The X-ray Universe 2017, 8th June 2017, Rome, Italy

Radial distribution of metals in the hot intra-cluster medium as observed by XMM-Newton

arXiv:1703.01183
(A&A, in press)

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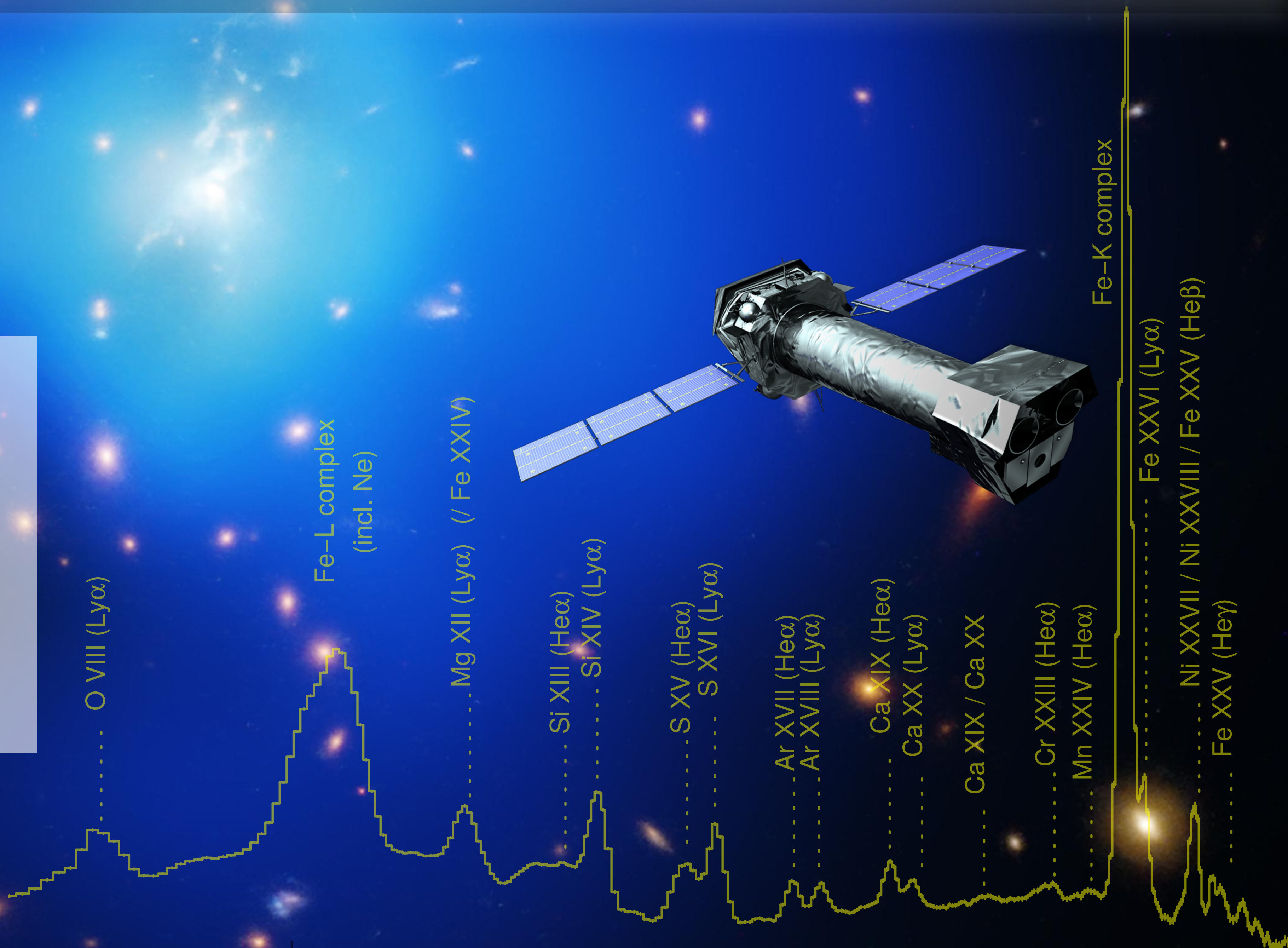
A. Simionescu, and N. Werner

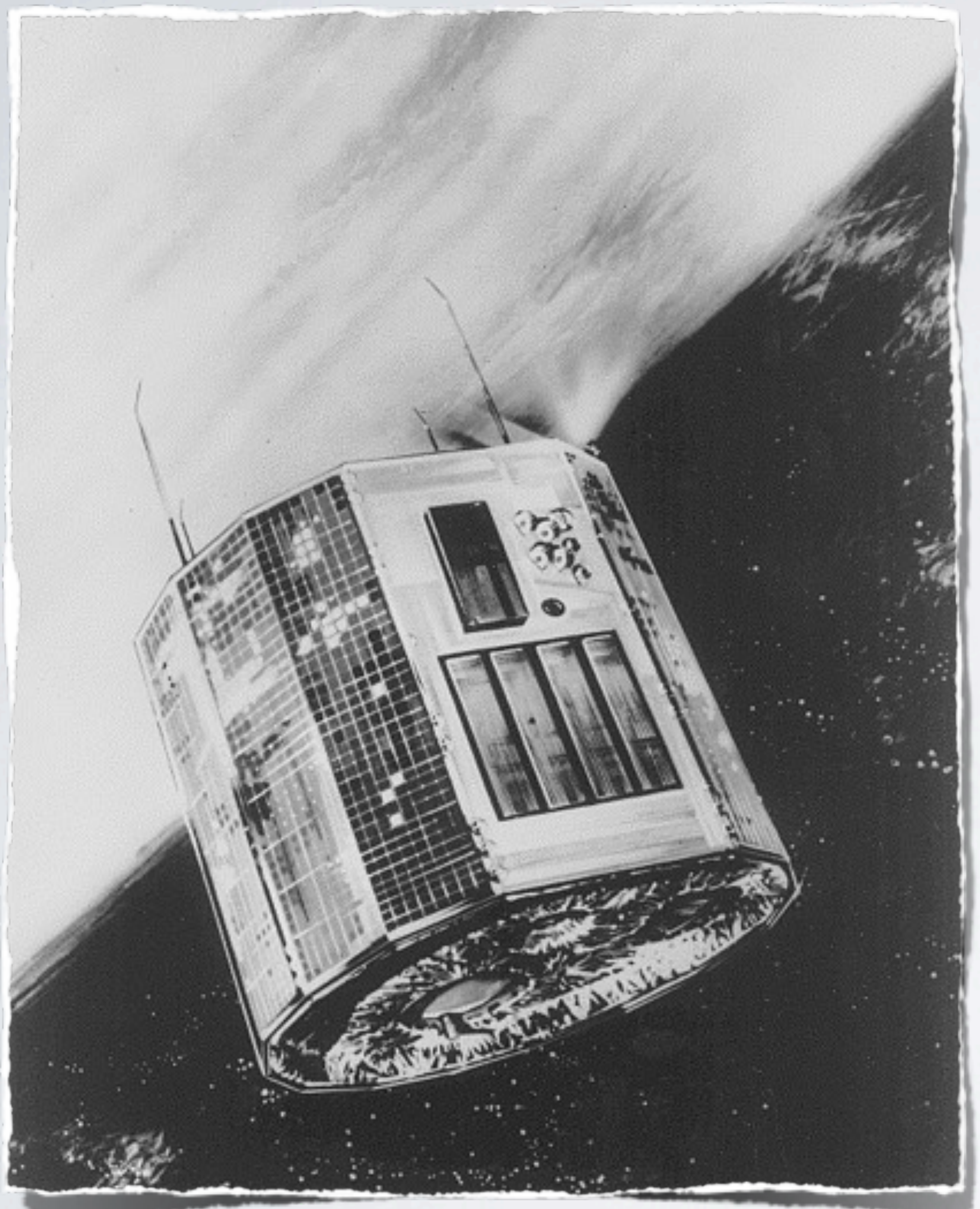


Sterrewacht Leiden

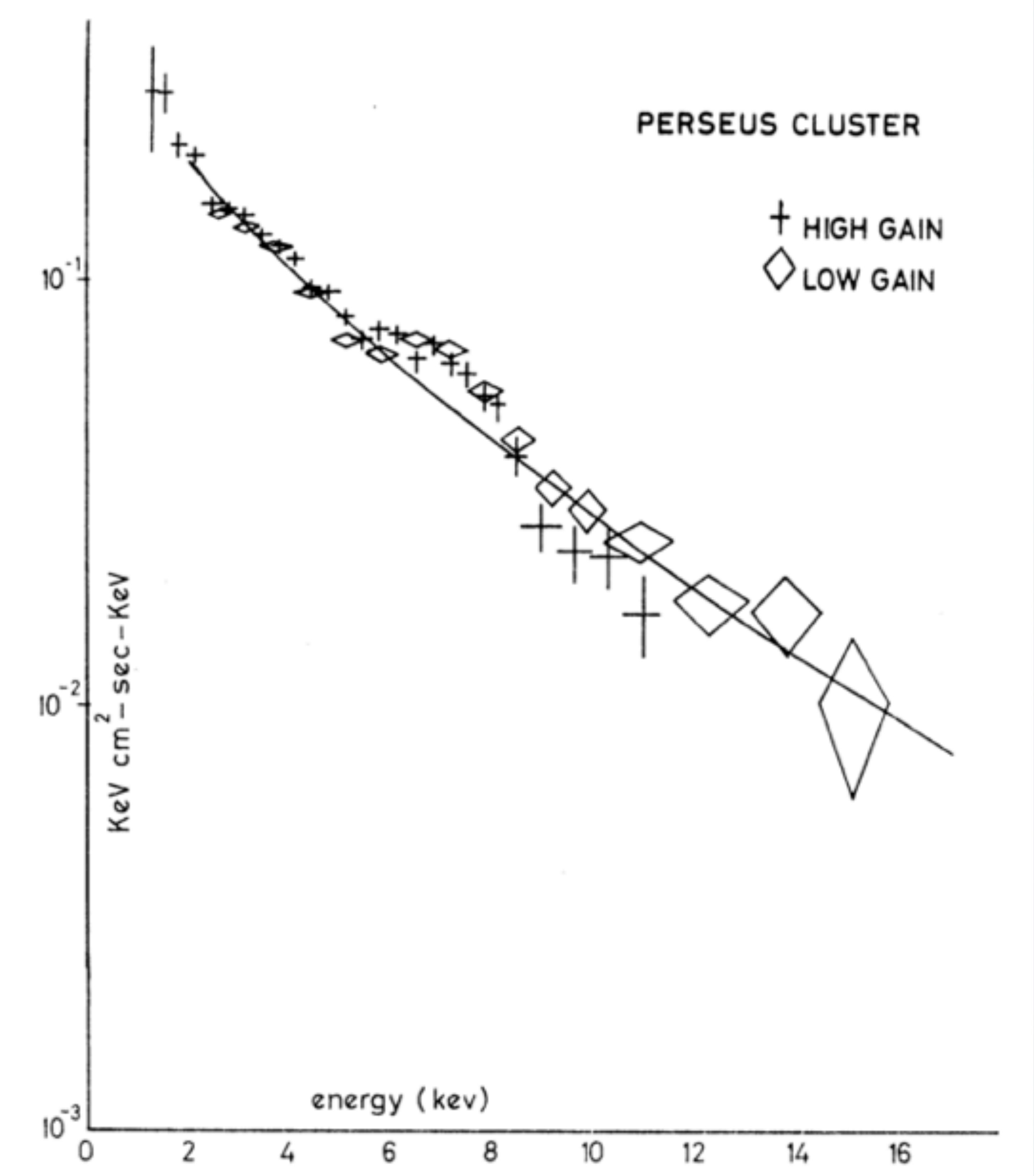
SRON
Netherlands Institute for Space Research

Introduction
&
Motivations

The intra-cluster medium (ICM) contains metals!



Ariel V



Mitchell et al. (1976)

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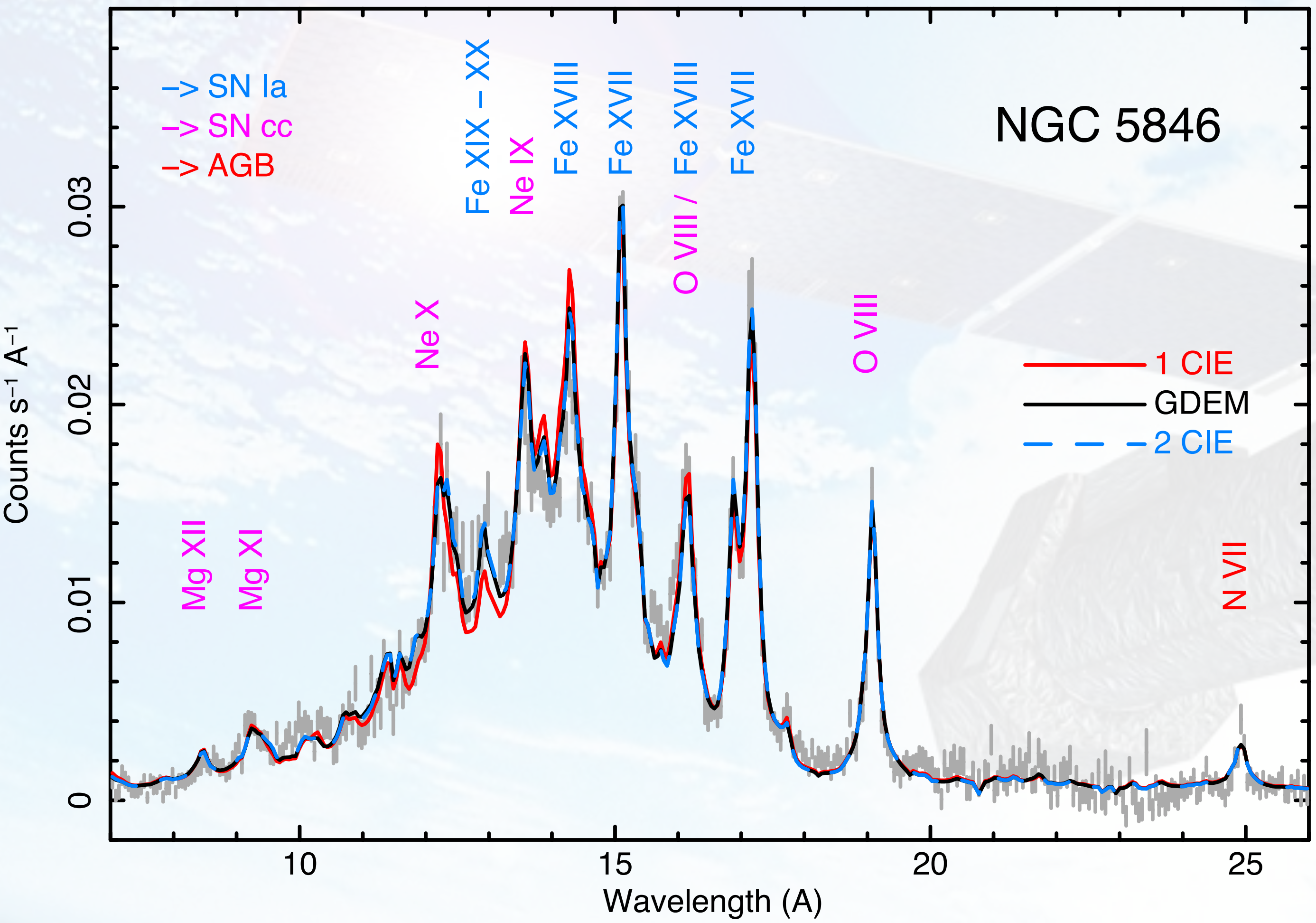
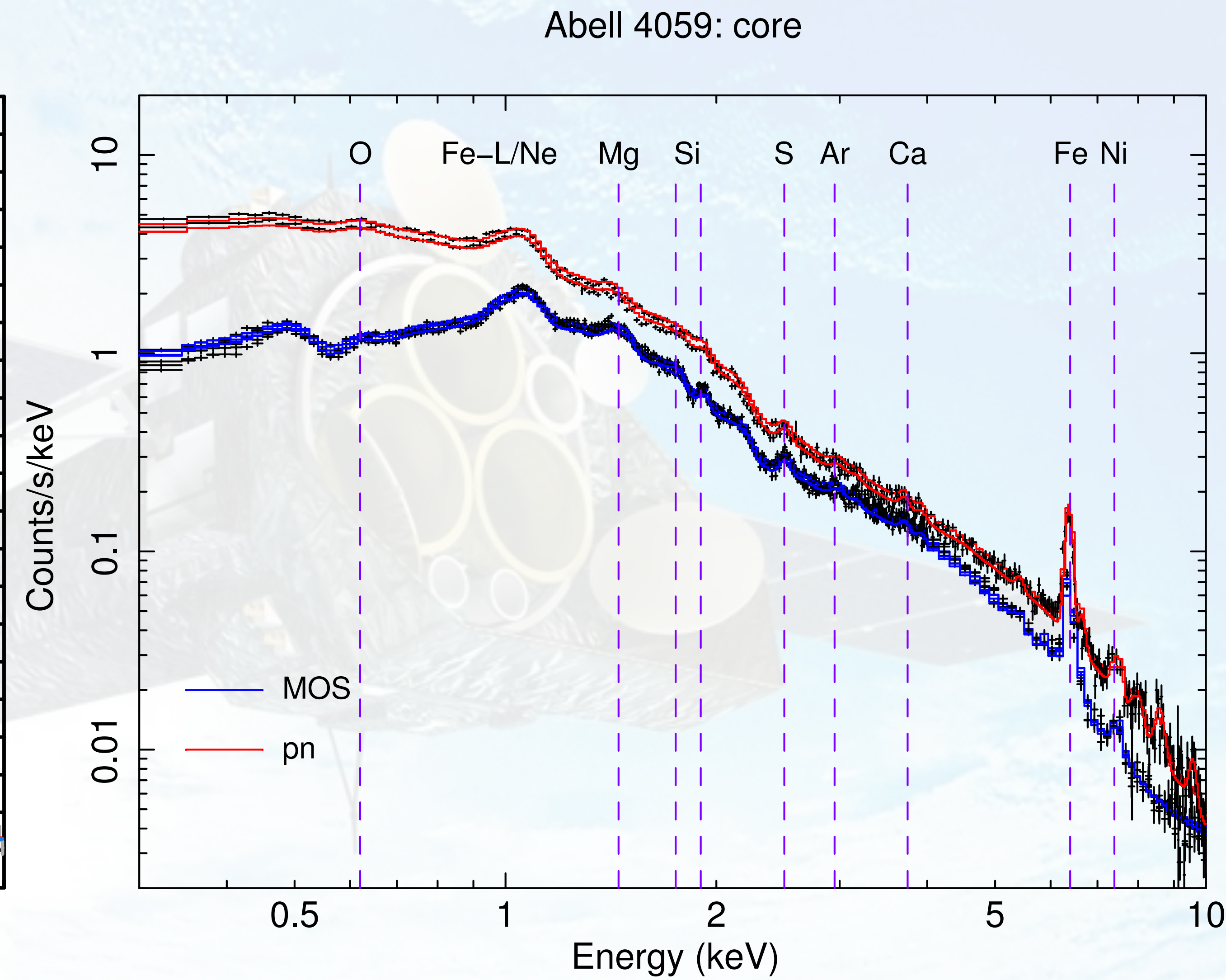


de Plaa et al. (submitted)

RGS



Mernier et al. (2015)

EPIC

The origin of (heavy) chemical elements

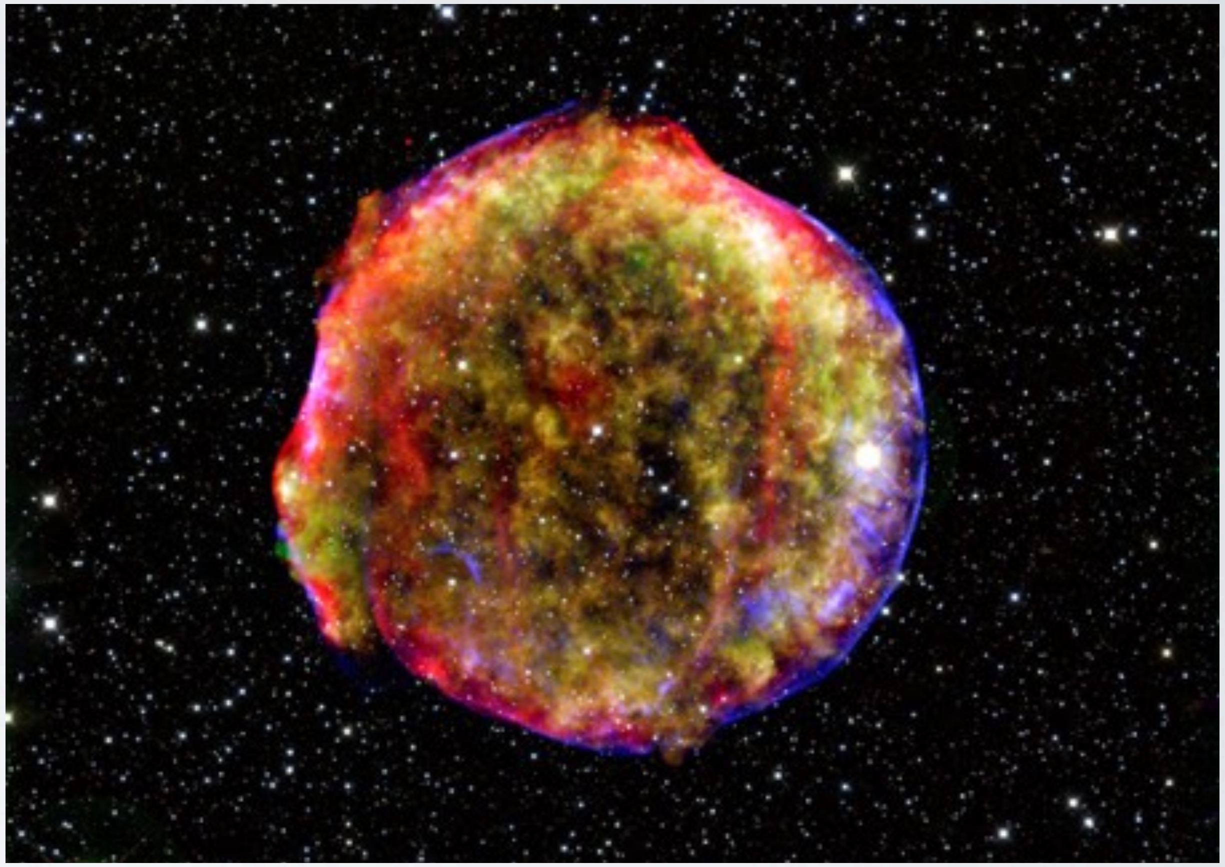
Core collapse supernovae (SNcc)

Produce:

➡ O, Ne, Mg, Si, S

Explode (and enrich) quite fast after star formation

Type Ia supernovae (SNIa)



Produce:

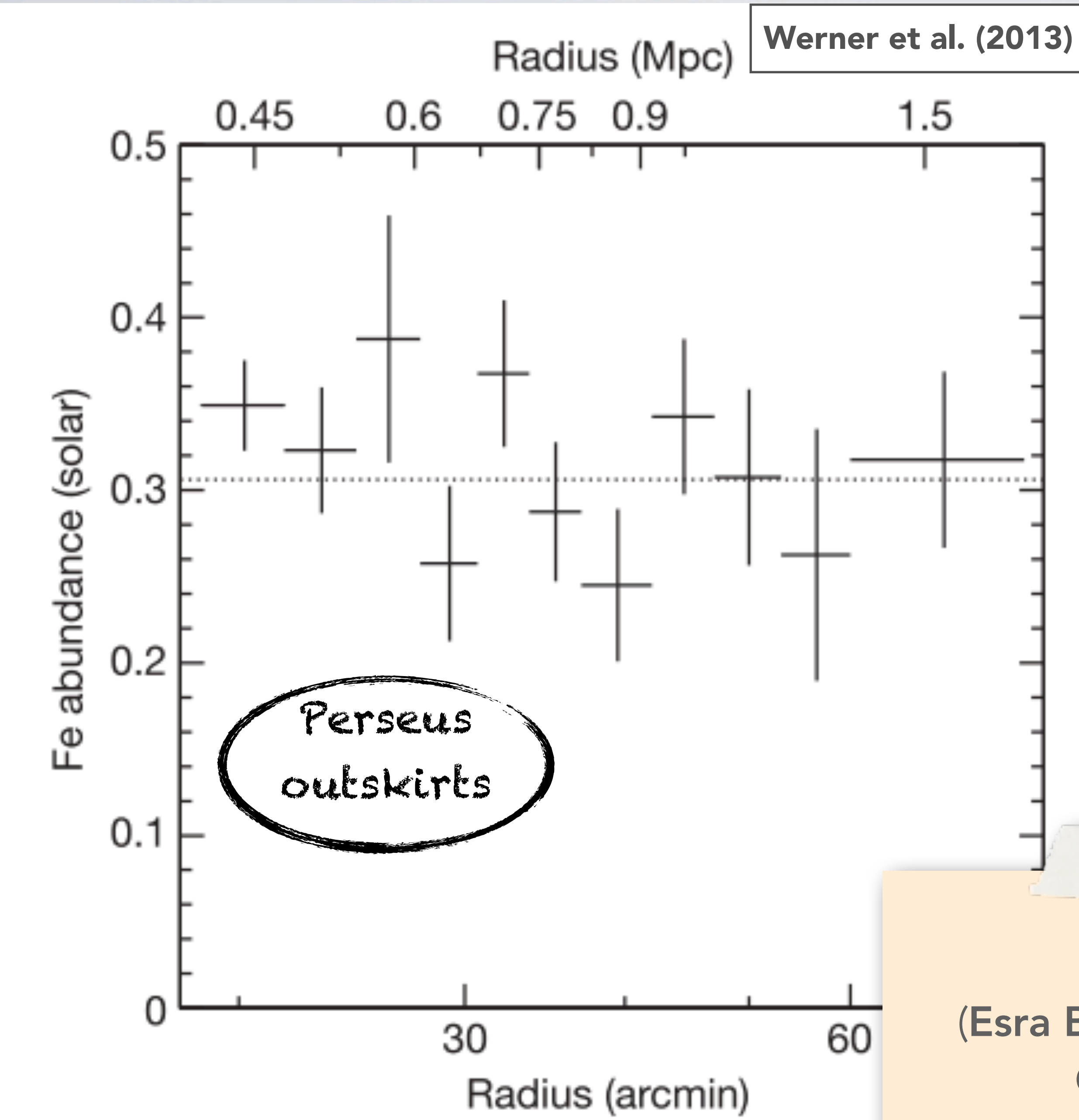
➡ Si, S, Ar, Ca, Fe, Ni

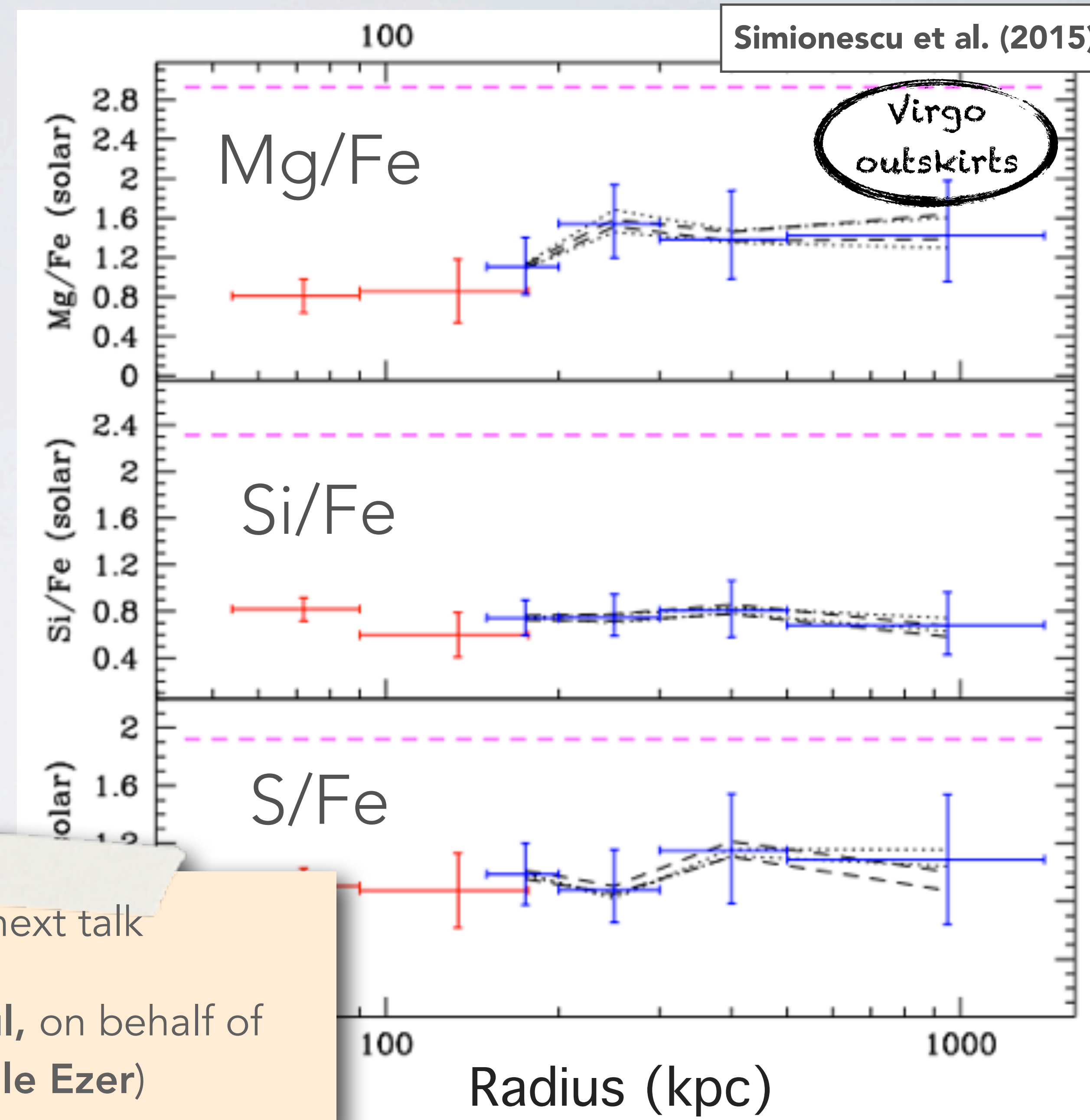
Time delay between star formation and SNIa explosions (?)

Motivation

The ***spatial distribution*** of metals through the ICM provides valuable information on the ***chemical enrichment history*** of galaxy clusters!

Enrichment history in clusters: abundance profiles





See next talk

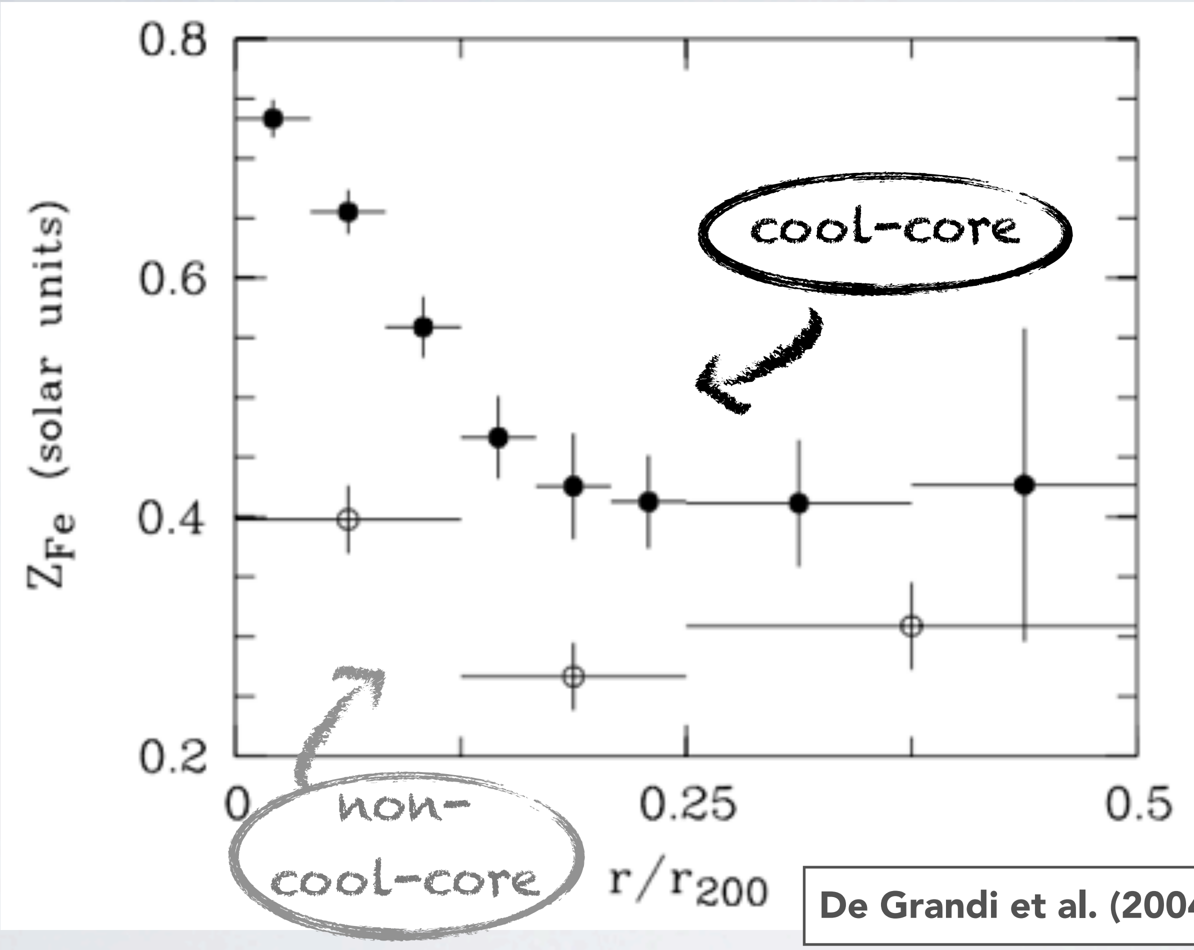
(**Esra Bulbul,** on behalf of **Cemile Ezer**)

1) Early enrichment

➡ **Uniform** abundance distribution in the **outskirts** (SNIa and SNcc)

➡ Metals already in place (and well mixed) at **z > 2-3**

Enrichment history in clusters: abundance profiles



De Grandi et al. (2004)

2) Later enrichment

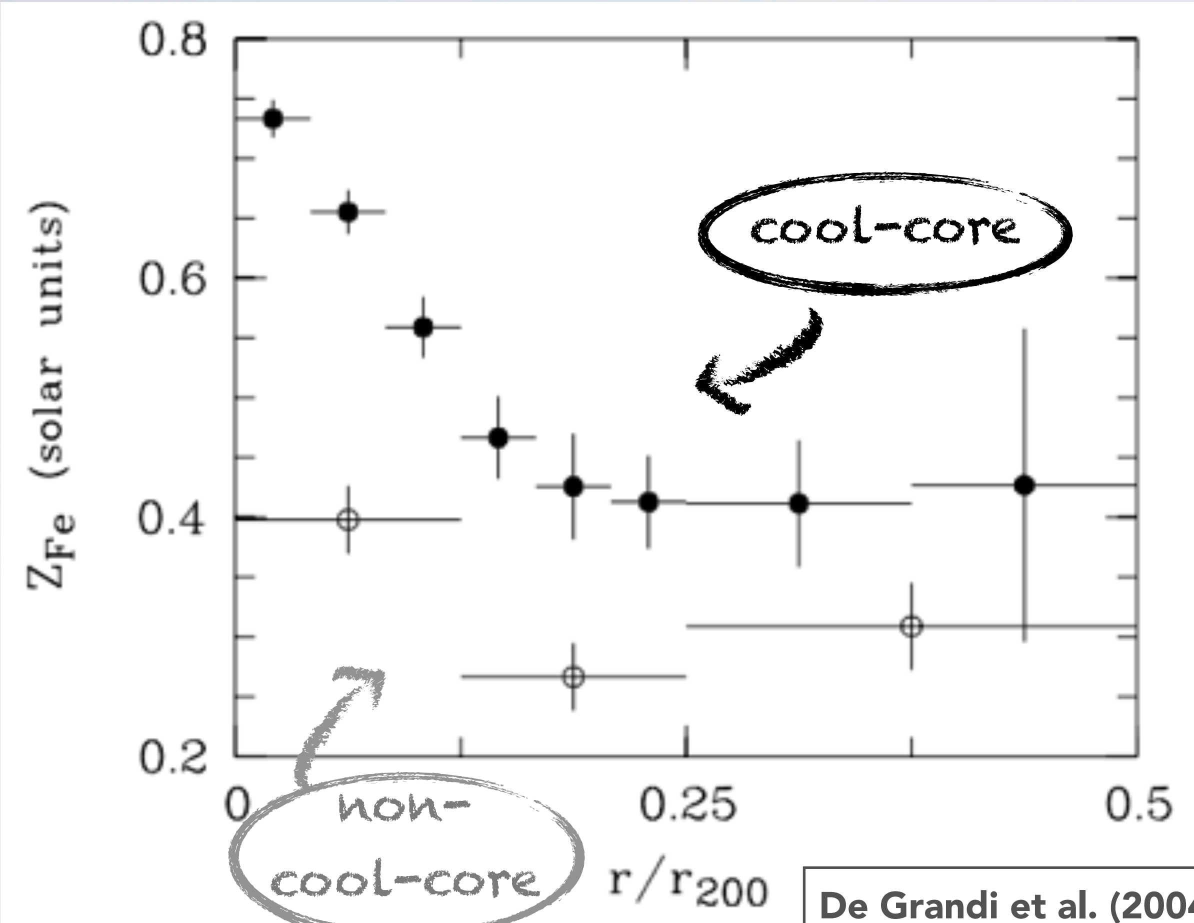
➡ **Peaked** abundance distribution in the **core** (Fe ⇒ SNIa)

➡ Enrichment by SNIa from the central brightest cluster galaxy (BCG) at **z > 1**

(see also: De Grandi et al. 2014)

How about enrichment by **SNcc** in the core?

Enrichment history in clusters: abundance profiles



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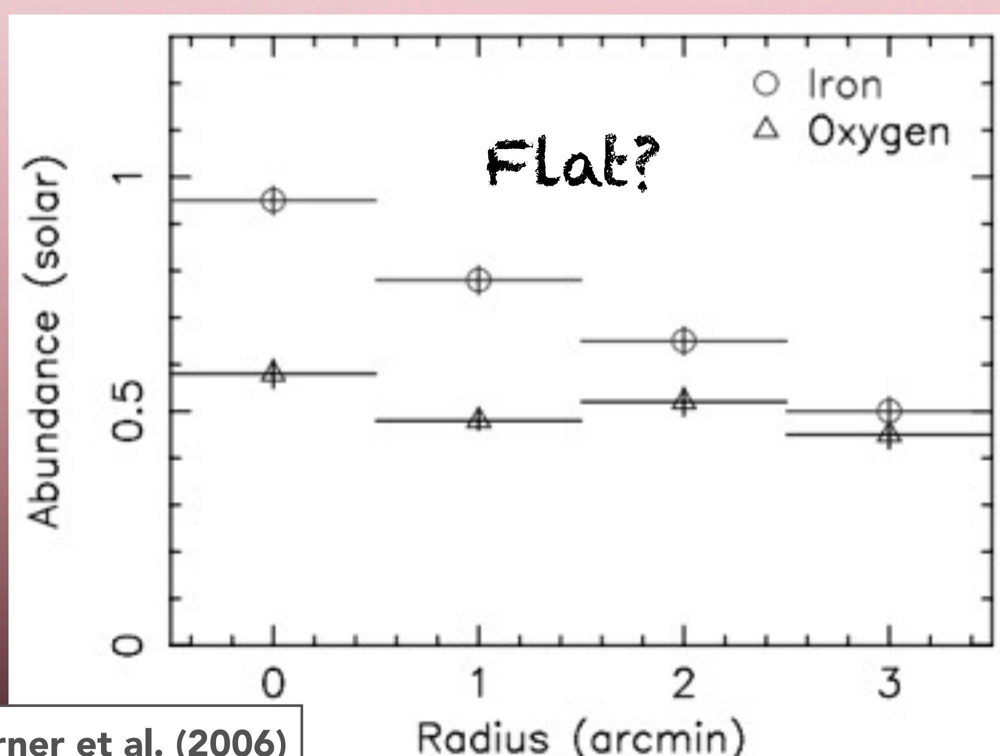
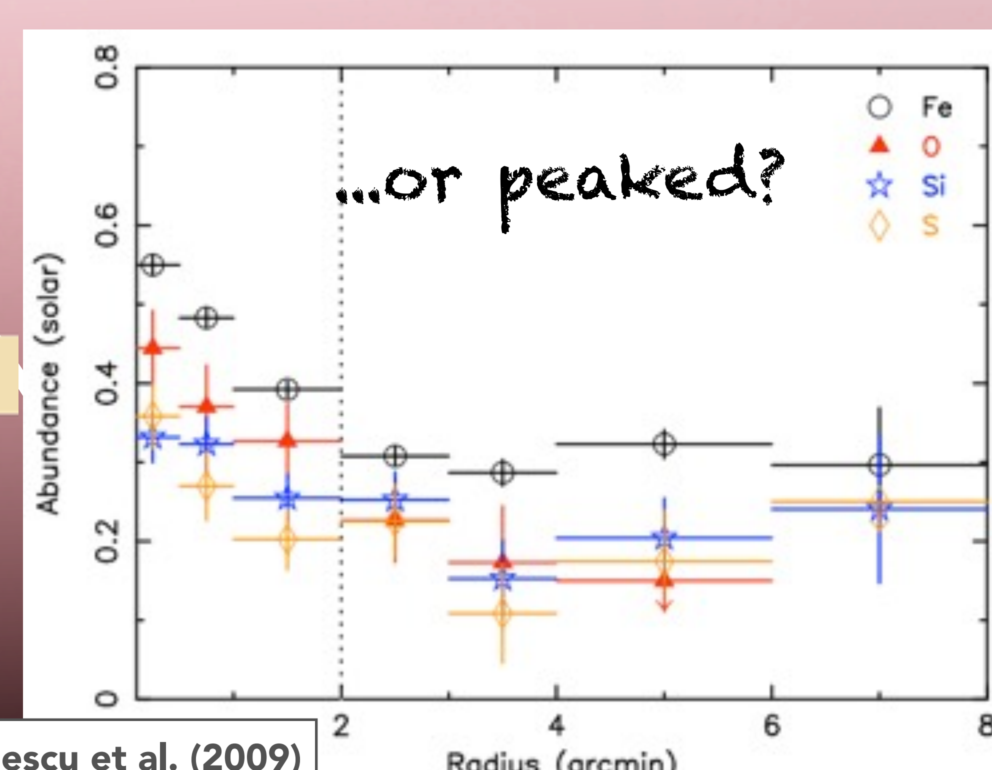


Werner et al. (2006)



Simionescu et al. (2009)

Observations

CHEERS!

CHEERS stands for:
***CHE**mical **E**nrichment **R**gs **S**ample*

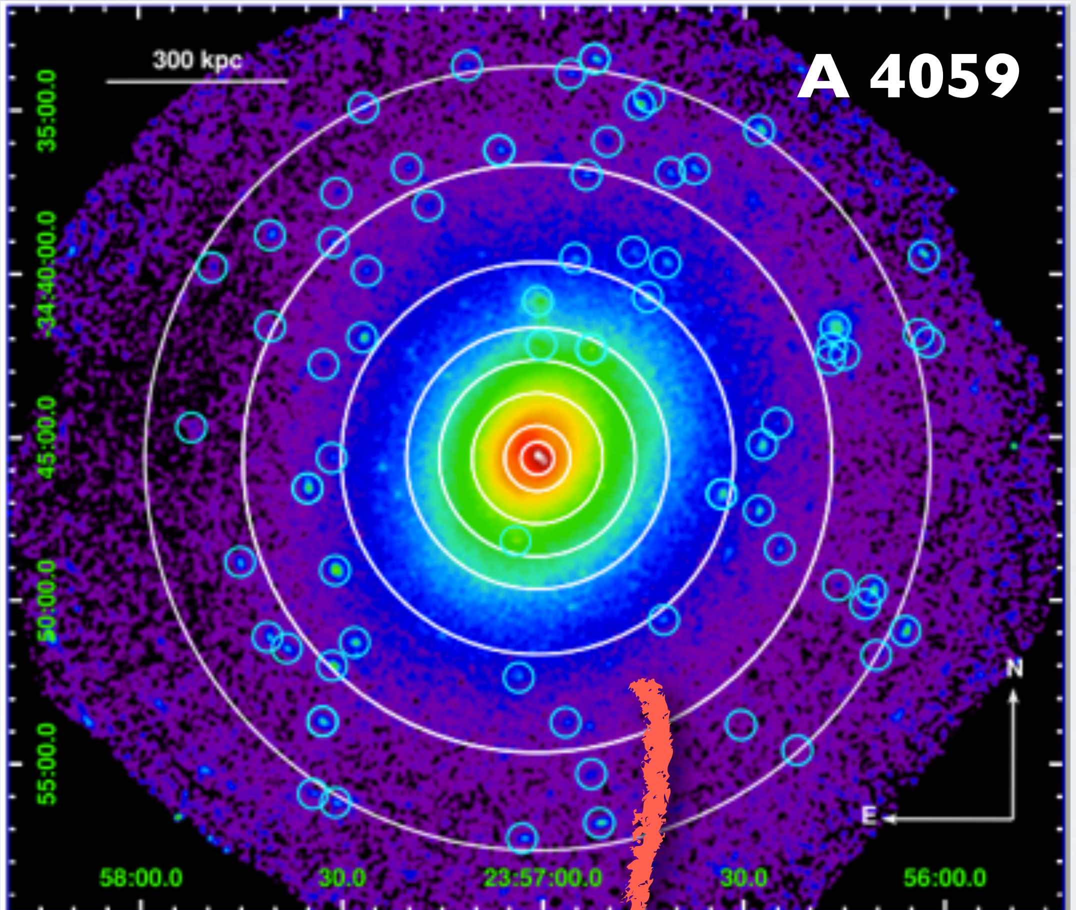
(PI: Jelle de Plaa)

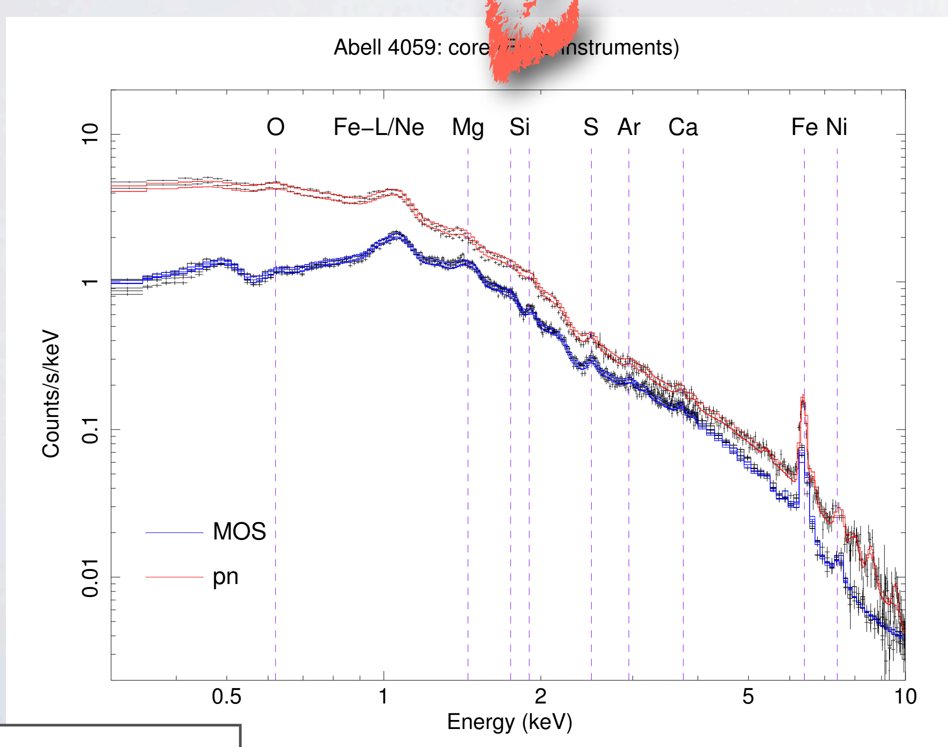
- **Cool-core** galaxy clusters, groups & ellipticals
- O VIII line in RGS: > 5σ
- **Nearby** (z < 0.1)
- New deep observations of 11 objects (1.6 Ms)
- + archival (public) data

➡ 44 objects

➡ ~4.5 Ms
of *XMM-Newton* total net exposure

Strategy



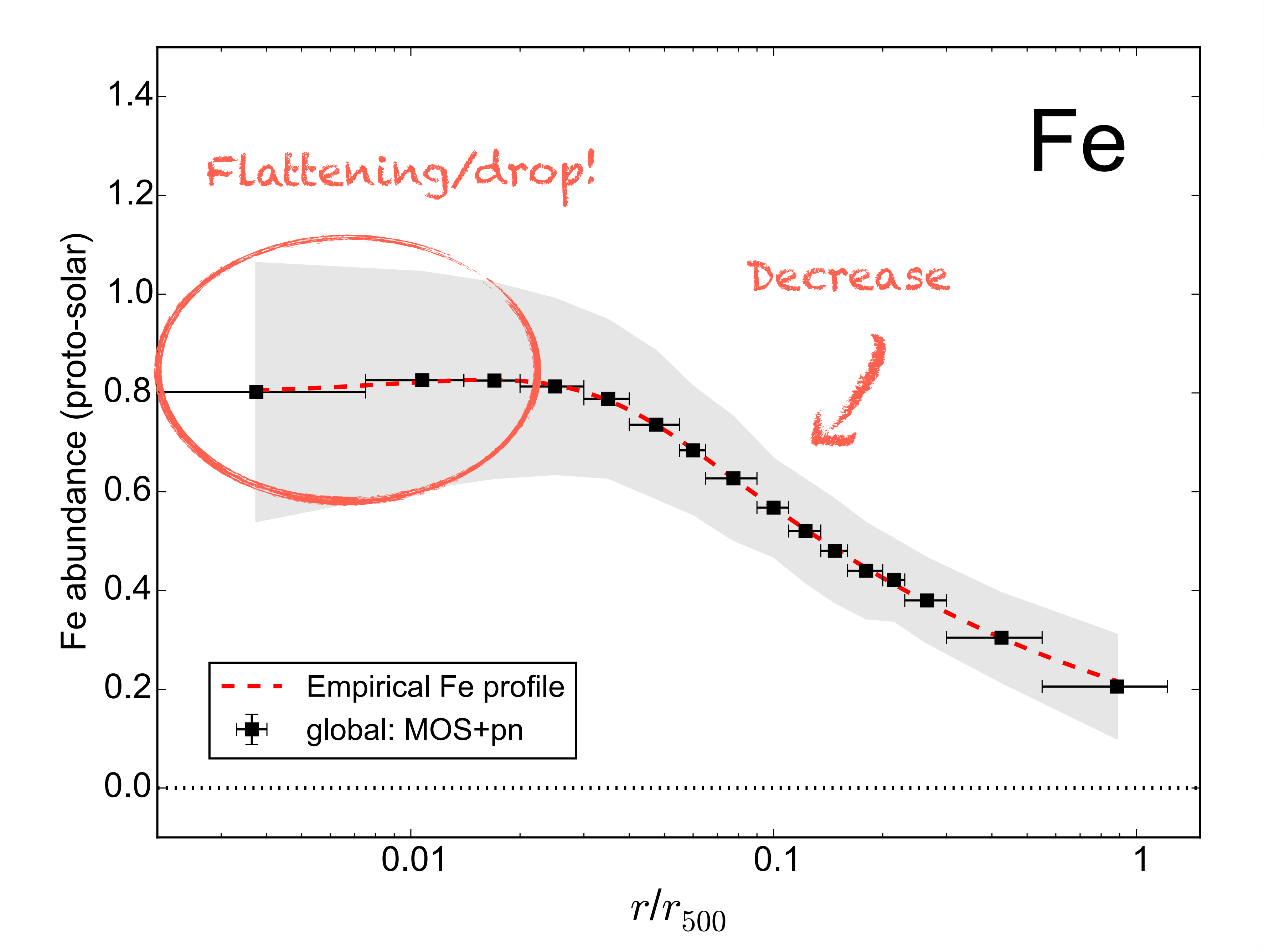


Mernier et al. (2015)

- Every pointing ➔ 8 concentric **annuli** (fixed angular sizes)
- **Point sources** are removed from the analysis
- **MOS** and **pn** spectra fitted **independently** (cross-calibration uncertainties are taken into account)
- SPEX (v2): Multi-temperature model (**GDEM**)
- Careful **background** modelling (five components)
- **Stacking** all the measurements (in units of r_{500}, ~20 measurements per reference radial bin)

Results

The (average) Fe profile

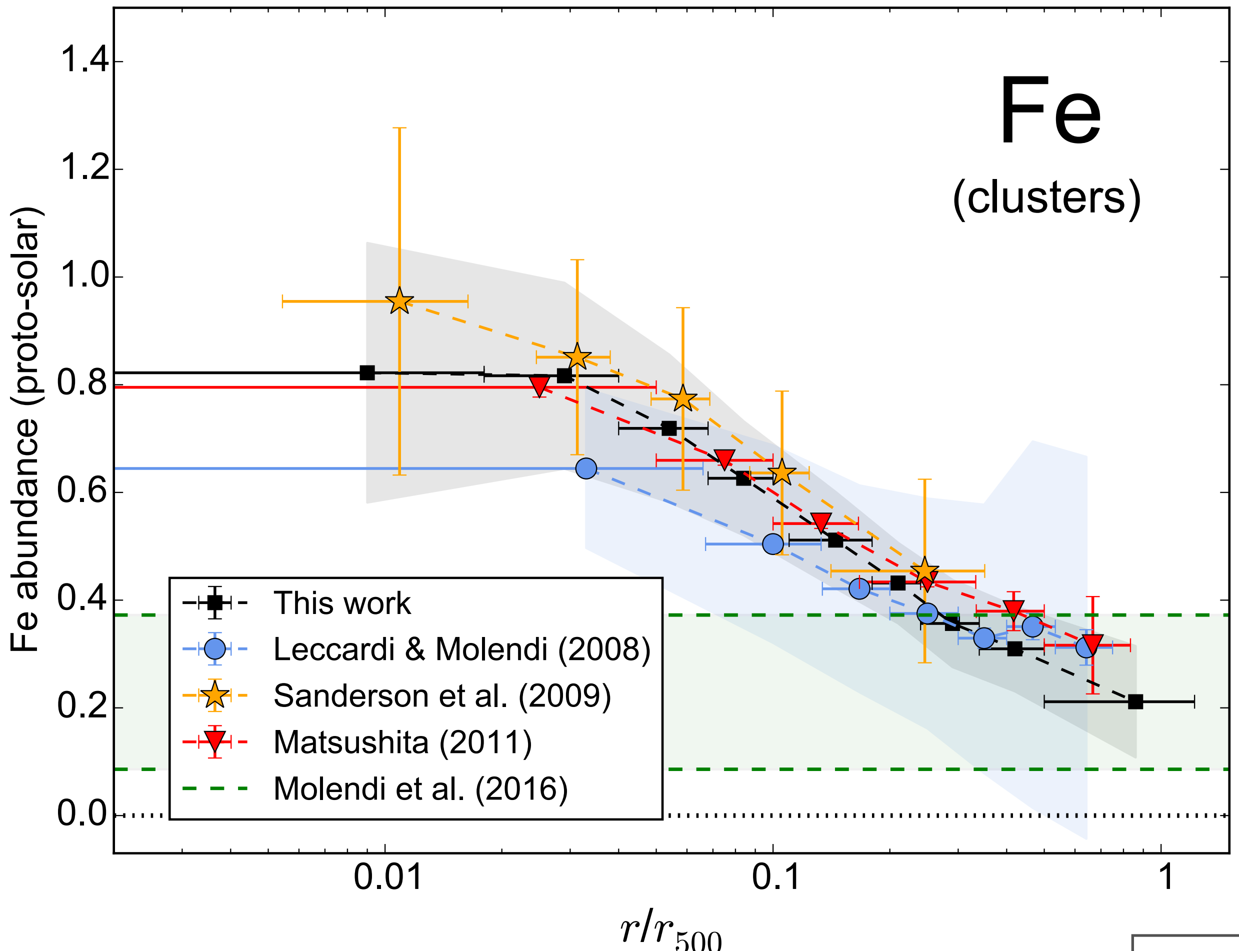


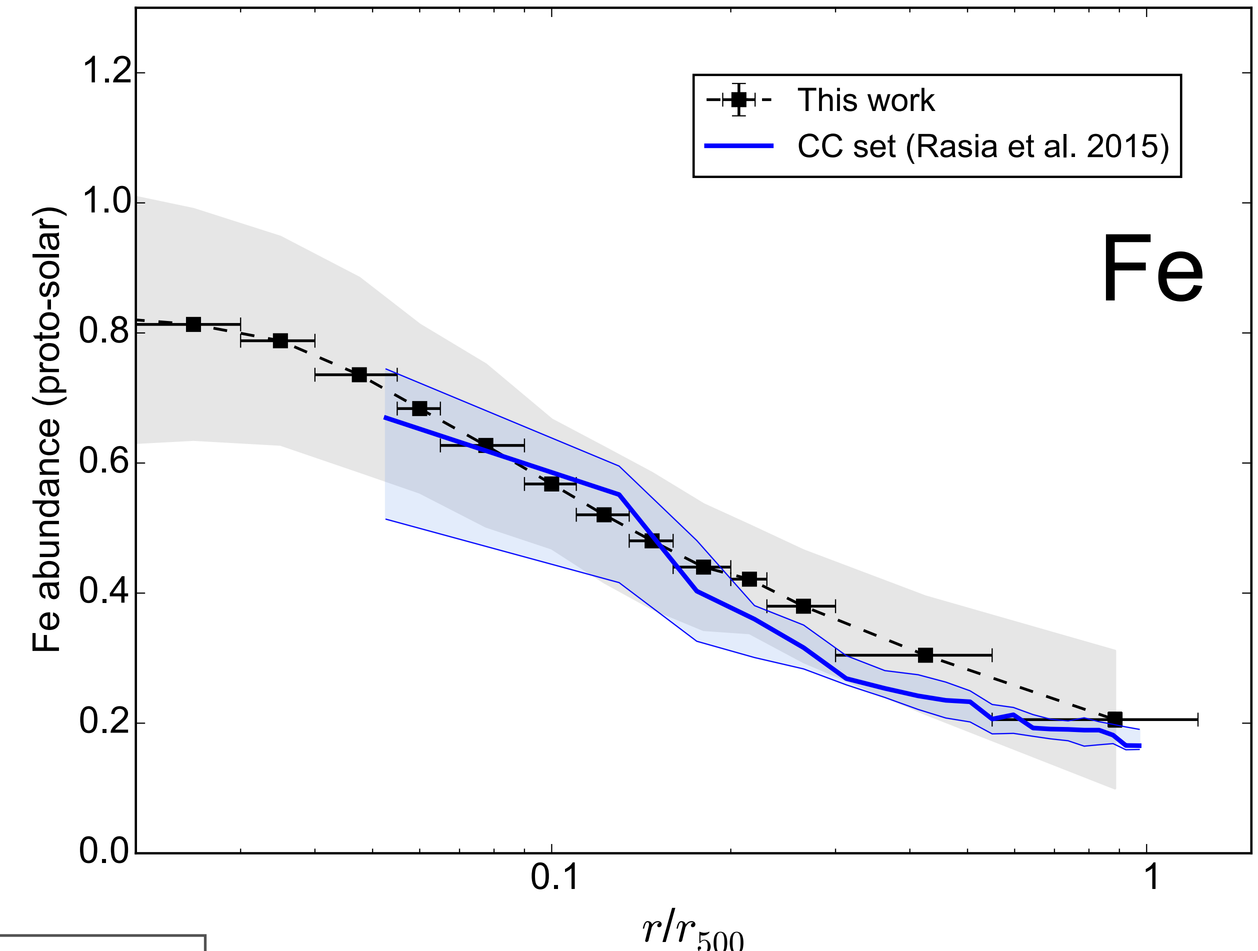
Mernier et al. (2017)

The (average) Fe profile

Previous measurements

Simulations

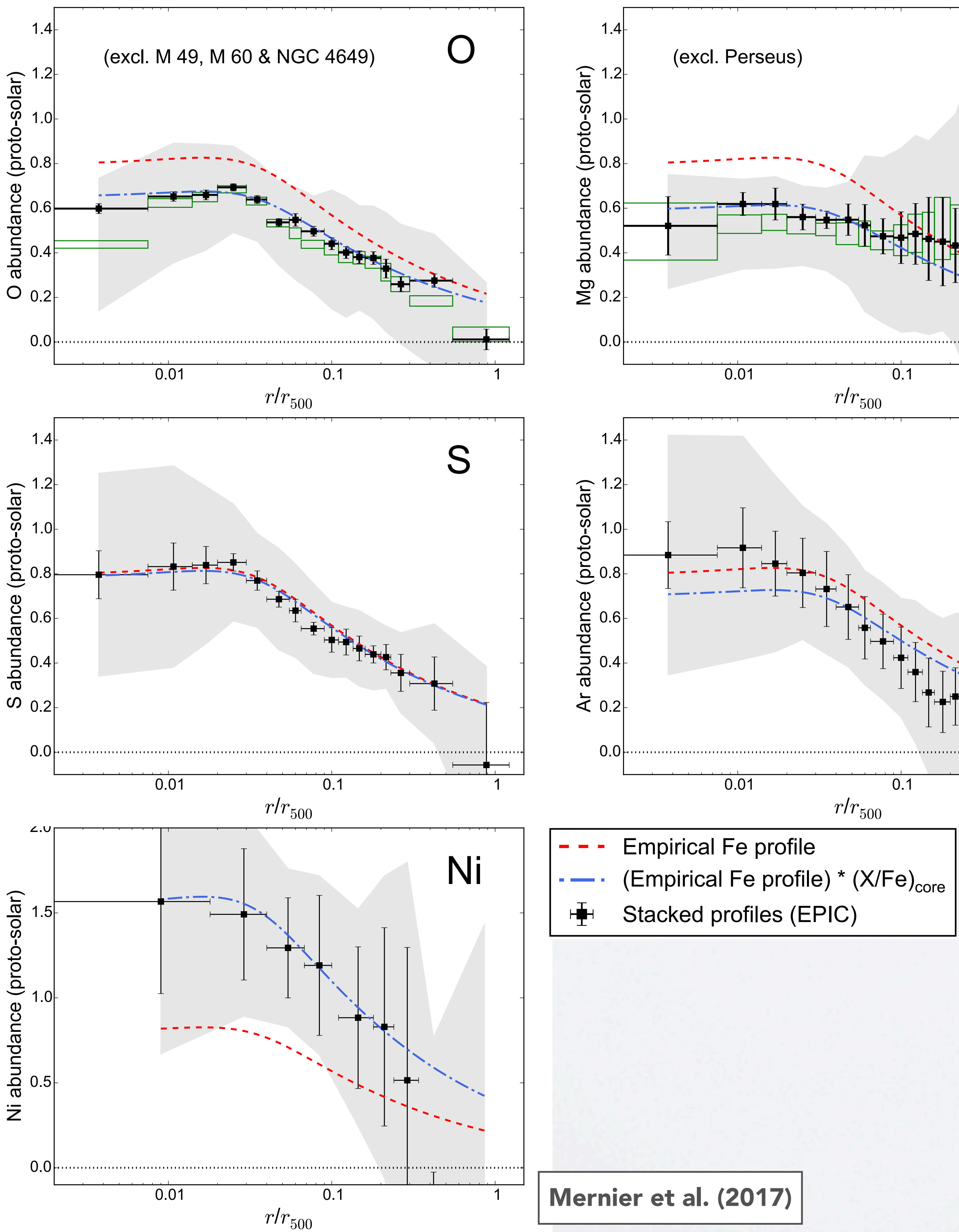




Mernier et al. (2017)

Comparison observations vs. simulations should be addressed very carefully!

Abundance profile of other metals

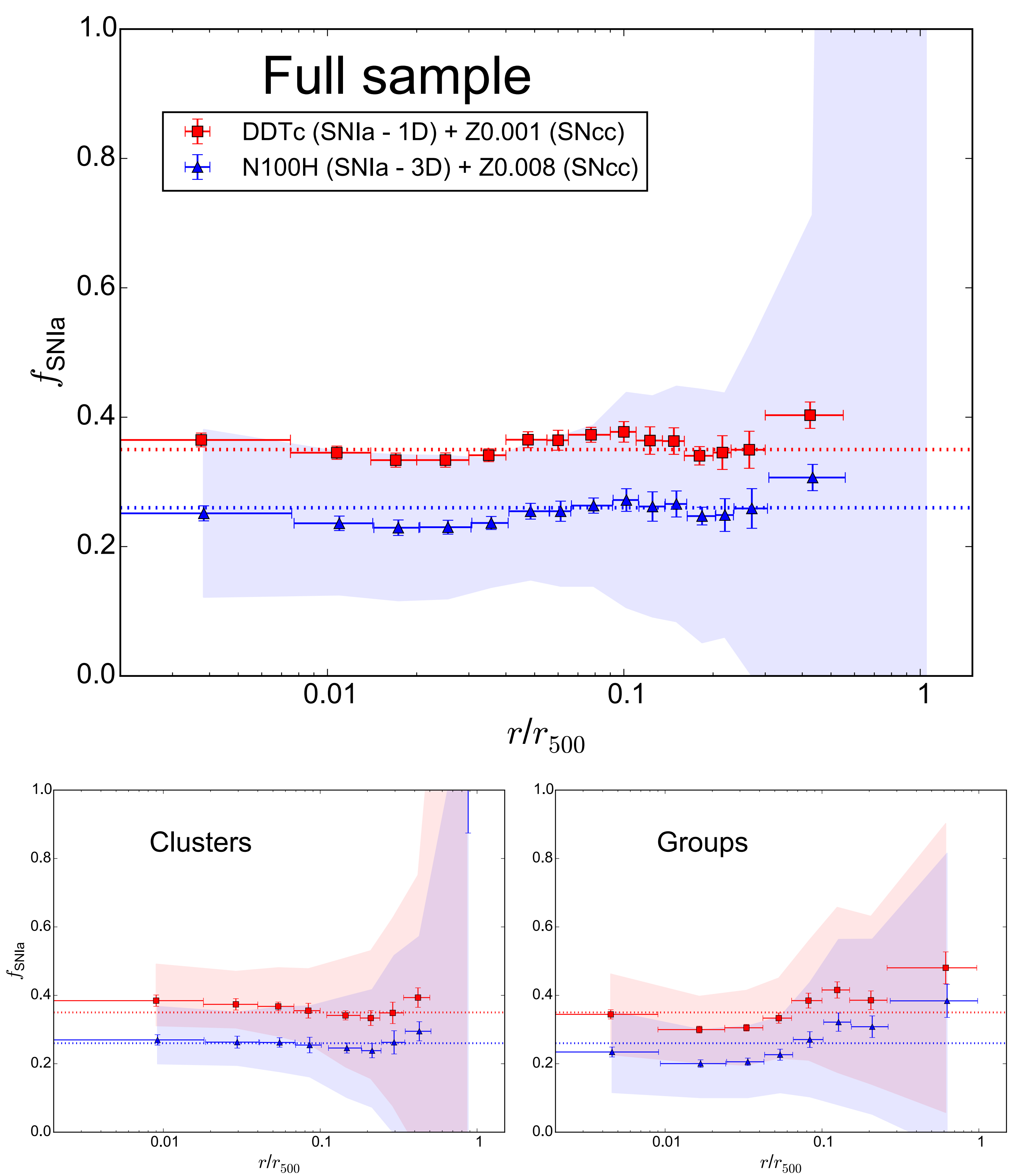


Mernier et al. (2017)

Systematic uncertainties under control:

- ✓ Projection effects
- ✓ Thermal modelling
- ✓ Background uncertainties
- ✓ Weight of individual observations
- ✓ Atomic code uncertainties

Radial distribution of the SNIa fraction



Mernier et al. (2017)

- **Uniform SNIa/(SNIa+SNcc) fraction** all across the ICM (at least up to ~$0.5r_{500}$)!
  (see also: Ezer et al. 2017)

- If the **BCG** (now red and dead) is indeed responsible for the central Fe peak, it **may have also produced SNcc**

- More generally, within ~$0.5r_{500}$, **SNIa and SNcc enrichment** may share the **same origin**

- The **time delay** between the bulk of SNIa and SNcc enrichment is **short**: less than the time scale necessary to diffuse out the metals

Conclusion

Conclusions

Take home message

Type Ia and core-collapse supernovae enrich the ICM at the same proportion (up to ~$0.5r_{500}$)

- Fe (produced by SNIa) centrally peaked, sometimes with an inner drop
- SNcc products (O, Mg, Si) are also centrally peaked
- Fe profile: very good agreement with previous measurements & simulations
- SNIa and SNcc contributions to the ICM enrichment may share the same origin, and occur at similar epochs
- Need for better measurements in the outskirts (Hitomi 2, Athena) and improved simulations in the very core

CHEERS!

The CHEERS collaboration

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- ➡ Hiroki Akamastu (SRON, Utrecht)
- ➡ Junjie Mao (SRON, Utrecht)
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- ➡ Jacco Vink (University of Amsterdam)