Probing the chemical enrichment of the ICM with the X-IFU

Edoardo Cucchetti (IRAP)
Supervisors: F. Pajot, E. Pointecouteau

Journée des thèses 16/05/2018

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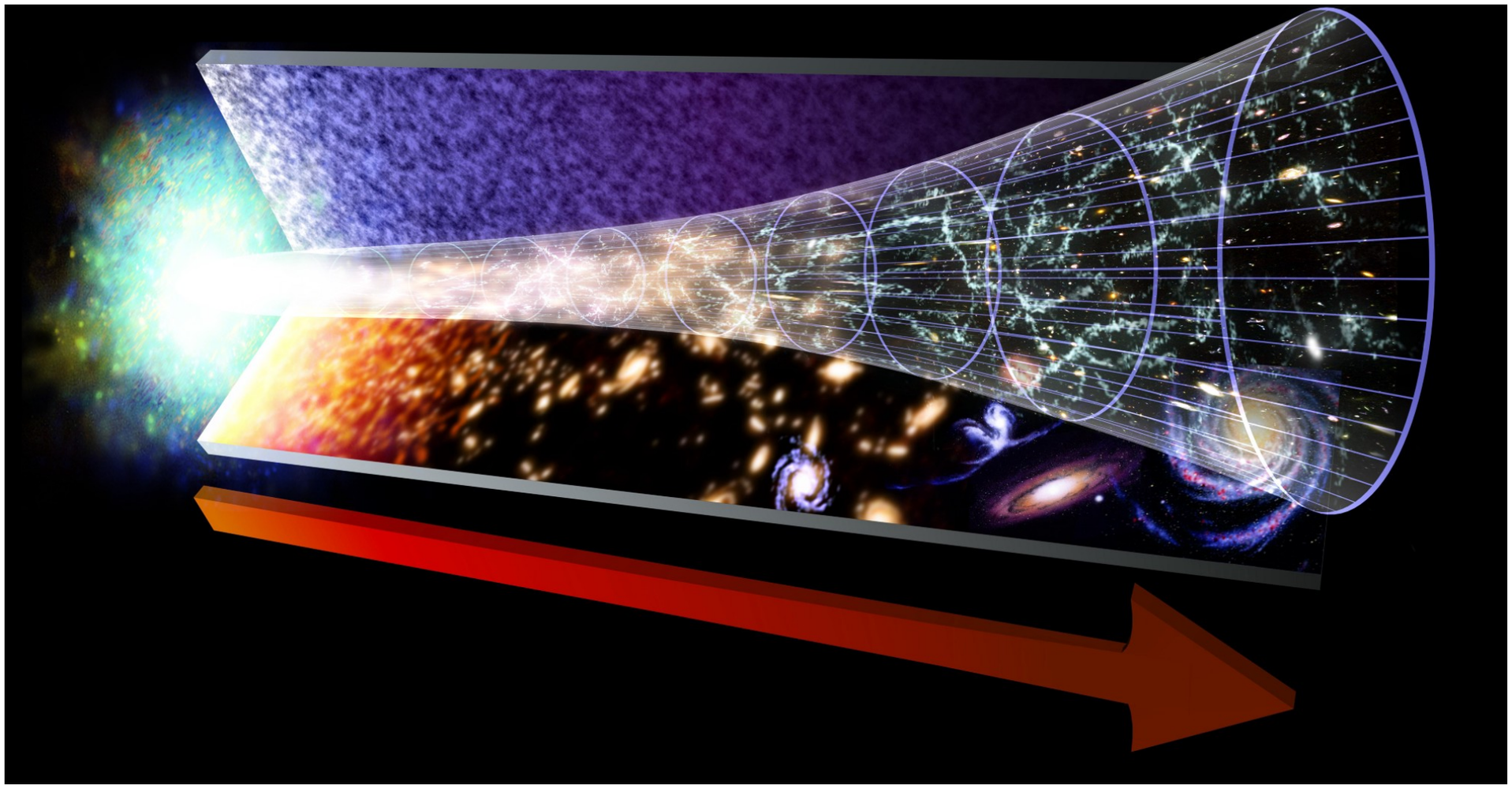
Where do metals come from?

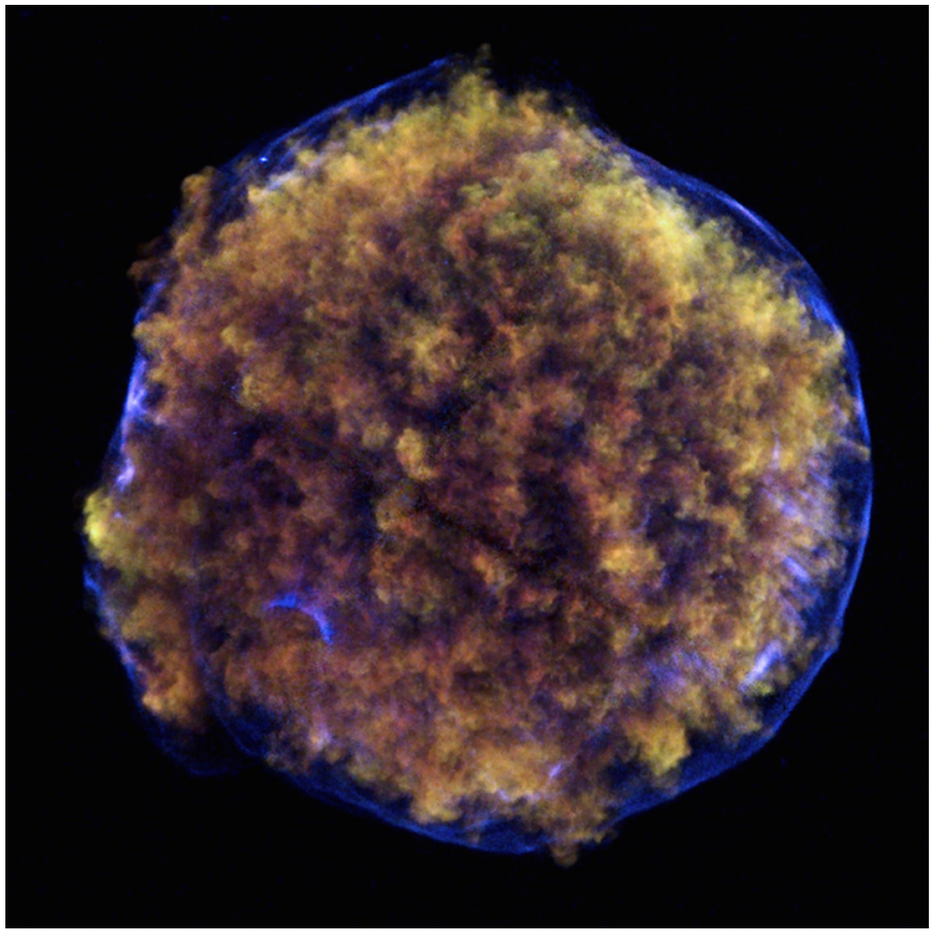
- Baryonic matter only accounts for 5% of the total Universe.
- Big Bang accounts for H/He formation, what about heavier elements?



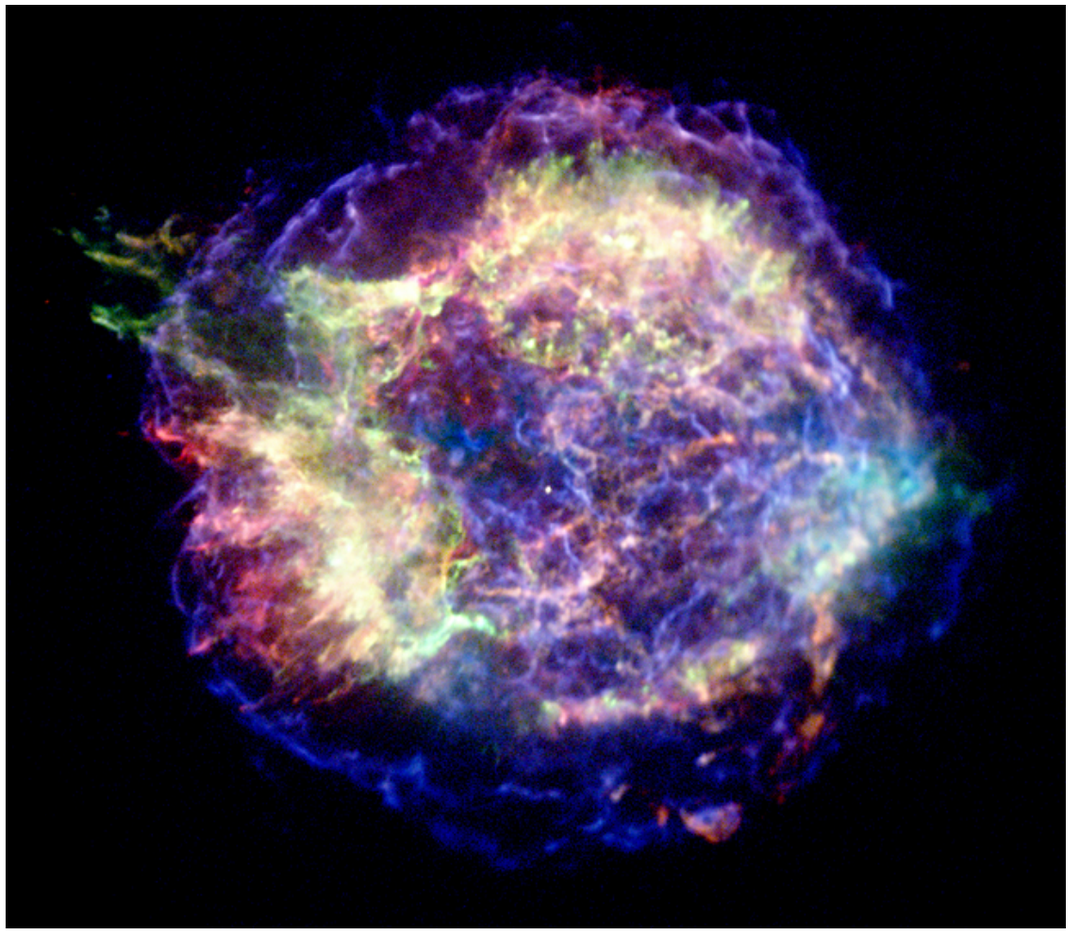
How and when were heavier elements created?

Where do metals come from?

- Stars hold (part of) the answer!
- Different types of supernovae, different type of enrichment!



Tycho SNIa (NASA)



CasA Type SNII (NASA)

What is the timescale of this enrichment?

Galaxy clusters

- Largest bound structures in the Universe (10^{13}/10^{15} solar masses)
- Created from perturbations in primordial matter distribution
- Composed of hundreds of galaxies and stars… but not only!

- Mass distribution is more complex
  - Dark matter accounts for 85% of the cluster mass (Zwicky, 1933)
  - Baryonic mass is only 15%
    - 85% of which is hot gas between galaxies!!

Bullet cluster (optical), Clowe+2006

Galaxy clusters

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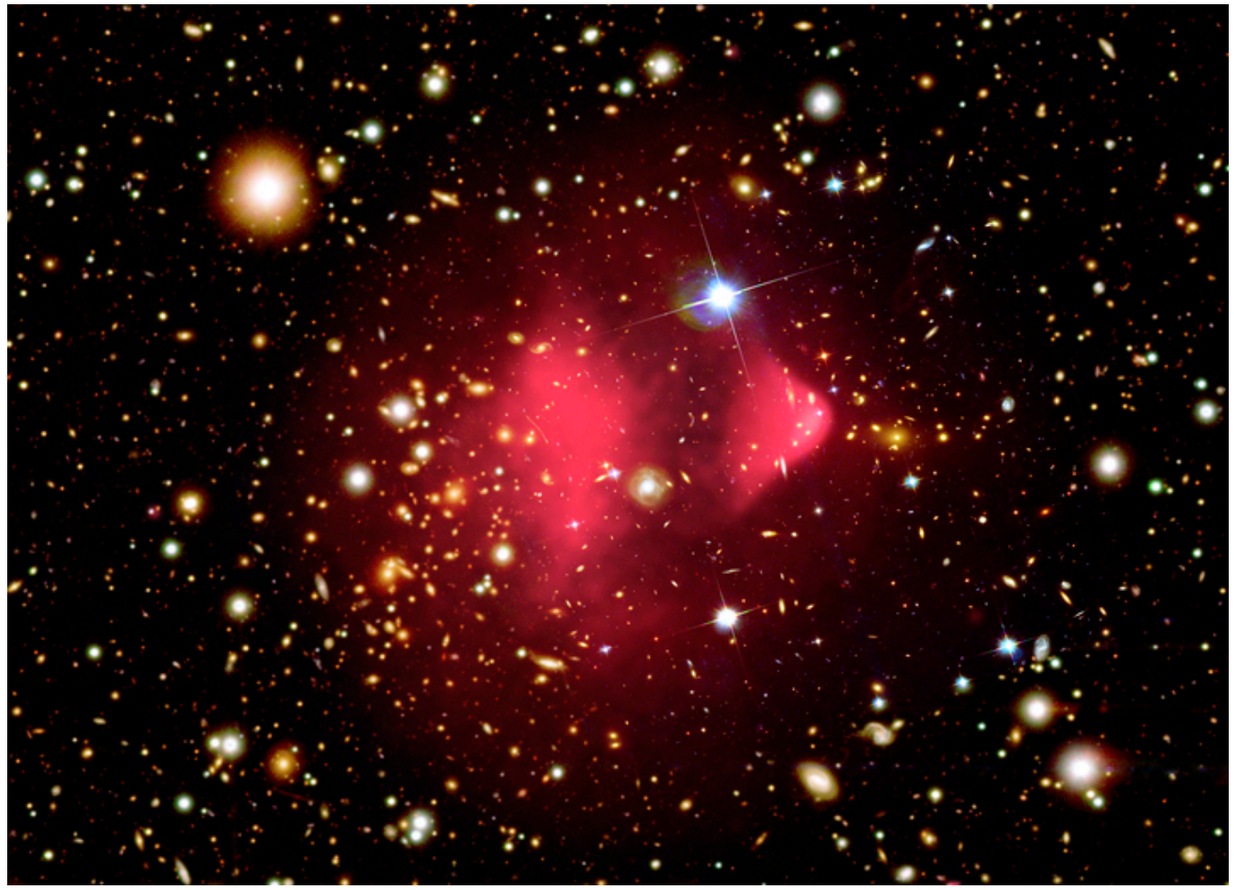
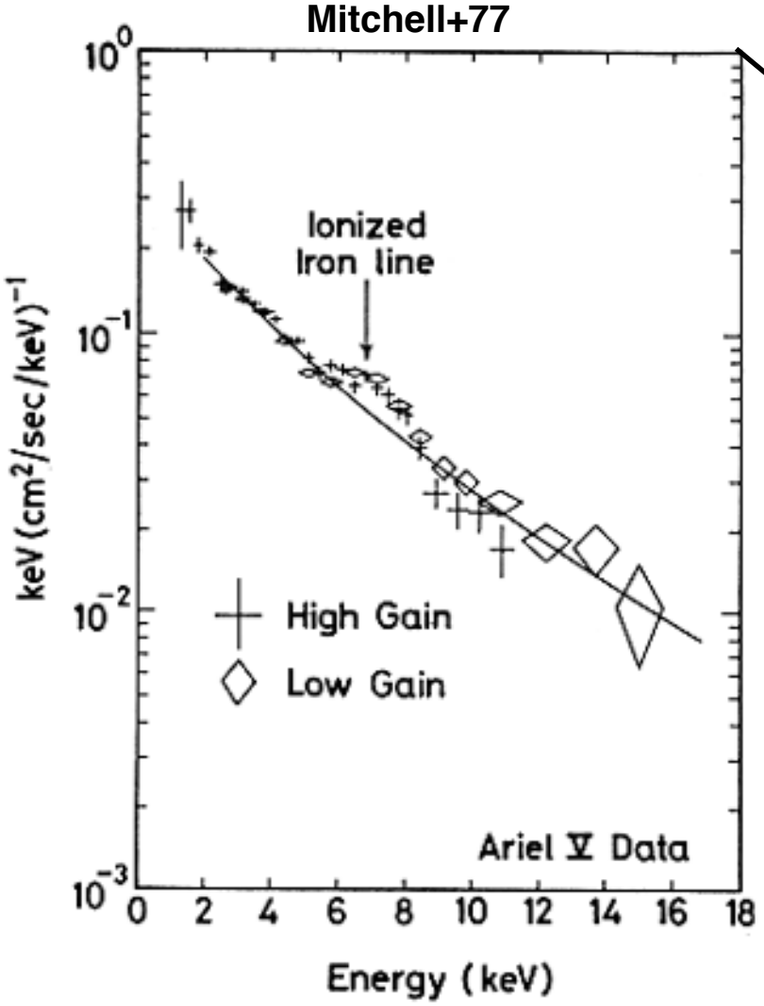
The hot gas in the Intra-Cluster Medium (ICM) emits in the X-rays!

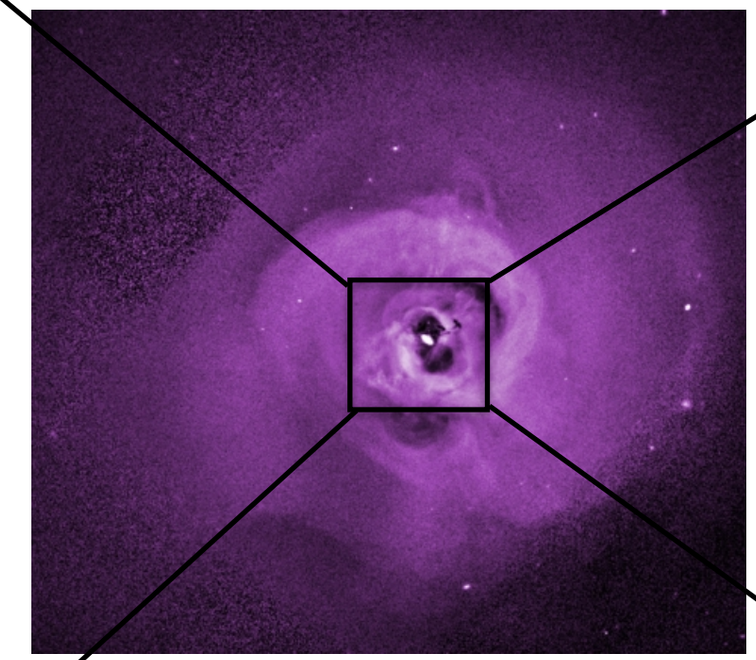


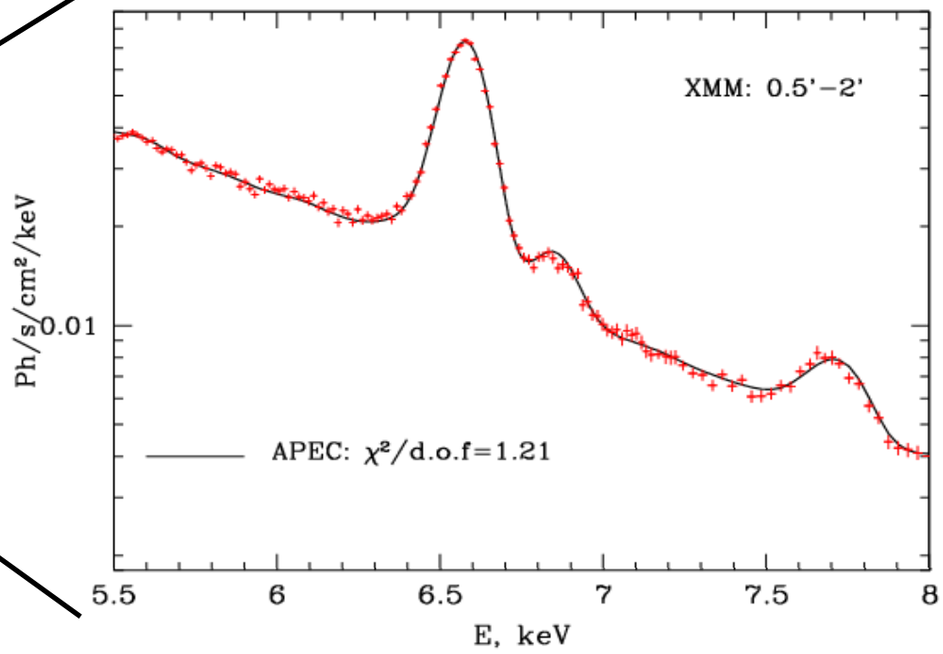
Bullet cluster (optical+x-rays), Markevitch+2007

The power of X-ray spectroscopy

Mitchell+77

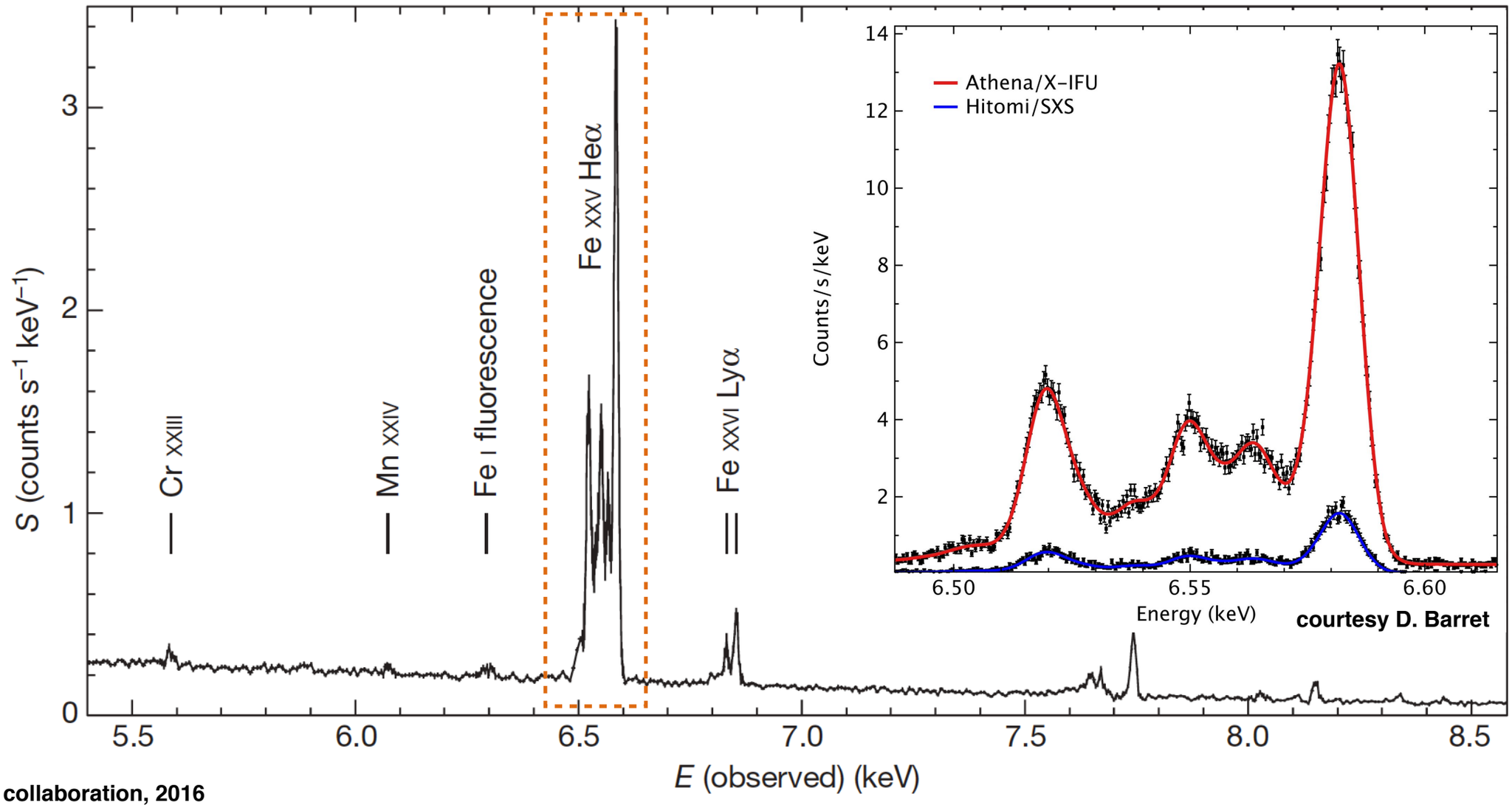






Zhuravleva+13

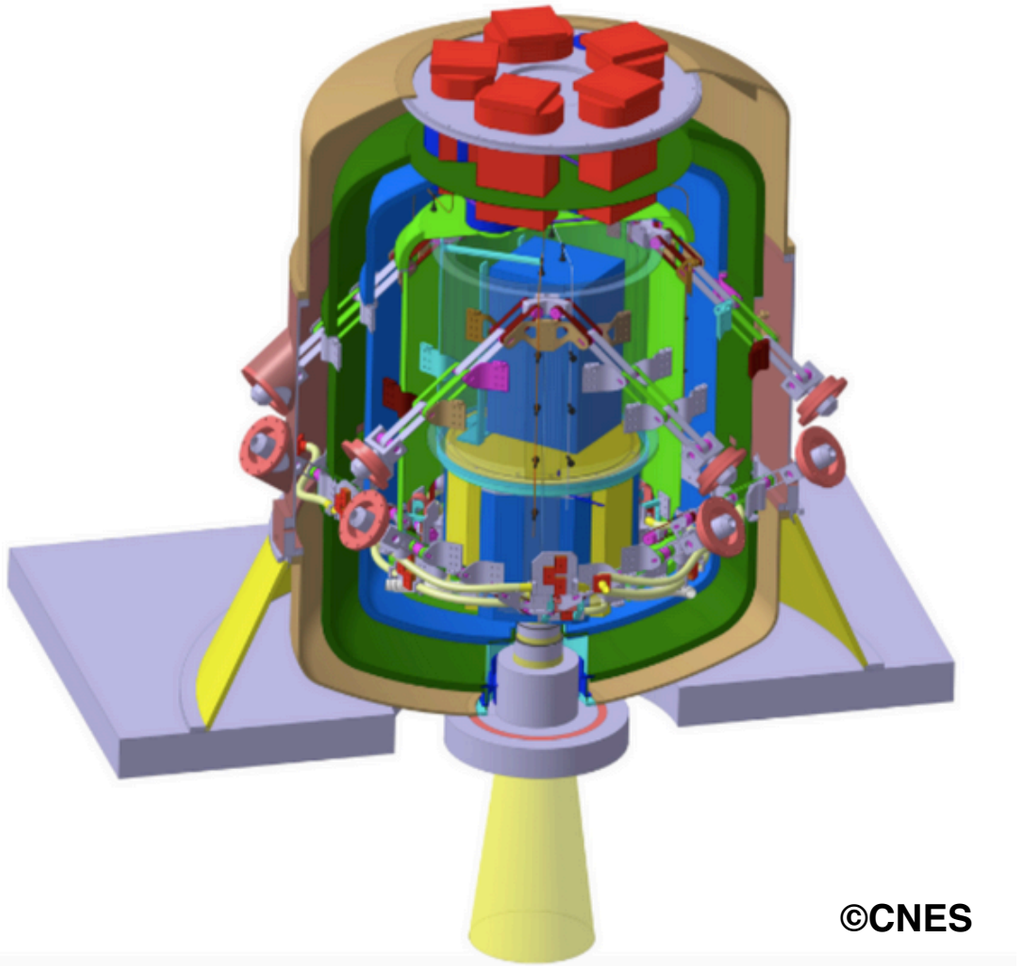
The power of X-ray spectroscopy

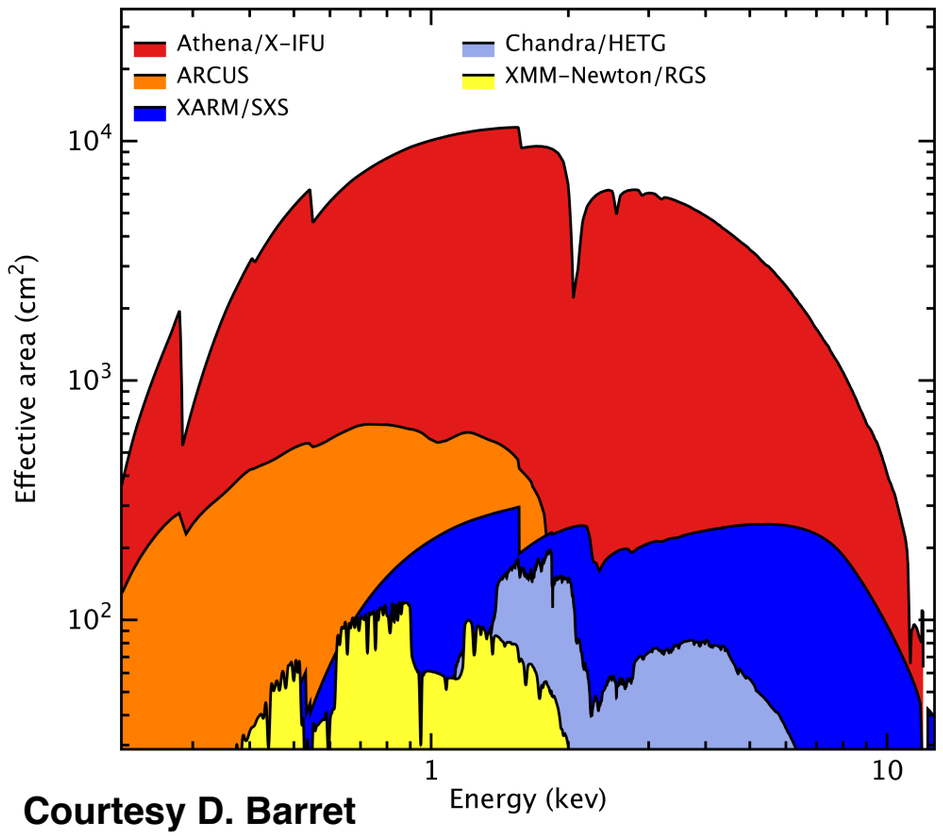


Hitomi collaboration, 2016

The X-ray Integral Field Unit

- Cryogenic imaging spectrometer (IFU)
- Micro-calorimeter based instrument
- 50mK cooled detector plane
- Developed by a consortium of >11 countries



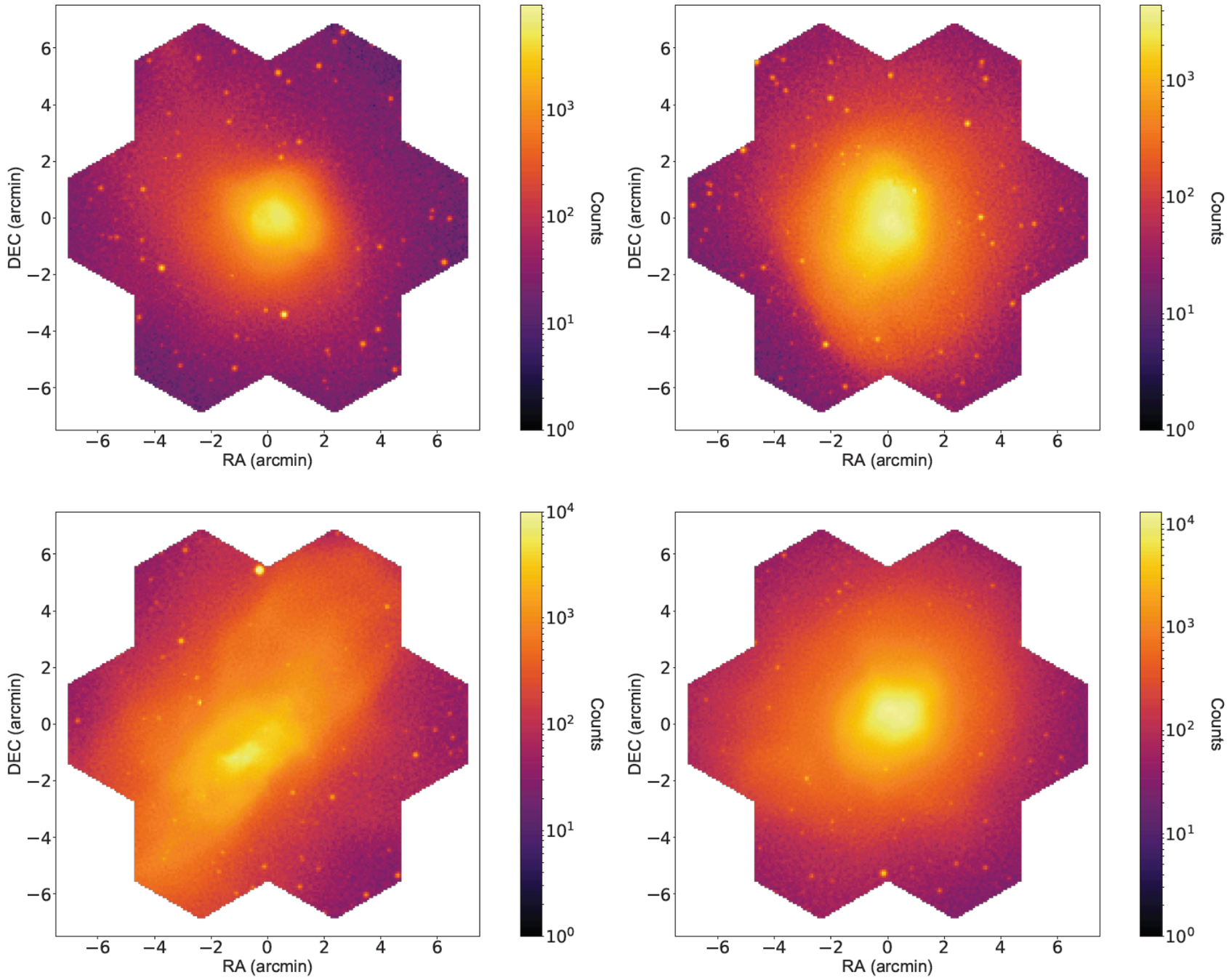


Courtesy D. Barret

Effective area	1.4m² @ 1keV
Spatial resolution	5″
Field-of-view	5′ (eq. diameter)
Spectral resolution	2.5eV @ <7keV

Properties of the ICM

- Observing clusters with X - IFU? Simulations are crucial!



Sample of 4 clusters

- $z = 0.1$
- $M = 10^{14}\ M_{sun}$

Simulated using the instrument E2E simulator SIXTE (Schmidt et al. 2012, Wilms et al. 2014)

Cucchetti+18 (A&A) in prep
Hydrodynamical simulations: S. Borgani, E. Rasia, V. Biffi

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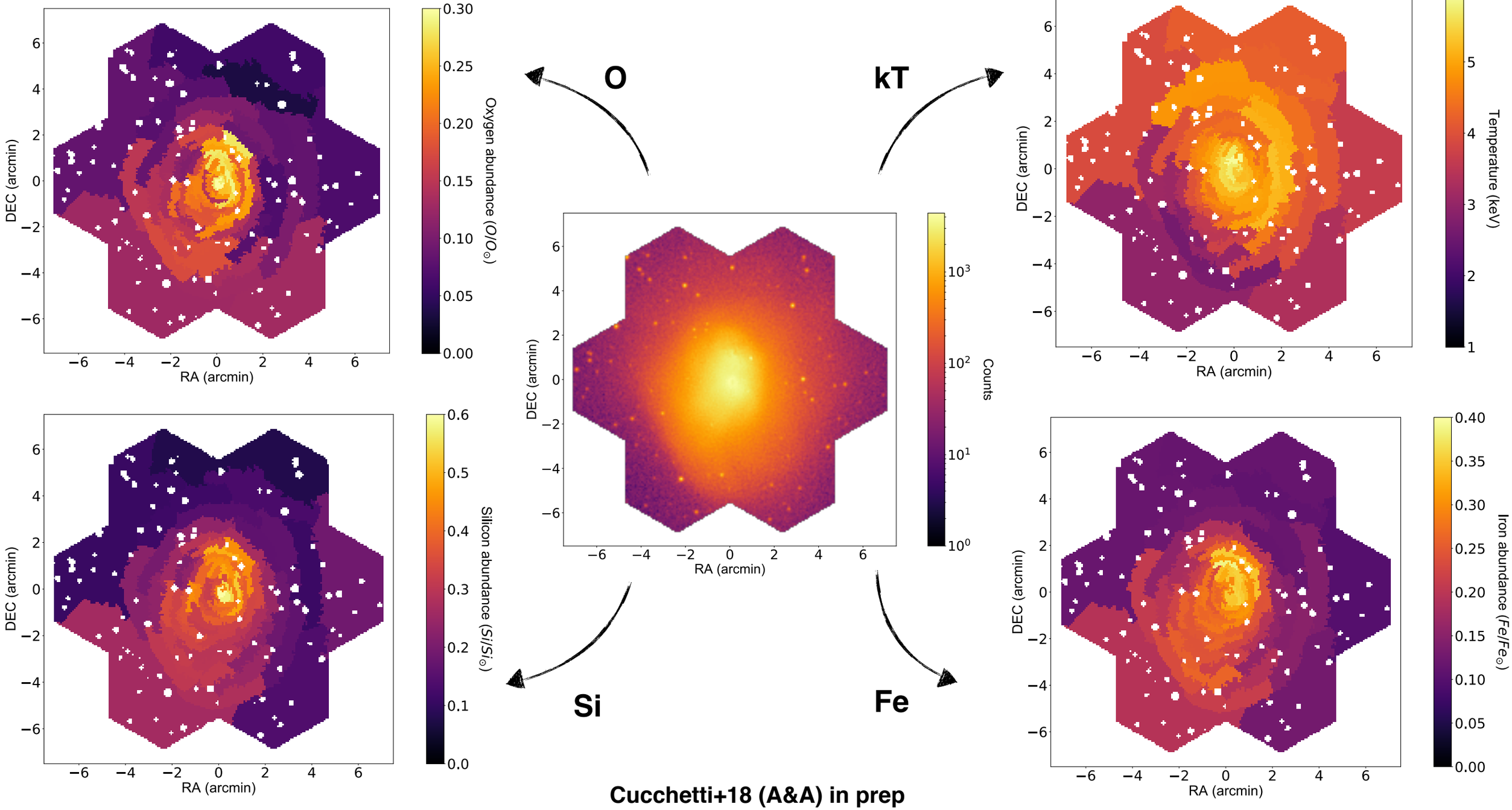
Properties of the ICM

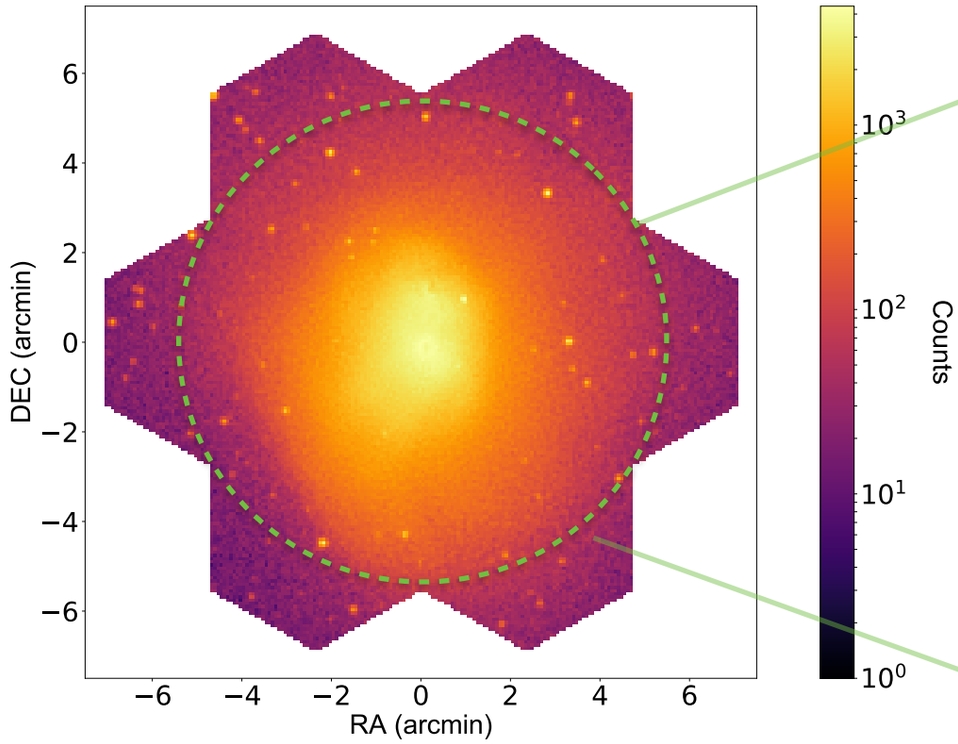


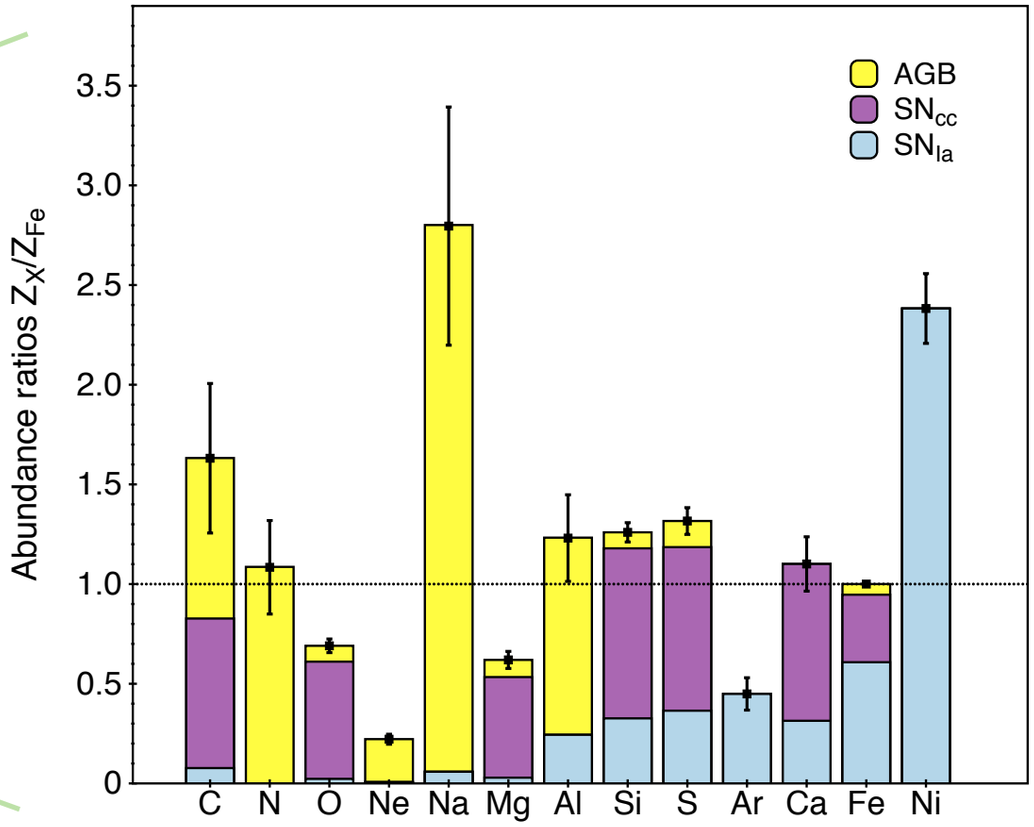
Cucchetti+18 (A&A) in prep

Enrichment of the ICM

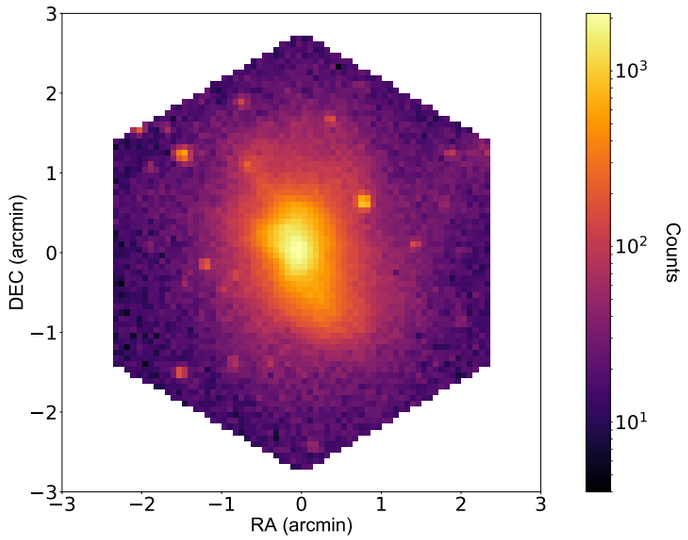
- Study how the ICM was enriched
  - Measurements of SNe yields through abundance ratios
  - Constrain metal formation

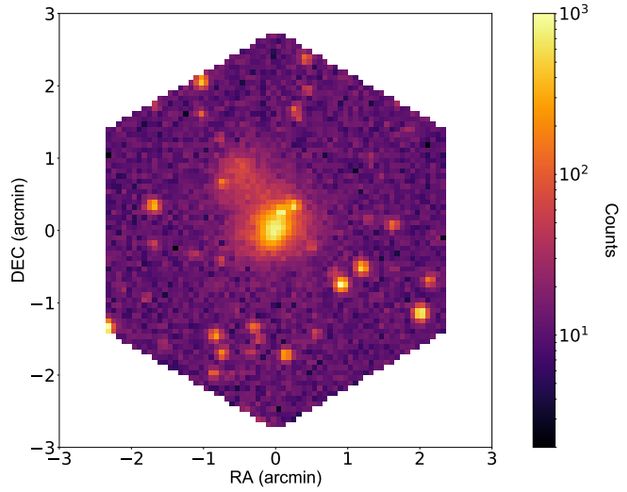
Cucchetti+18 (A&A) in prep

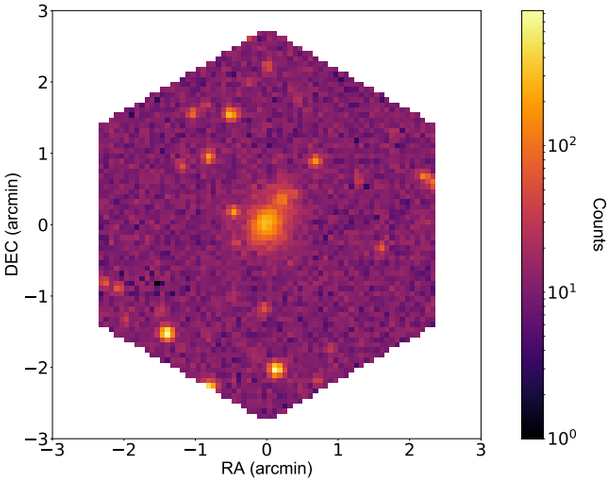


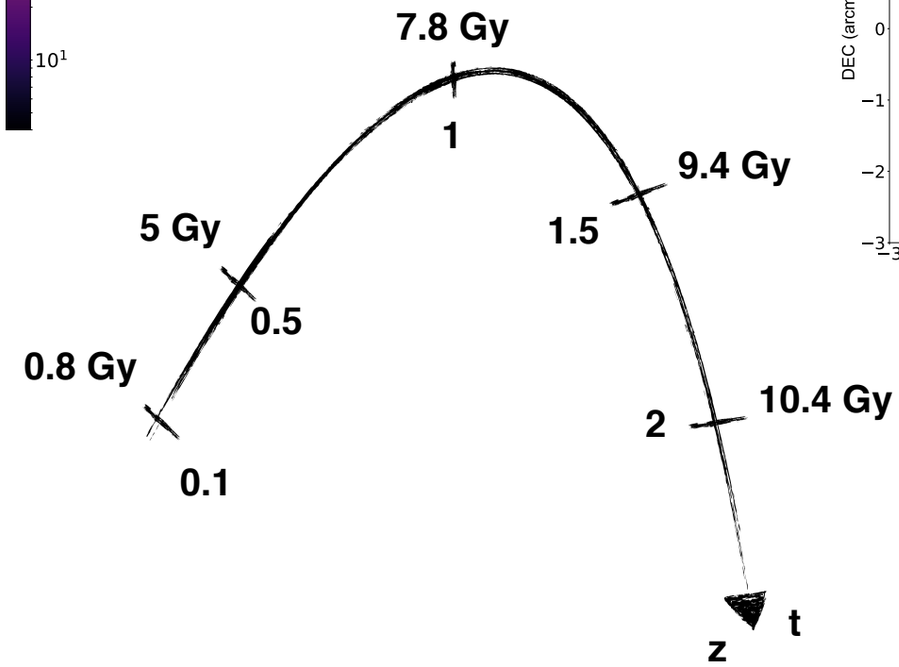


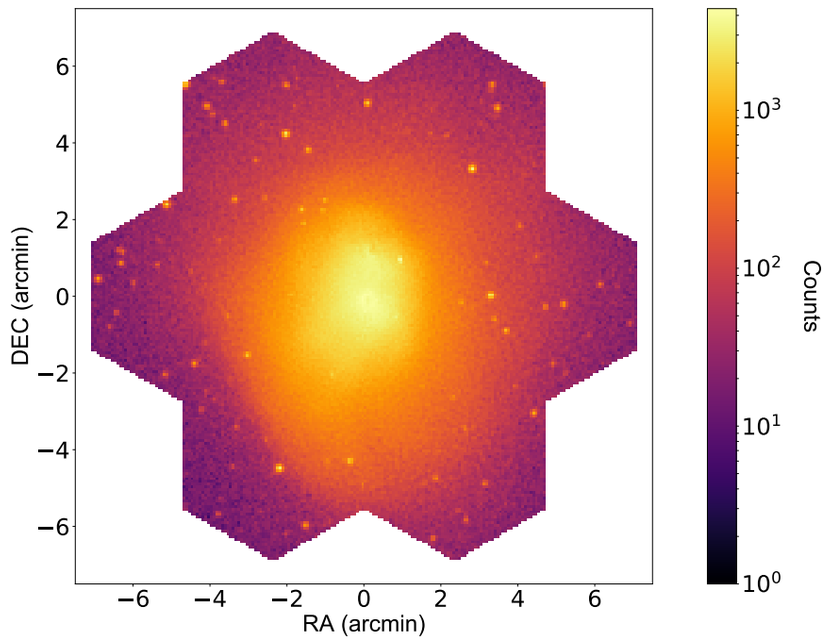
Enrichment of the ICM through time

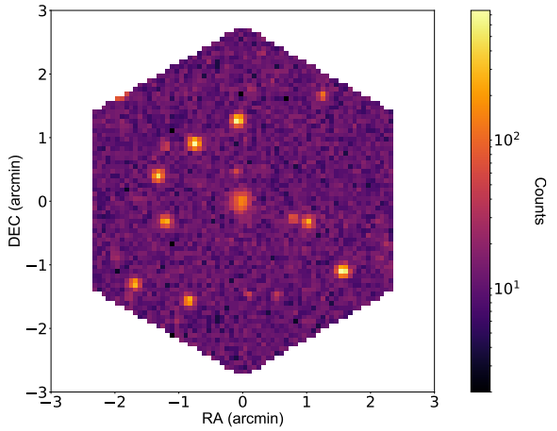








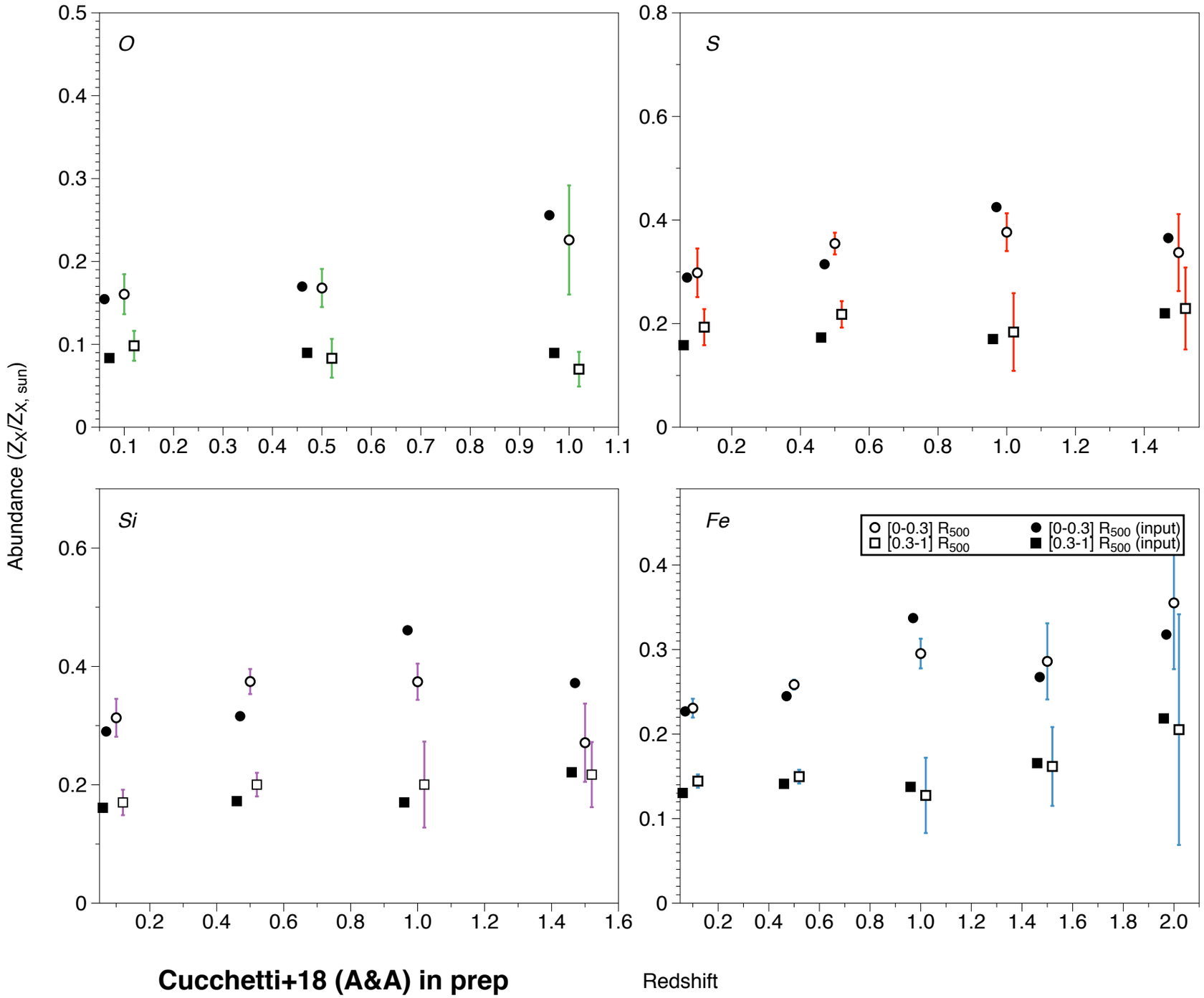




Enrichment of the ICM through time

- Enrichment through time
  - Discover how the Universe evolved
  - Constrain how and when metal production was made

- Study the dynamical evolution of the cluster



Cucchetti+18 (A&A) in prep

Summary and outlooks

- Cluster physics is still to be explored!
- A high resolution IFU is needed!

- The X-IFU will provide unprecedented information notably through its spatially-resolved high-resolution spectroscopy

- Measurements of the ICM properties will allow to trace the metallicity of the Universe though cosmic time
- Cluster science is extremely challenging and drives the X-IFU performance

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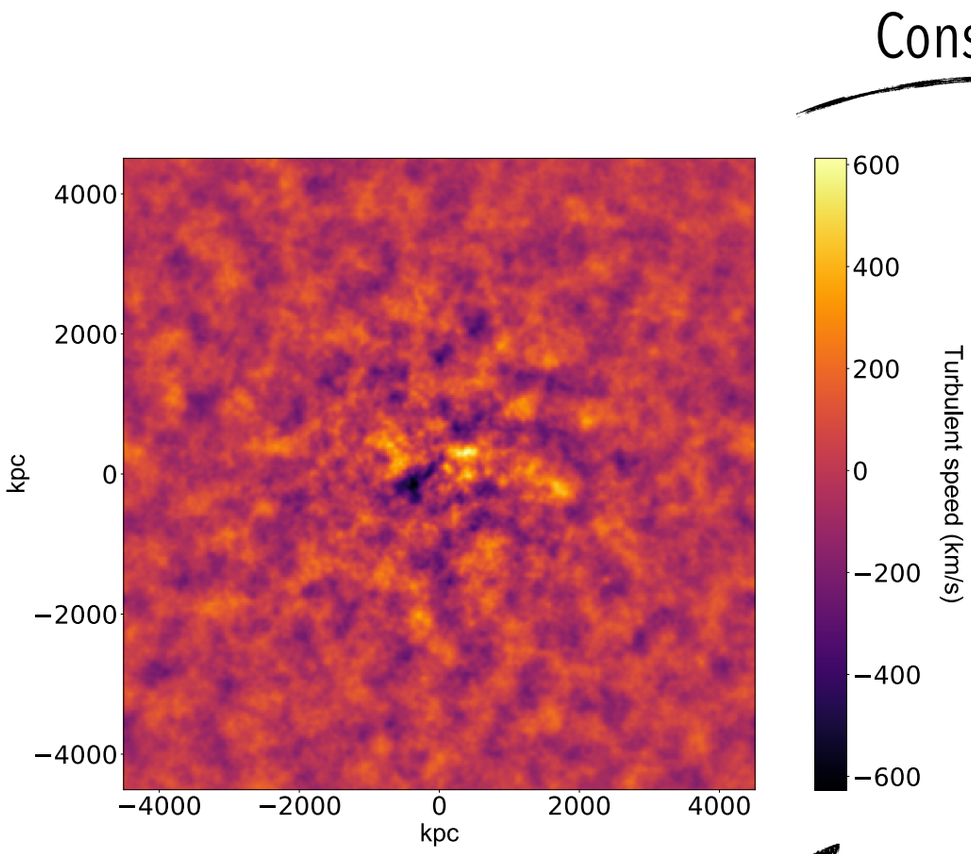
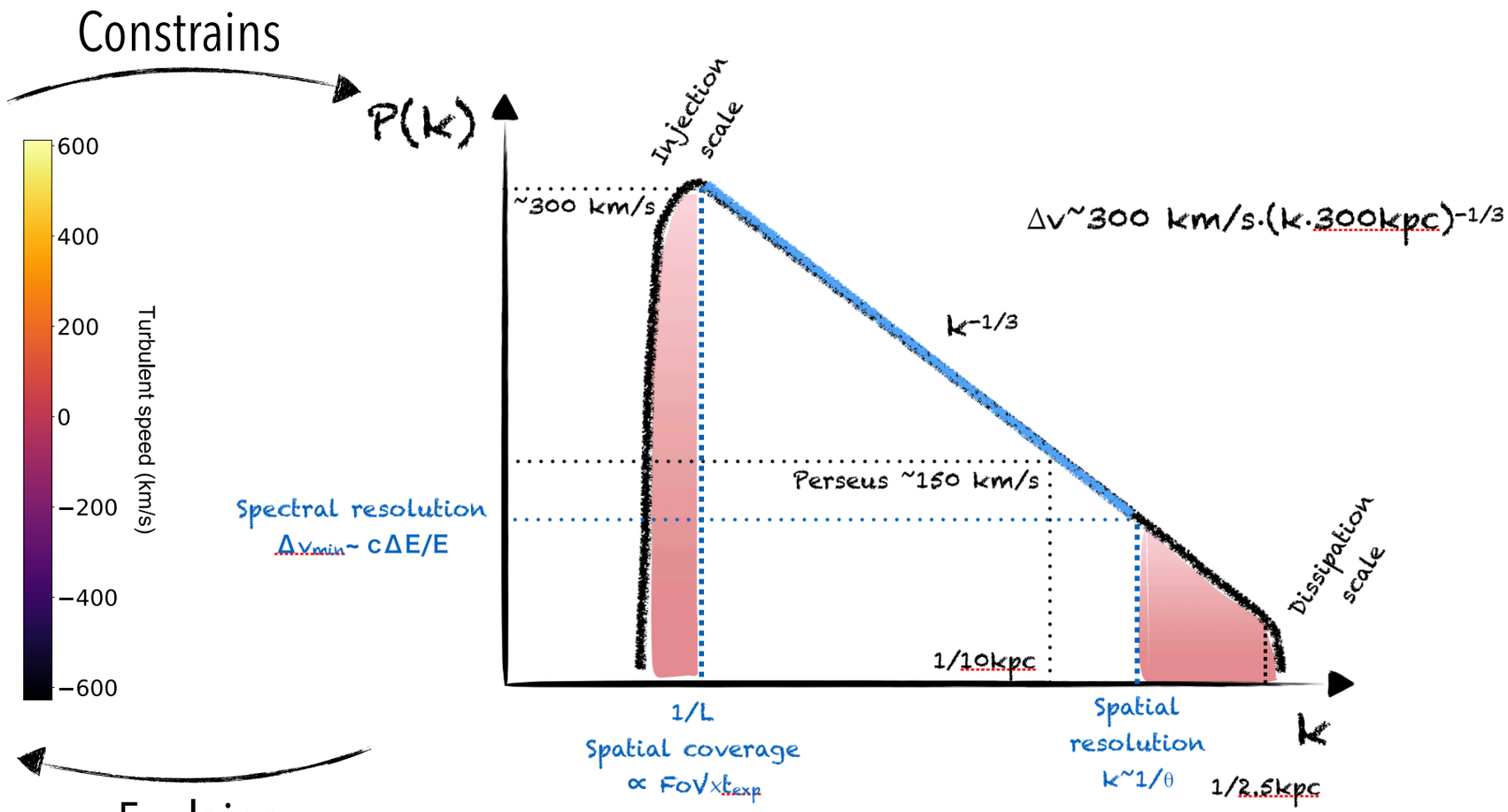
Turbulence in the ICM

- Extend the study to measurements of turbulence in the ICM
  - Accurate redshift reconstruction was demonstrated
  - Can we constrain the power spectrum of the ICM? The cosmic variance?

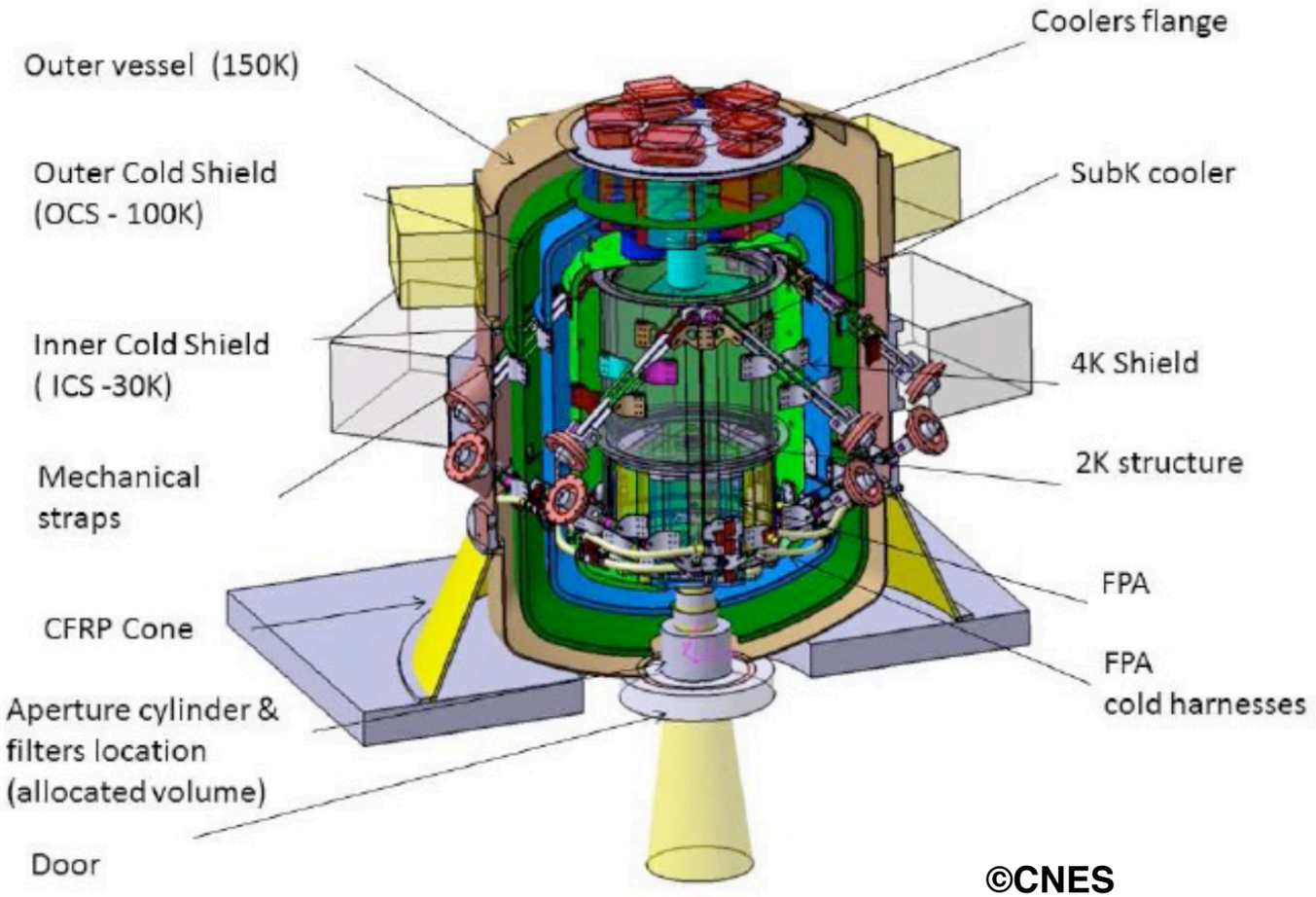


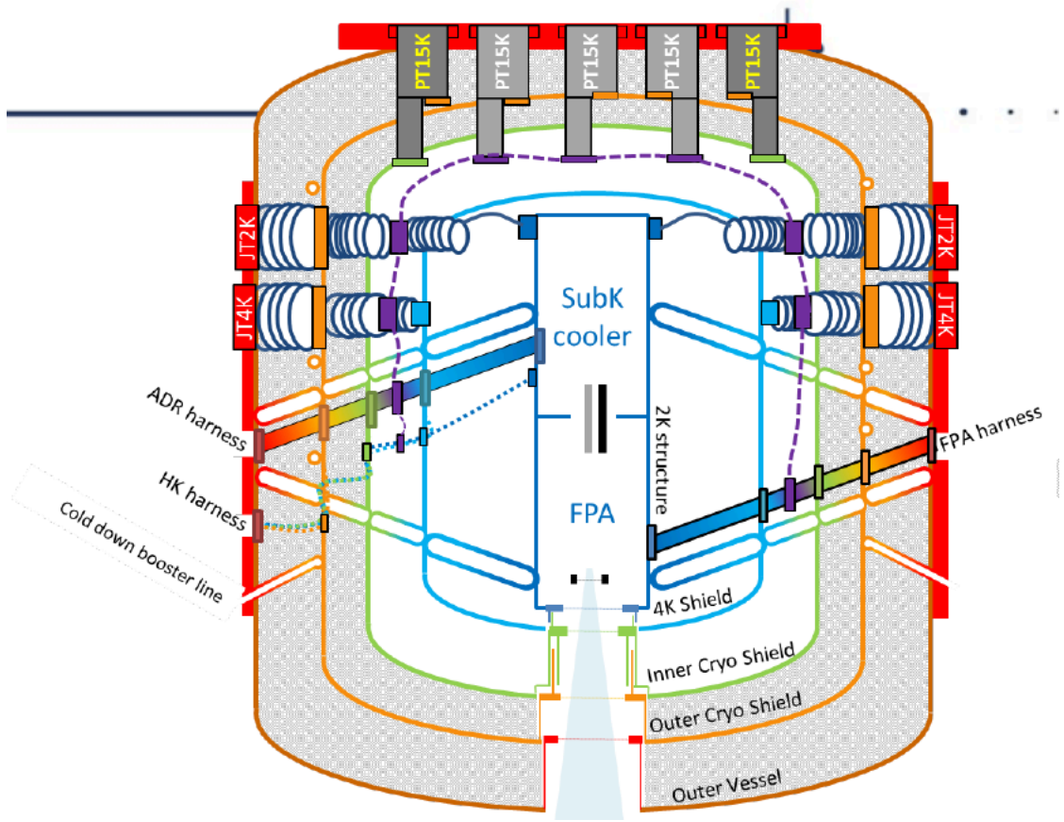


Discussion with E. Churazov and SWG1-1 members

The X-ray Integral Field Unit

- Cryogenic instrument @50mK
- 800kg of total mass





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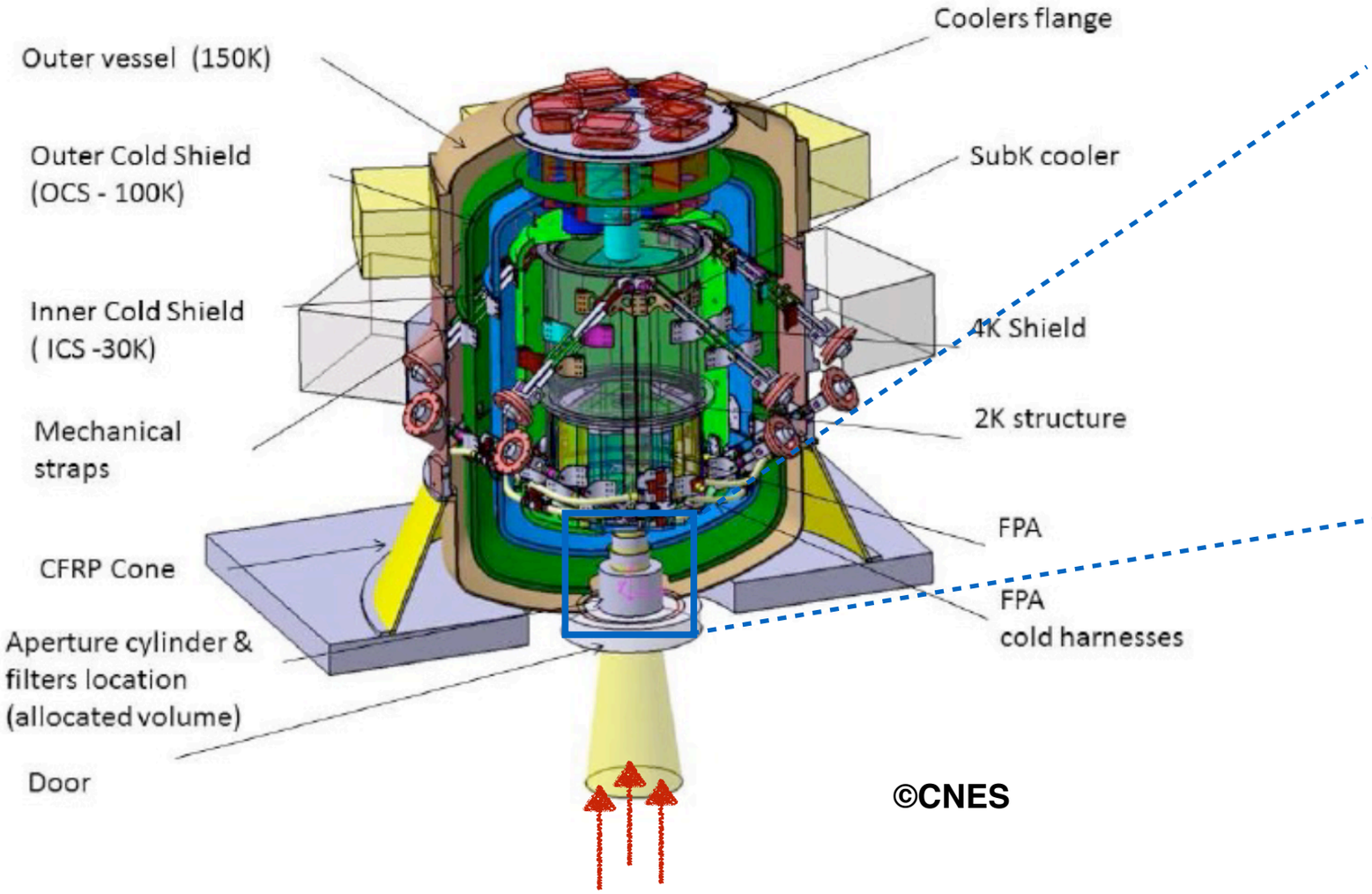
The X-ray Integral Field Unit

- Aperture cylinder focuses the light into the instrument
- 5 filters to cut IR/visible light
- Low-energy cut of the instrument



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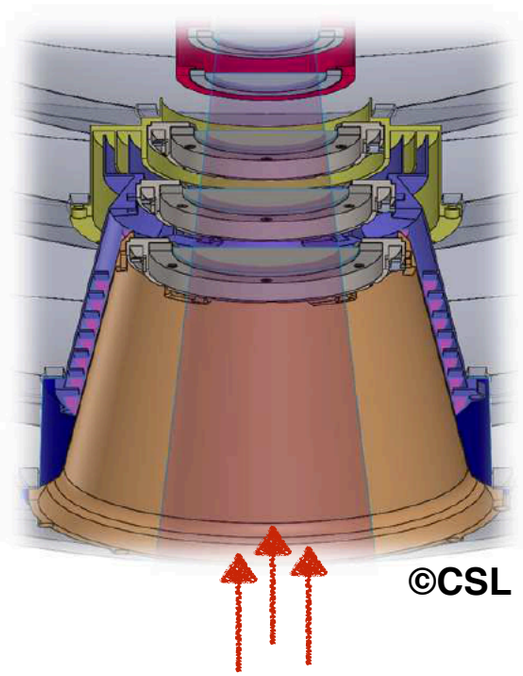

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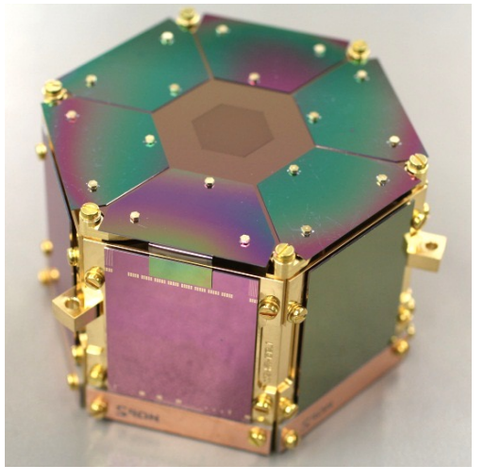
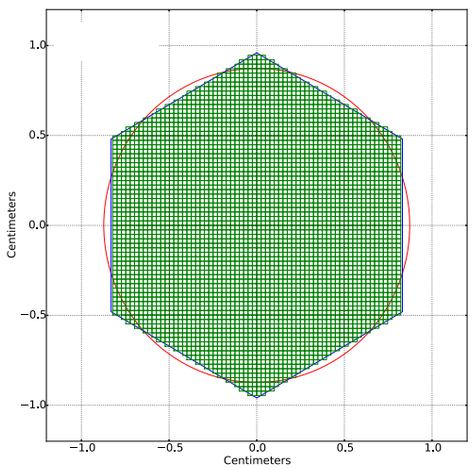
The X-ray Integral Field Unit

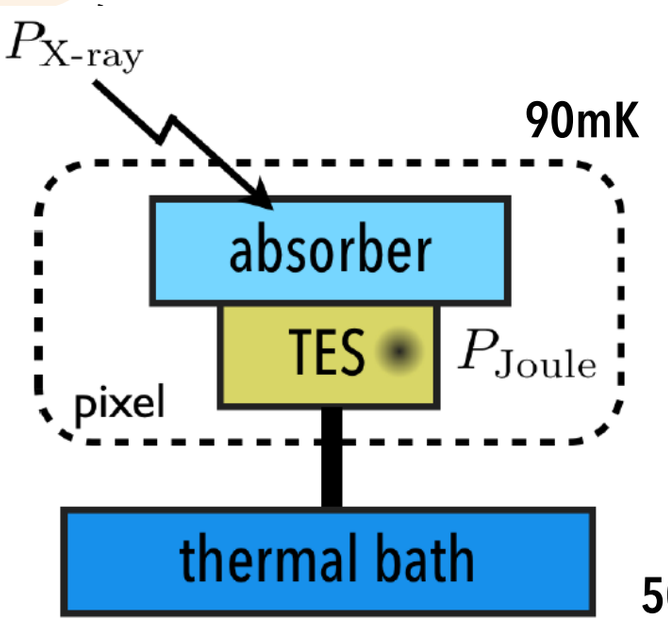




Smith et al. 2016

Calorimetric detection

Array of 3840 superconducting TES
Absorbed photon=Temperature rise



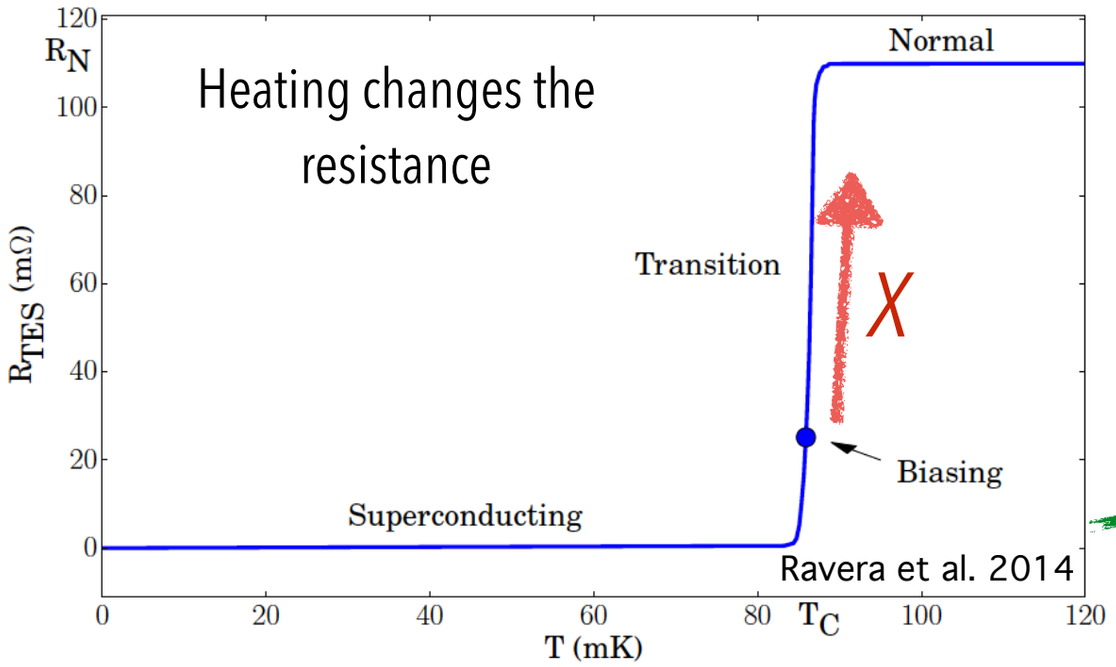
Peille 2016

X

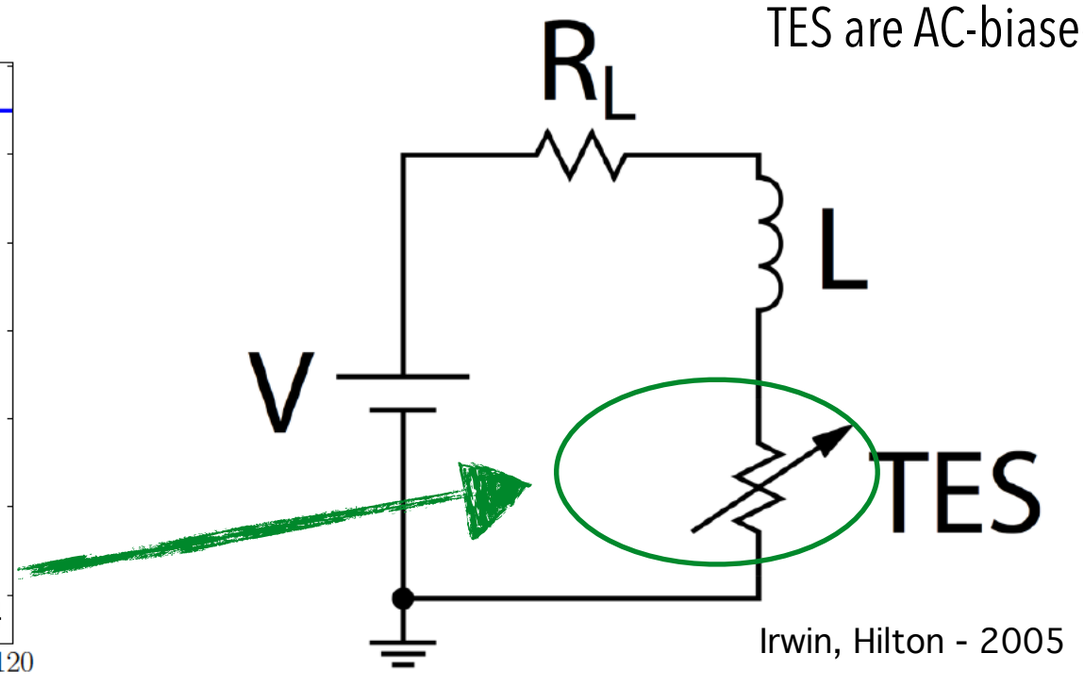
TES array

Anti-coincidence detector

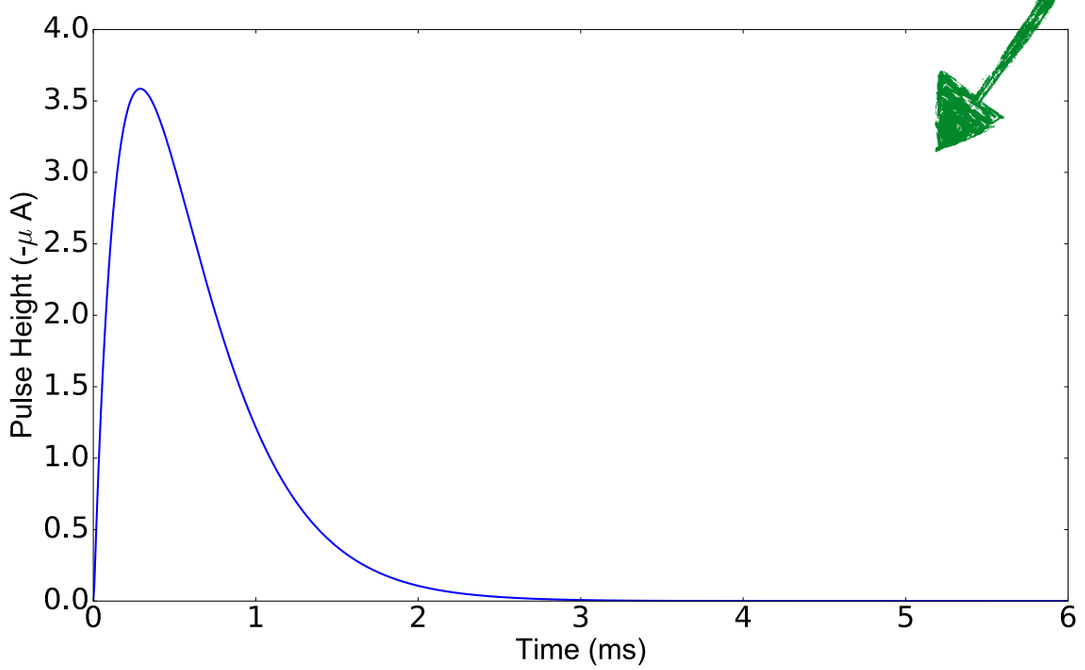
The X-ray Integral Field Unit



TES are AC-biased



Irwin, Hilton - 2005



Photon impact

=

Current pulse

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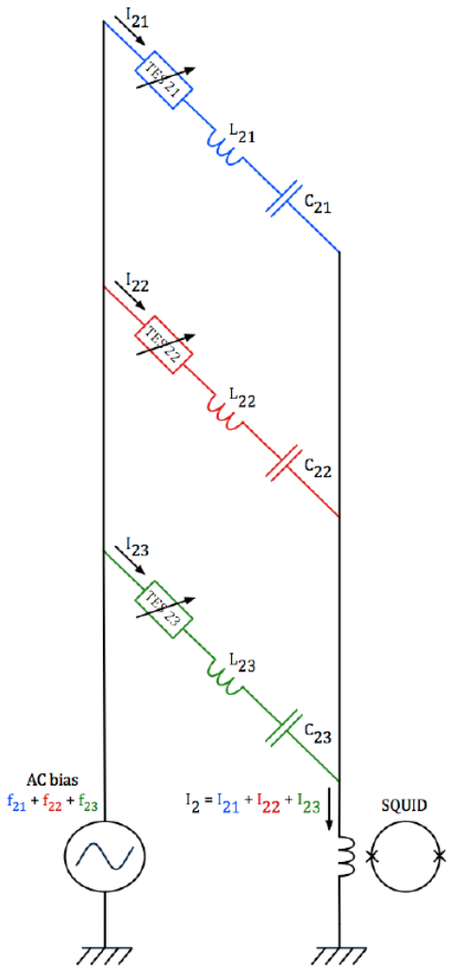
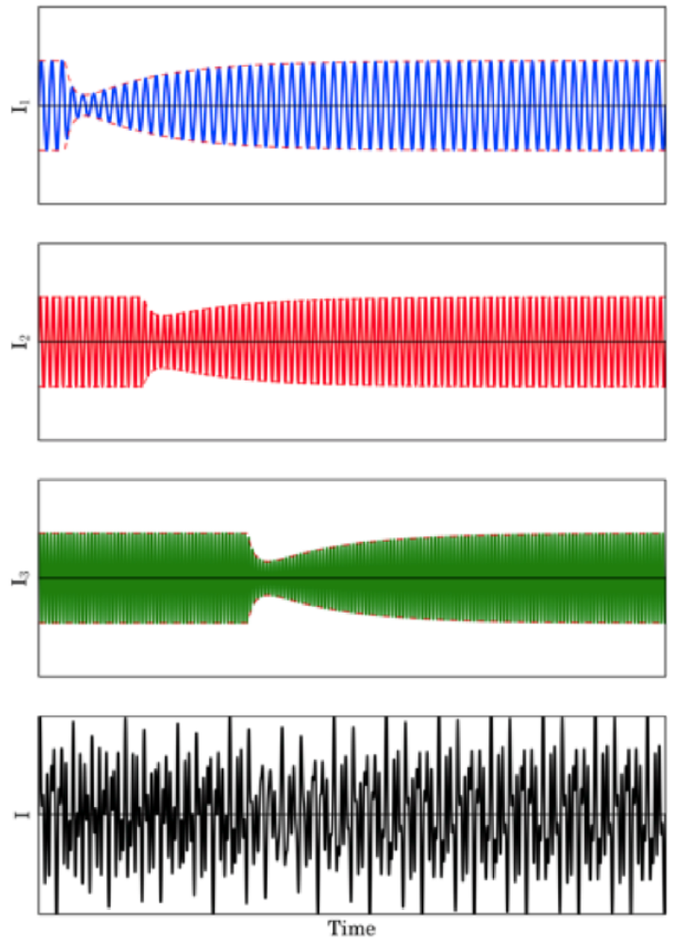
Principle of detection - FDM

- Each TES is AC-biased
- Readout scheme:
  Frequency Domain Multiplexing (FDM)
- One frequency carrier per pixel ([1-5] MHz)
- 96 channels of 40 pixels
- Pulse processing and grading
- Obtain the “Pulse-Height” of the event





Ravera+14