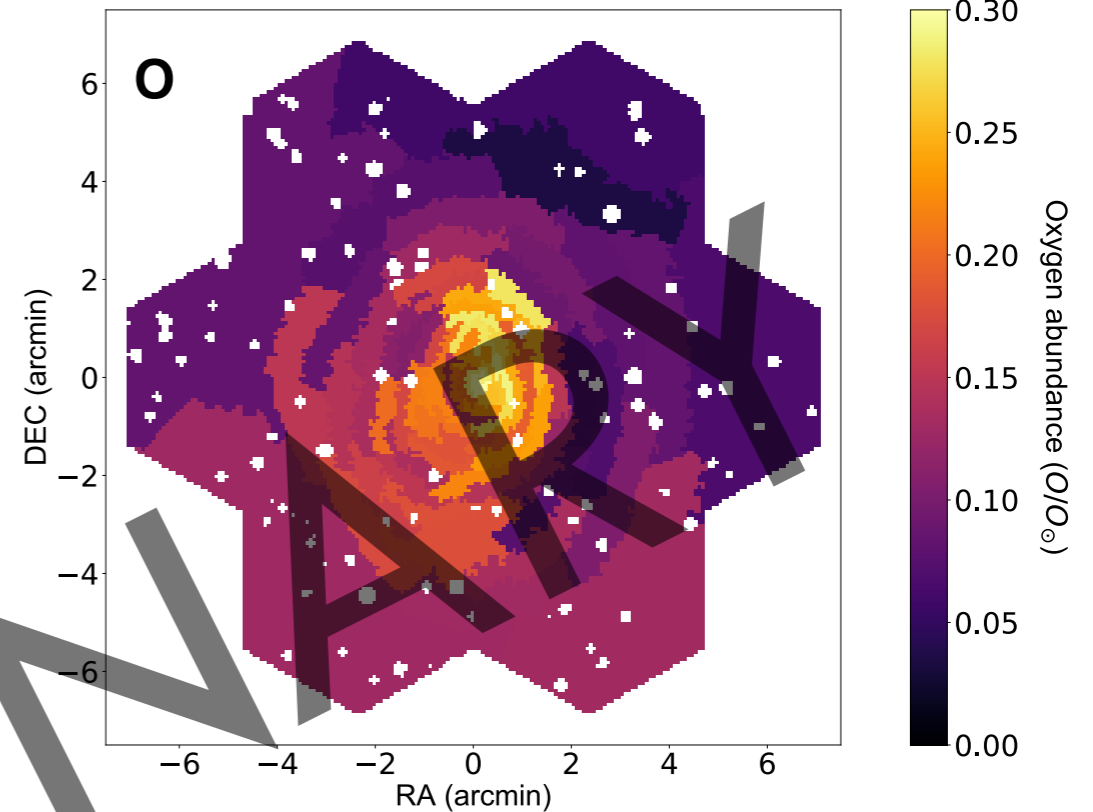
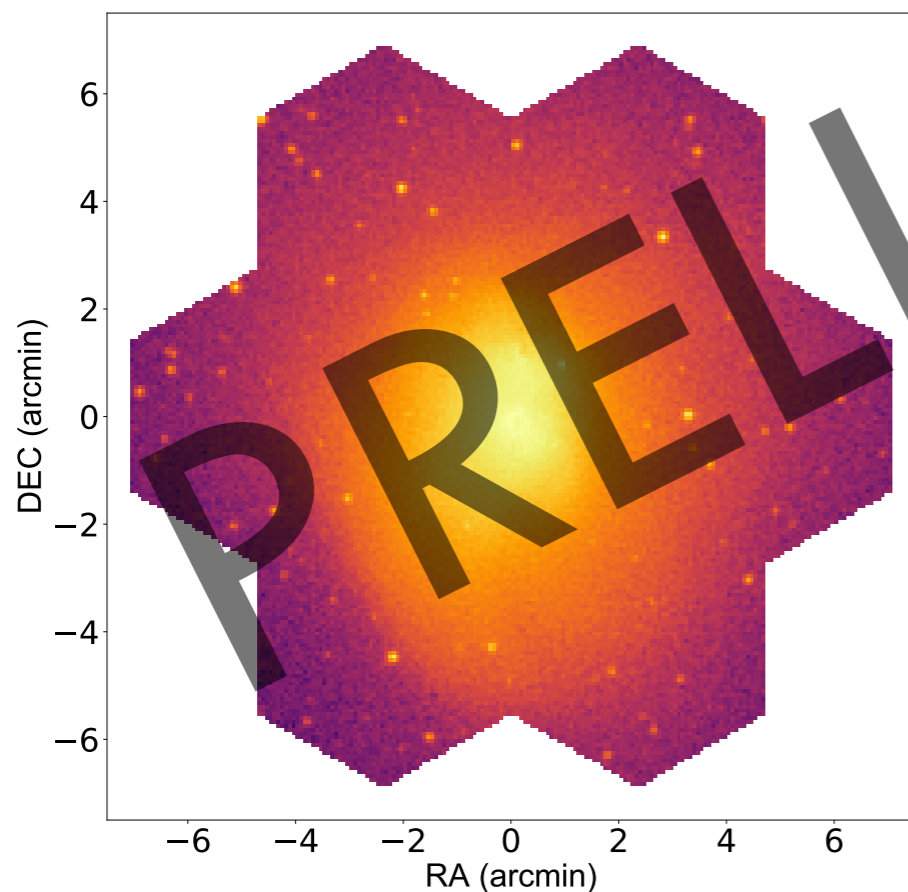
Courtesy of C. Pinto

Chemical evolution

Edoardo
Cucchetti



- 4 simulated clusters
 - from Rasia, Biffi et al.
- X-IFU simulations with SIXTE
 - 100 ksec per pointing
 - CXB, Galaxy, Instrument noise
 - J. Sanders binning scheme



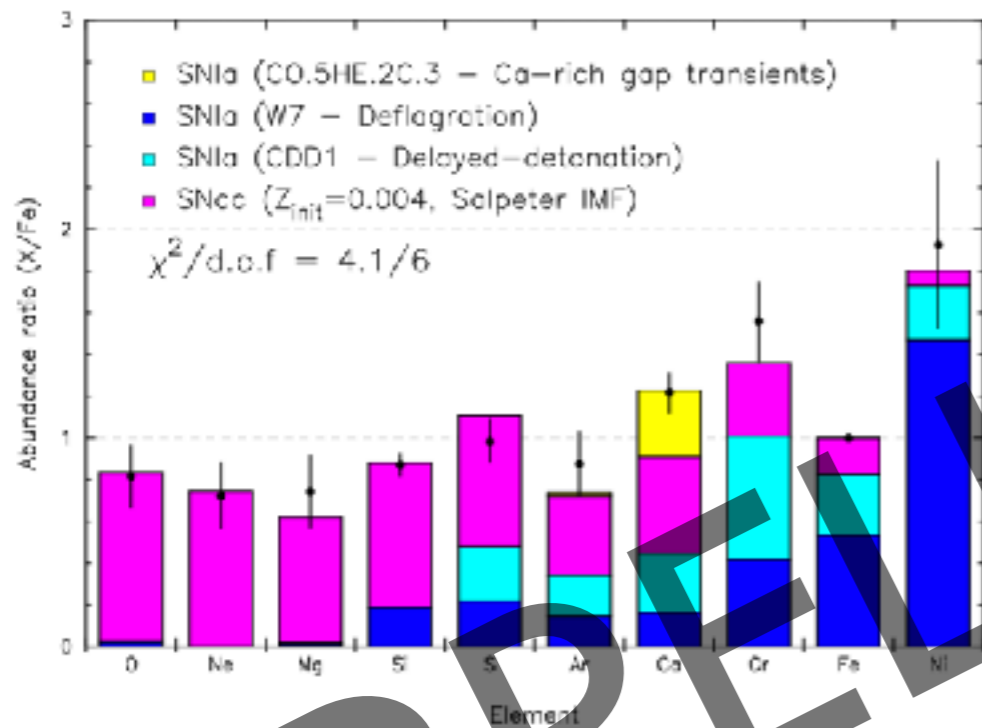
Cucchetti+ in prep

Chemical evolution

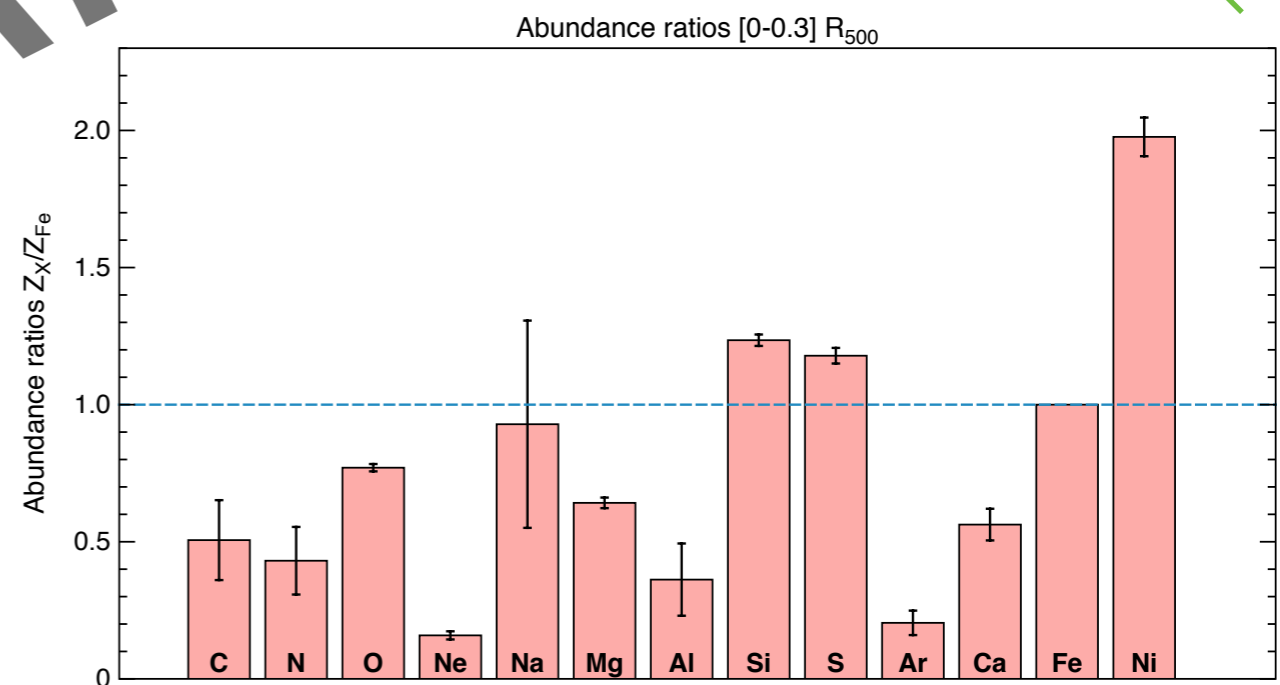
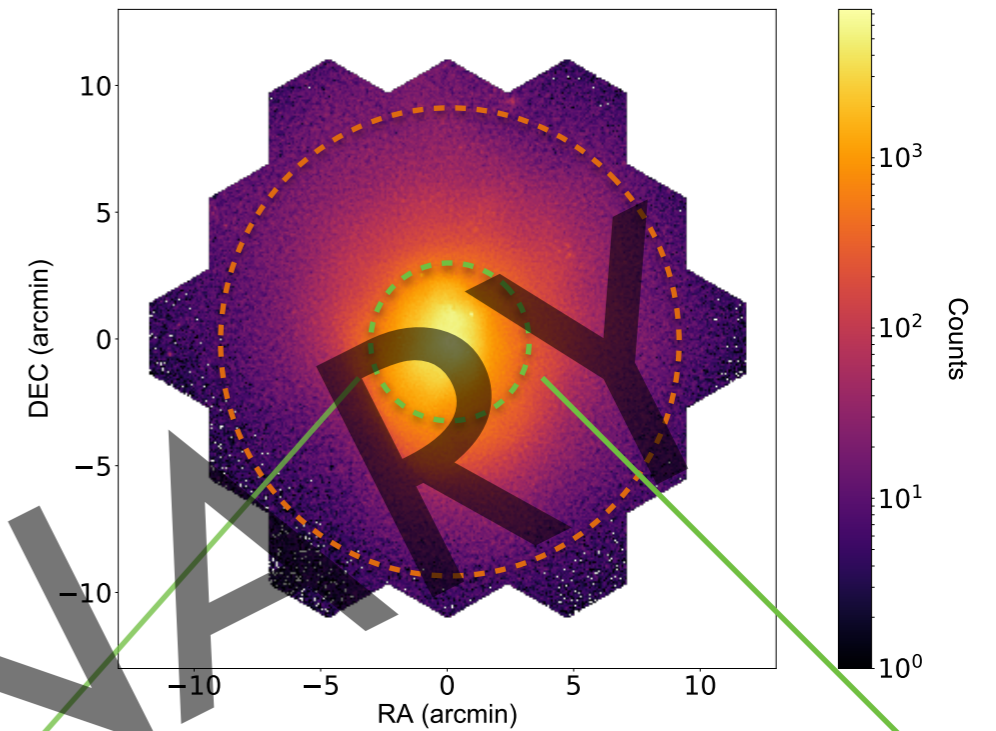
Edoardo
Cucchetti



- Source of production for chemical elements



Mernier+16a,b,+17
on the CHEERS sample

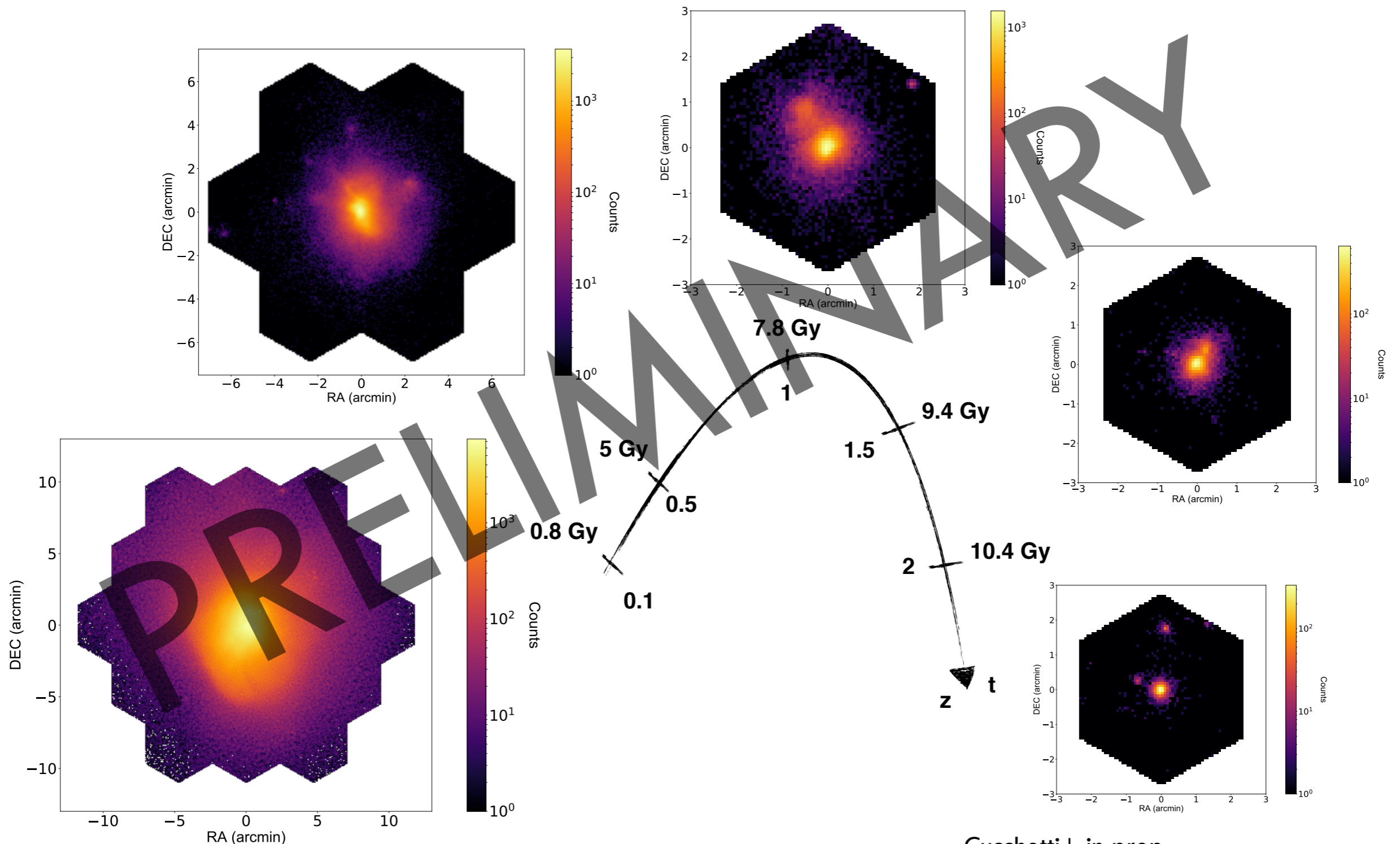


Chemical evolution

Edoardo
Cucchetti



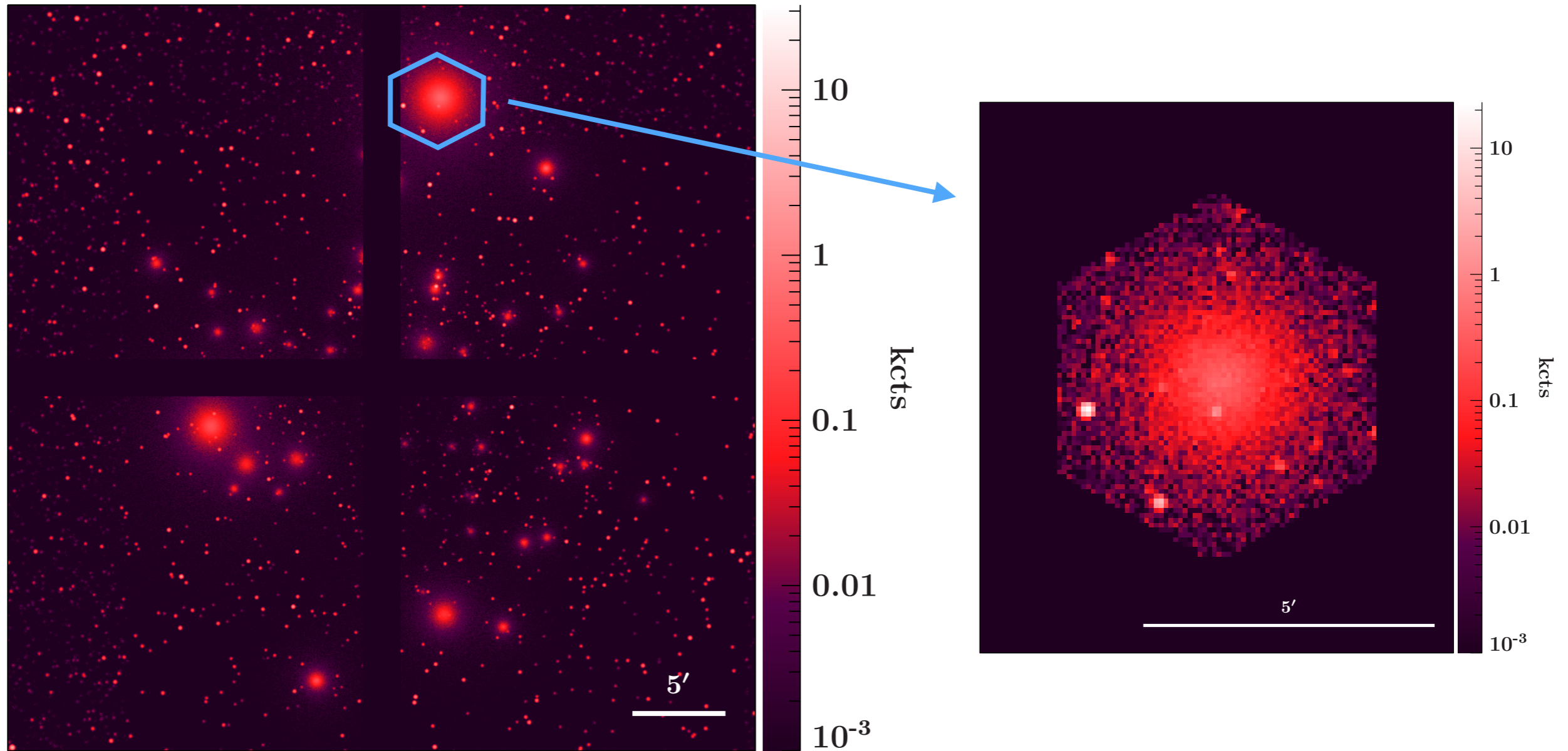
- Enrichment of the ICM across cosmic times



Cucchetti+ in prep

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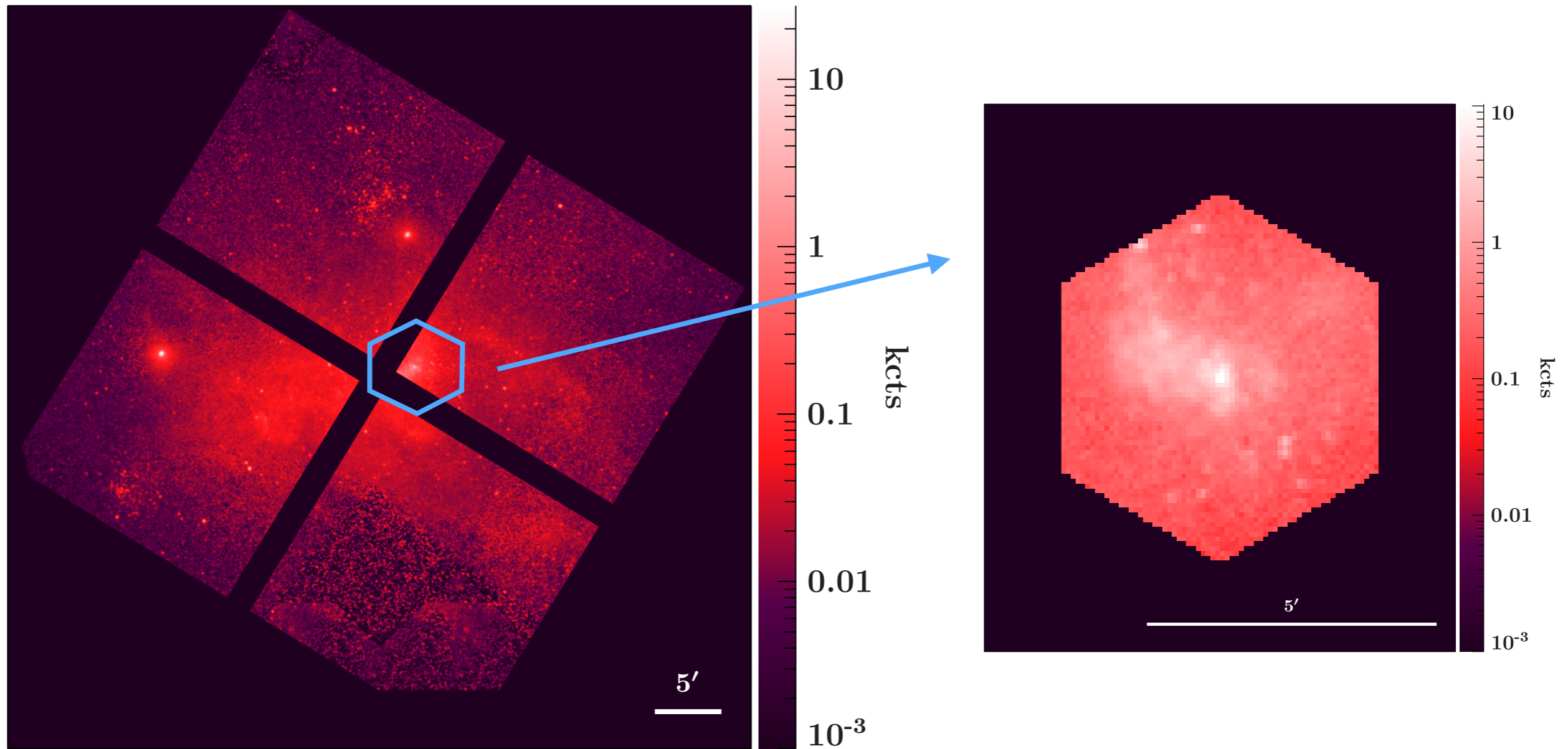
- 150 ksec WFI and X-IFU



Courtesy of Thomas Dauser and Joern Wilms

Galactic centre

- 150 ksec WFI and X-IFU

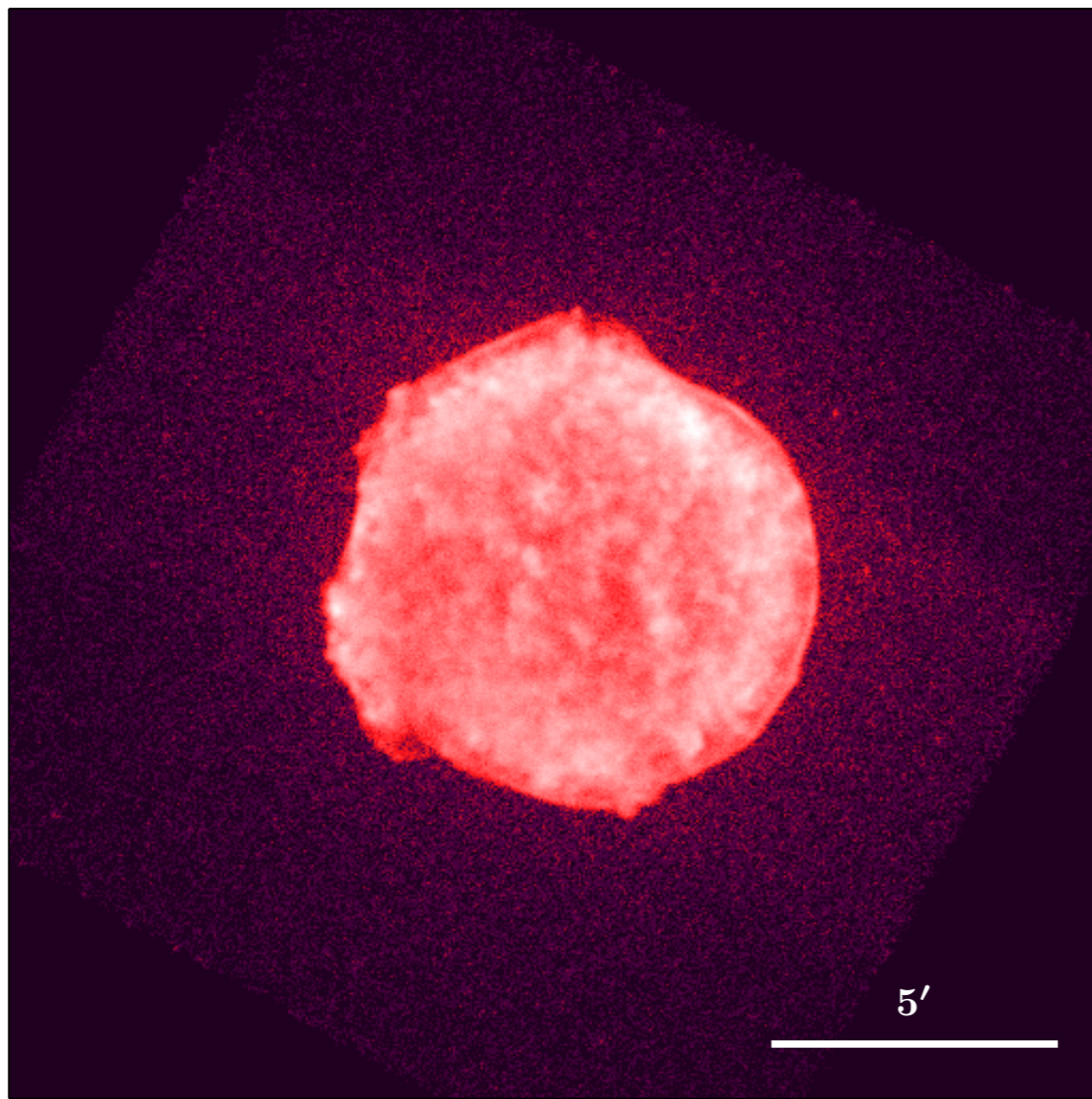


Courtesy of Thomas Dauser and Joern Wilms

Galaxies and SNRs

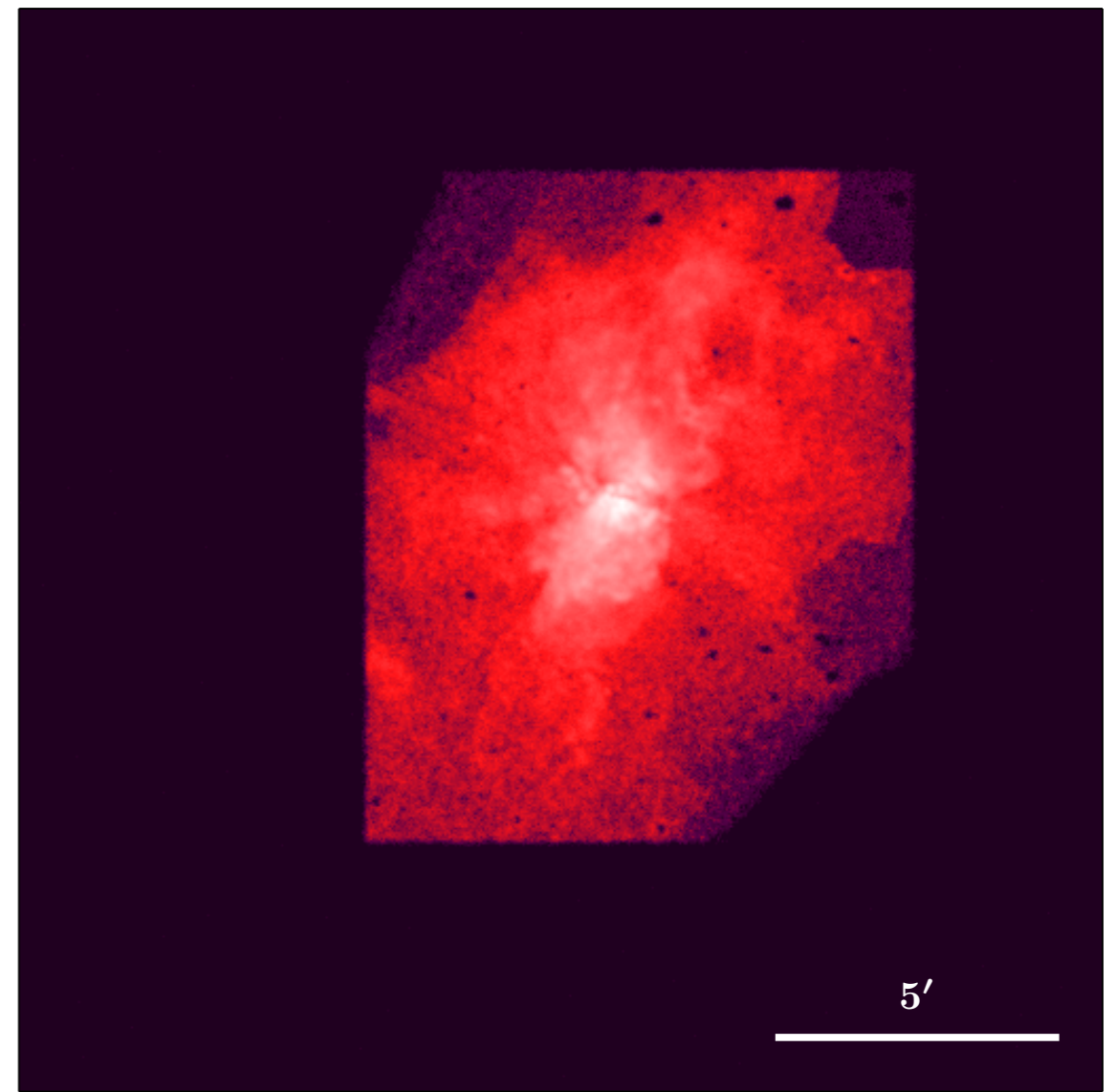
- Tycho

- ▶ WFI 1.5 ksec



- M82

- ▶ WFI 150 ksec



Courtesy of Thomas Dauser and Joern Wilms

Take home messages

- Athena and its instruments are in feasibility/definition phase
- Cluster science is at the core of the Athena science case
 - ▶ Driving the telescope and instruments performance (effective area, spatial resolution, energy resolution, energy coverage, FoV, etc)
- Athena will enable a wealth of science on the hot and energetic Universe, and on observatory science

