Astrophysics of groups and clusters

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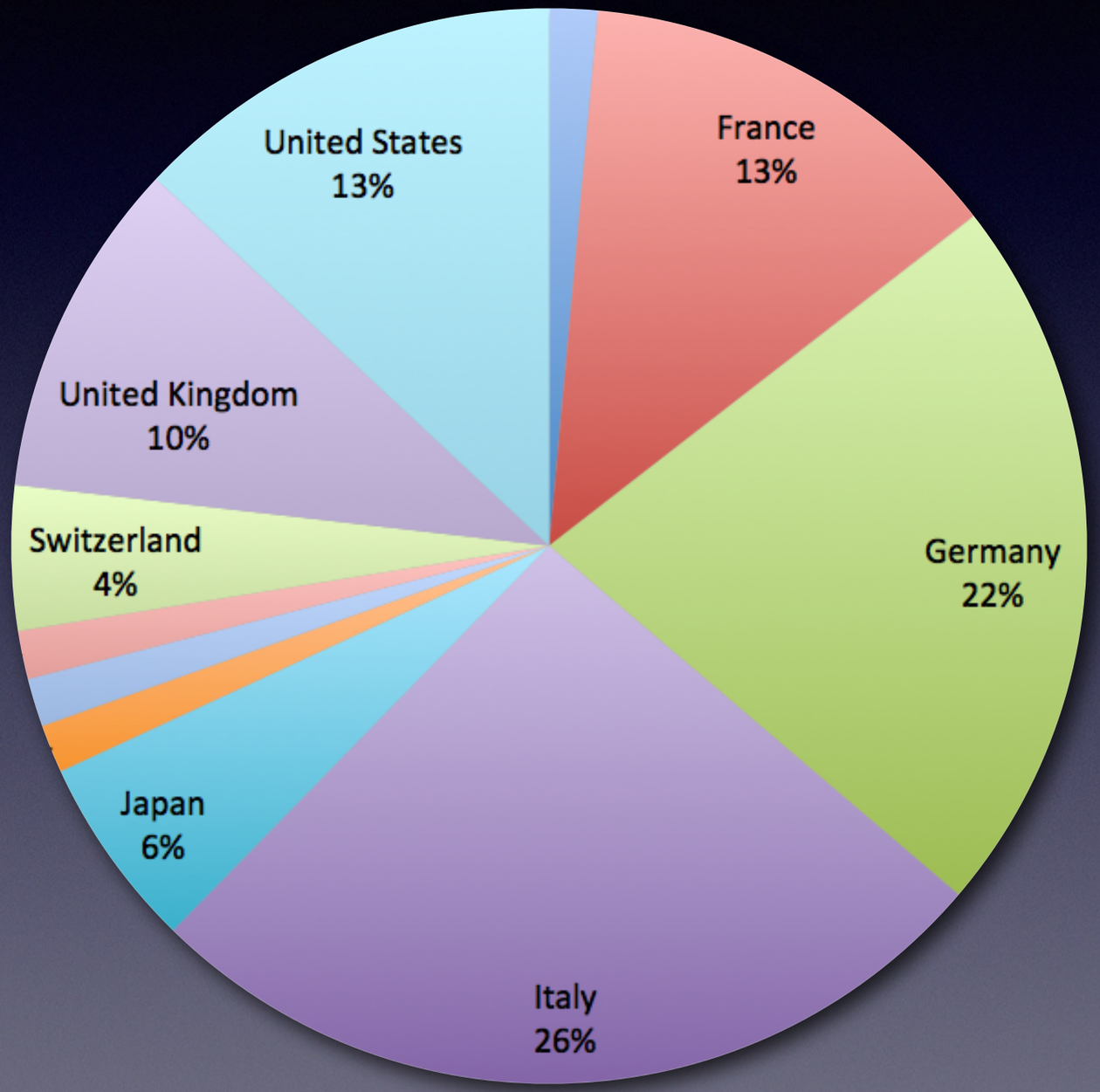
TWG 1.2

122 members (Sept. 2015)



The hot and energetic Universe

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The hot and energetic Universe

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

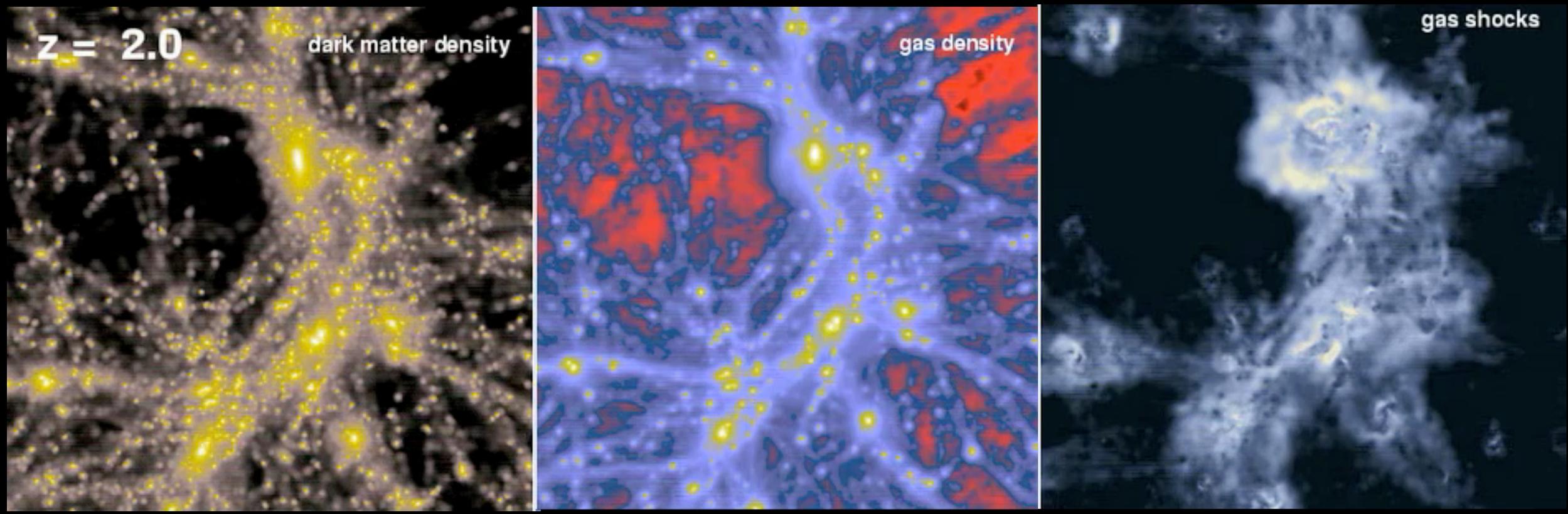
- How do diffuse hot baryons accrete and dynamically evolve in the dark matter potential?
- How and when was the energy in the ICM generated and distributed?
- When and where are heavy elements produced and how are they circulated?

Total mass: 10^{14}-10^{15} $M_\odot$

Stars < 5%

Gas ~ 10%

Dark matter ~ 85%



V. Springel

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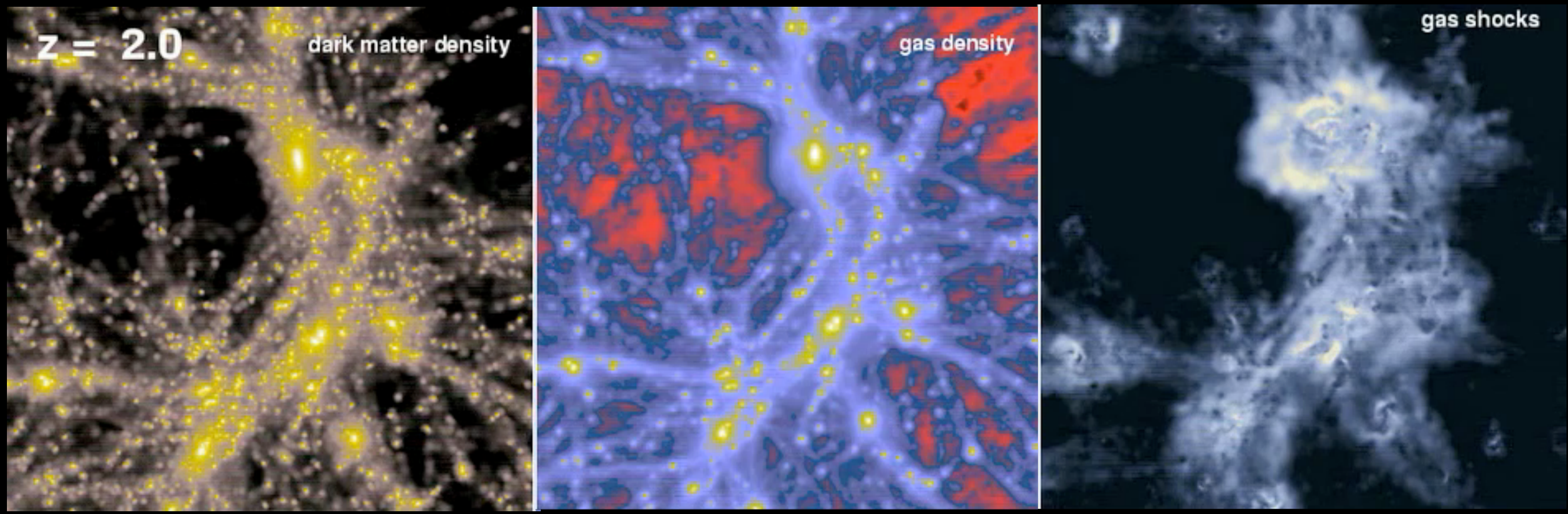
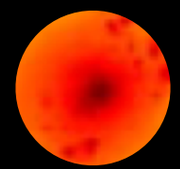


V. Springel

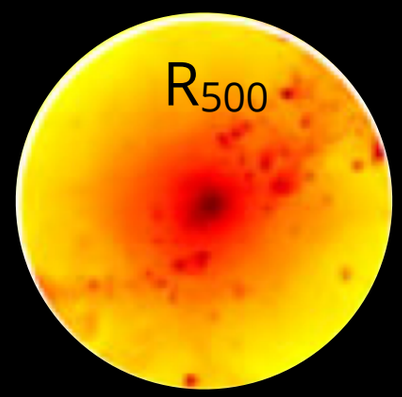
Level 1 science objectives

- R-SCIOBJ-112
  - Athena shall measure how gravitational energy is dissipated into **bulk motions and gas turbulence** in the galaxy cluster population, by achieving a 5σ detection of these quantities
- R-SCIOBJ-121
  - Athena shall determine which physical process dominates the injection of non-gravitational energy into clusters as a function of cosmic epoch by measuring **entropy** ($K = kT/n_e^{2/3}$) **profiles** to the **virial radius (locally)**
- R-SCIOBJ-122
  - Athena shall constrain SN yields by measuring the **abundances** (Z) and distribution of rarer metals (e.g., Al, Cl, Mn, Co) in clusters from the core to the **virial radius locally** (5σ detection)

R_{2500} - ~limit for Chandra

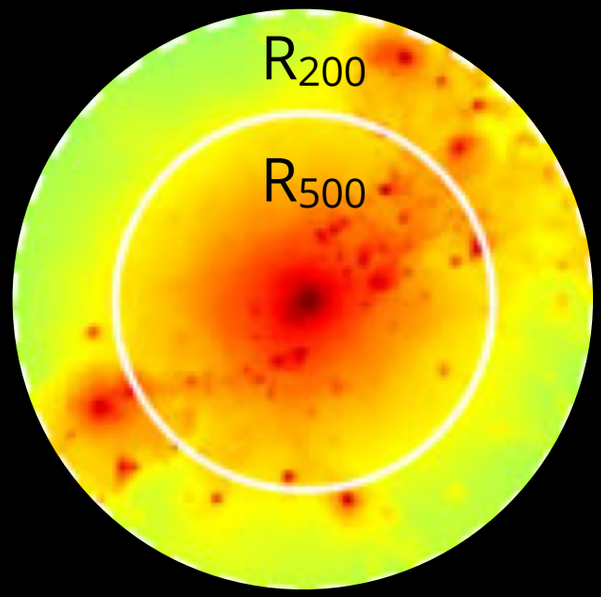


R_{500} - limit for XMM/Chandra



$$\left[\frac{R_{500}}{R_{\rm vir}\,(z=0)}\right]^3 \sim 0.1$$

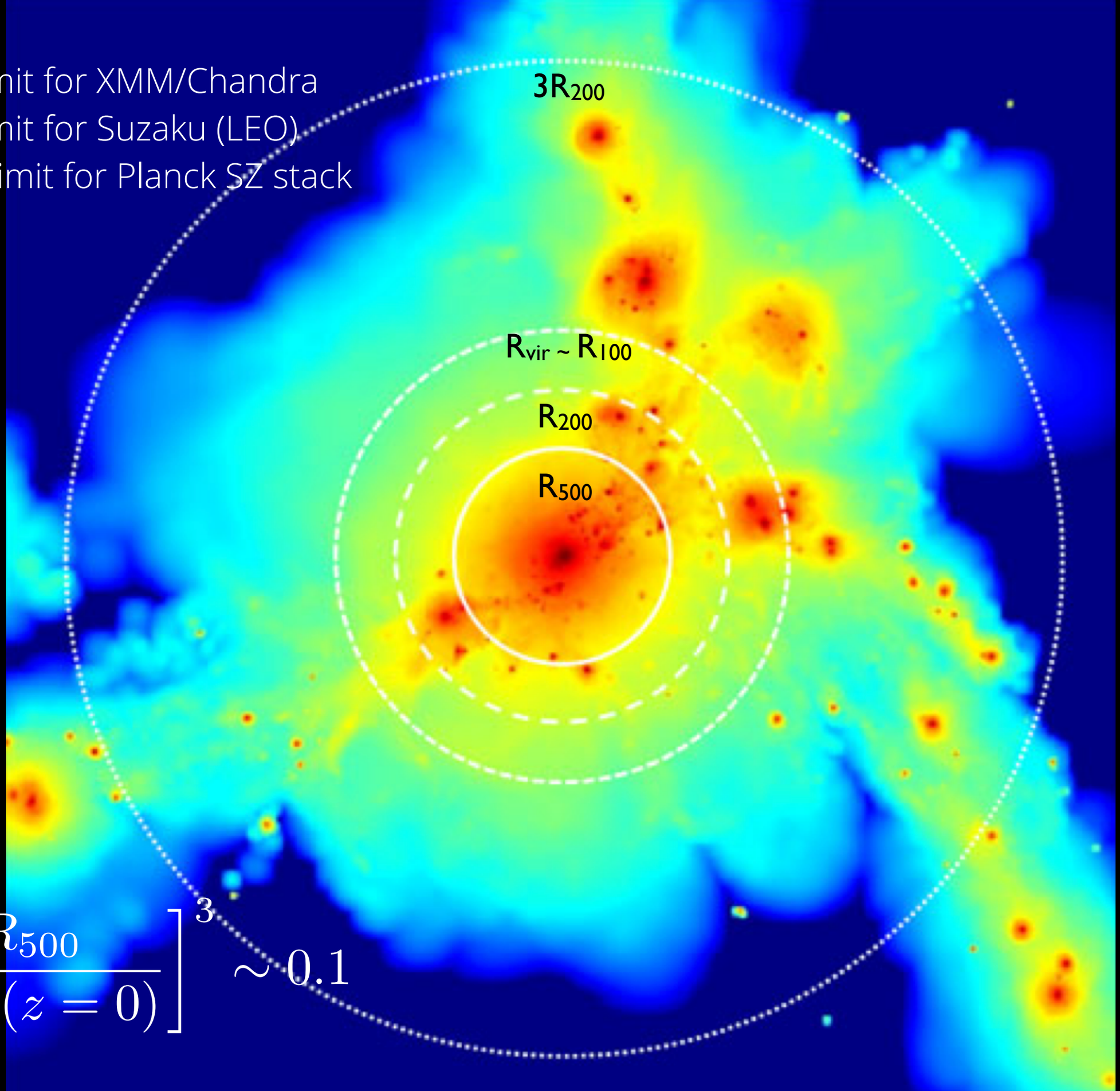
R_{200} - limit for Suzaku (LEO)



R_{500} - limit for XMM/Chandra

R_{200} - limit for Suzaku (LEO)

$3R_{500}$ - limit for Planck SZ stack



$$\left[\frac{R_{500}}{R_{\rm vir}\,(z=0)}\right]^3 \sim 0.1$$

Roncarelli et al 2006

Importance of outskirts

For this talk, $R > R_{500}$

- They contain 90% of the cluster volume

- They are the region where the cluster and large-scale environment meet
  - sub clump infall along filaments
  - external accretion shock

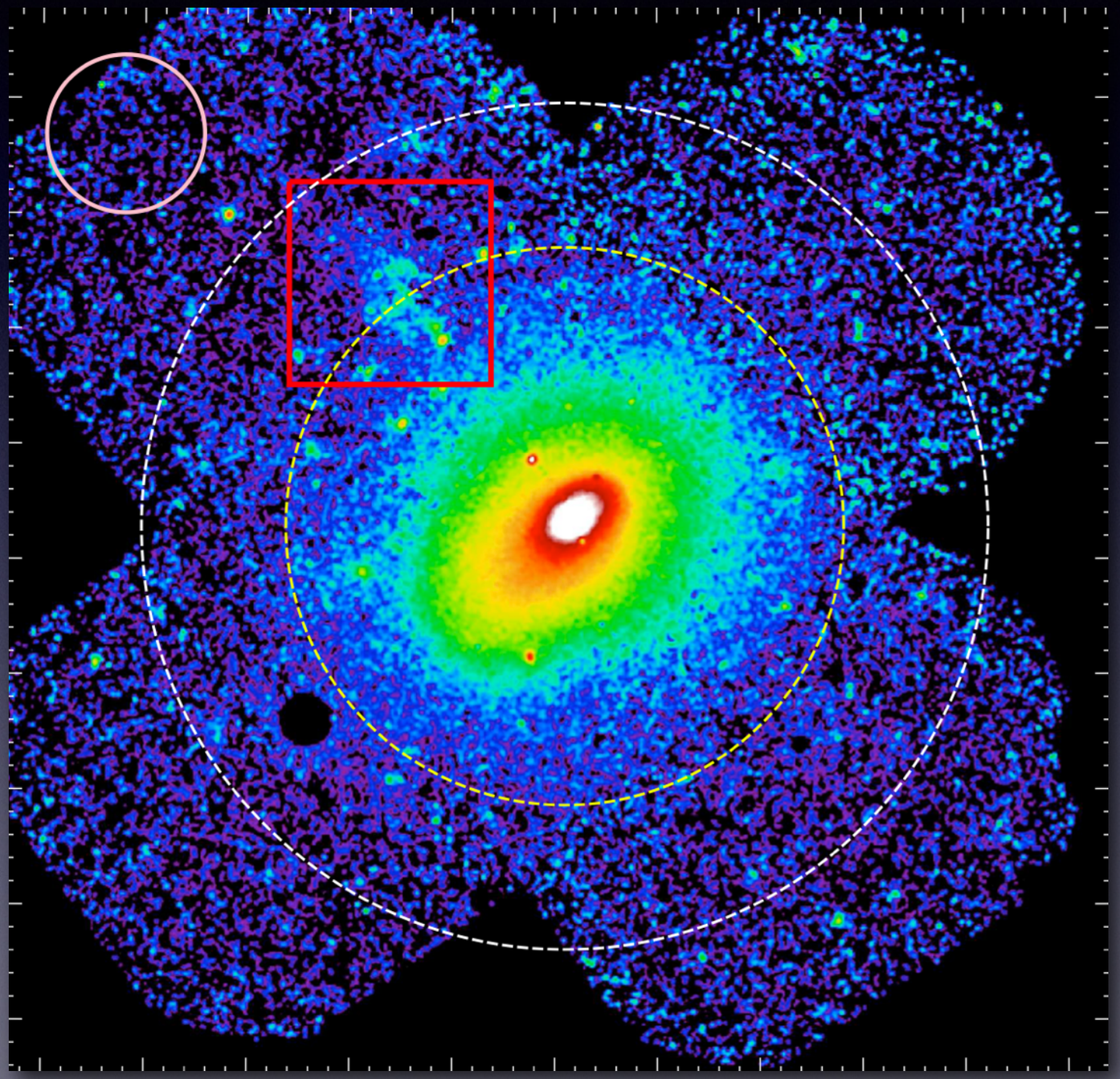
- Critical test of the gravitational collapse model
  - minimal sensitivity to AGN feedback

- Region where various equilibria break down
  - hydrostatic, thermal eq. and equipartition, ionisation...

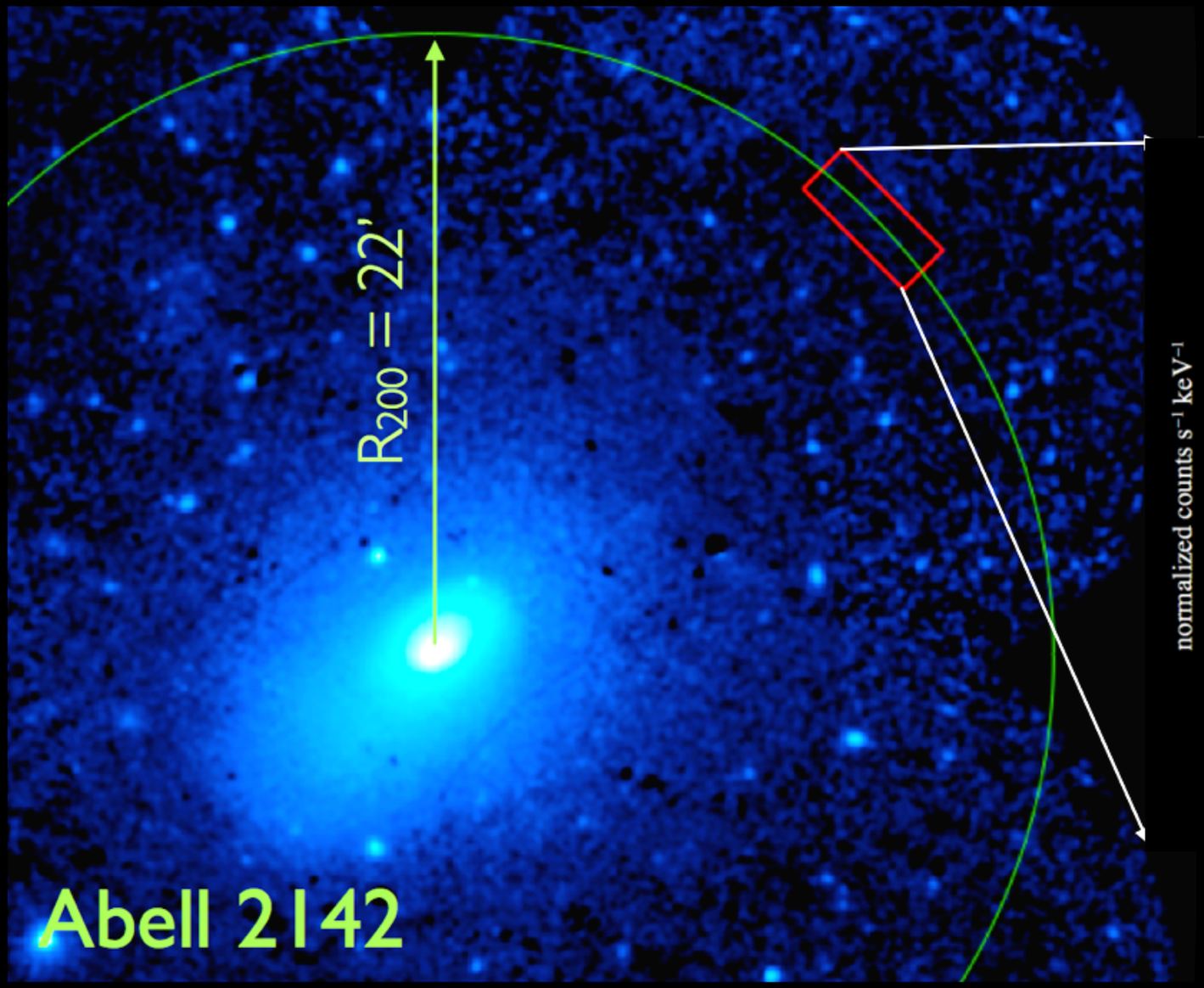
- They are currently almost completely inaccessible

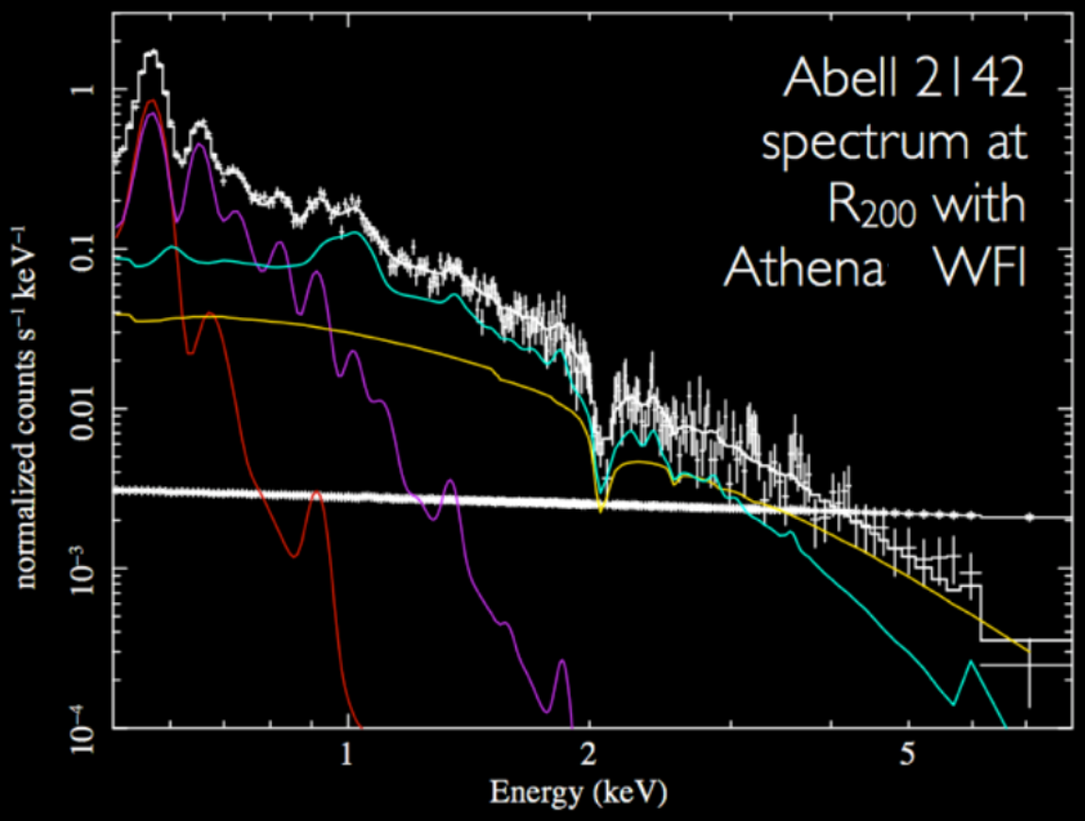
Accretion in the outskirts with XMM

Eckert et al 2014



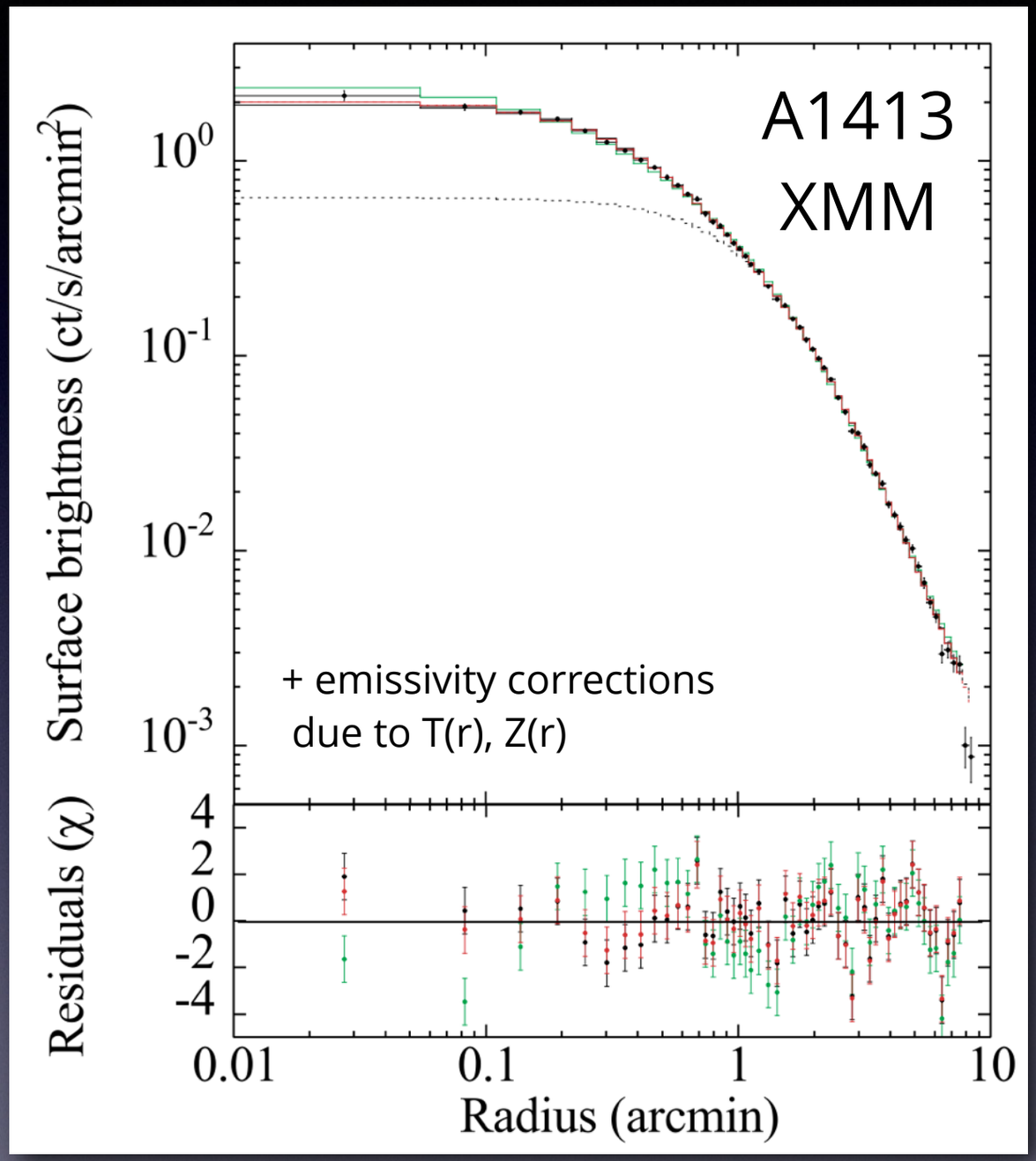
Thermodynamics of the outskirts





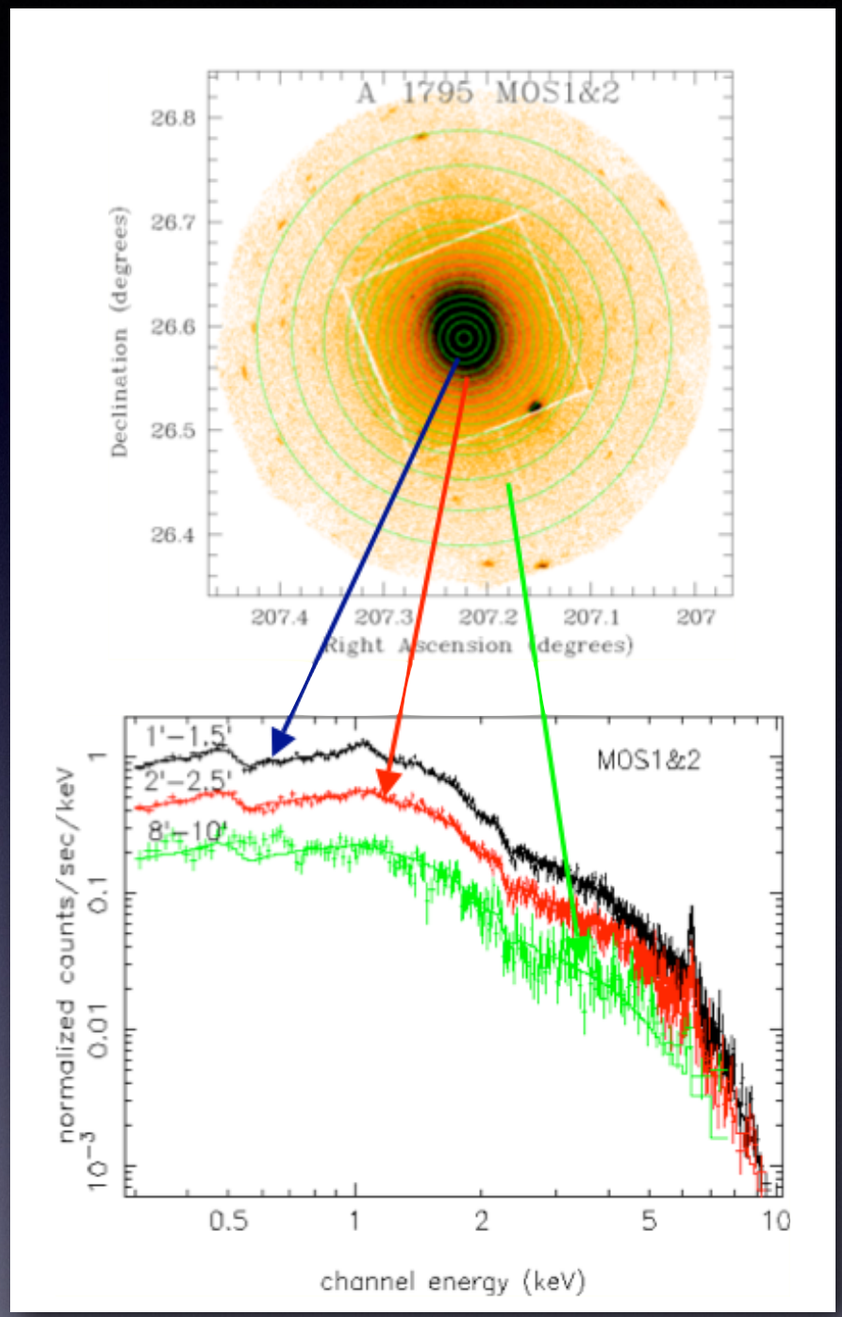
- Throughput+, spatial resolution+
- Measurement of kT, Z in the outskirts (3%, 18% at 90% in 100 ks)

Other X-ray observational tools



GWP & Arnaud 2002 (A1413)

Density

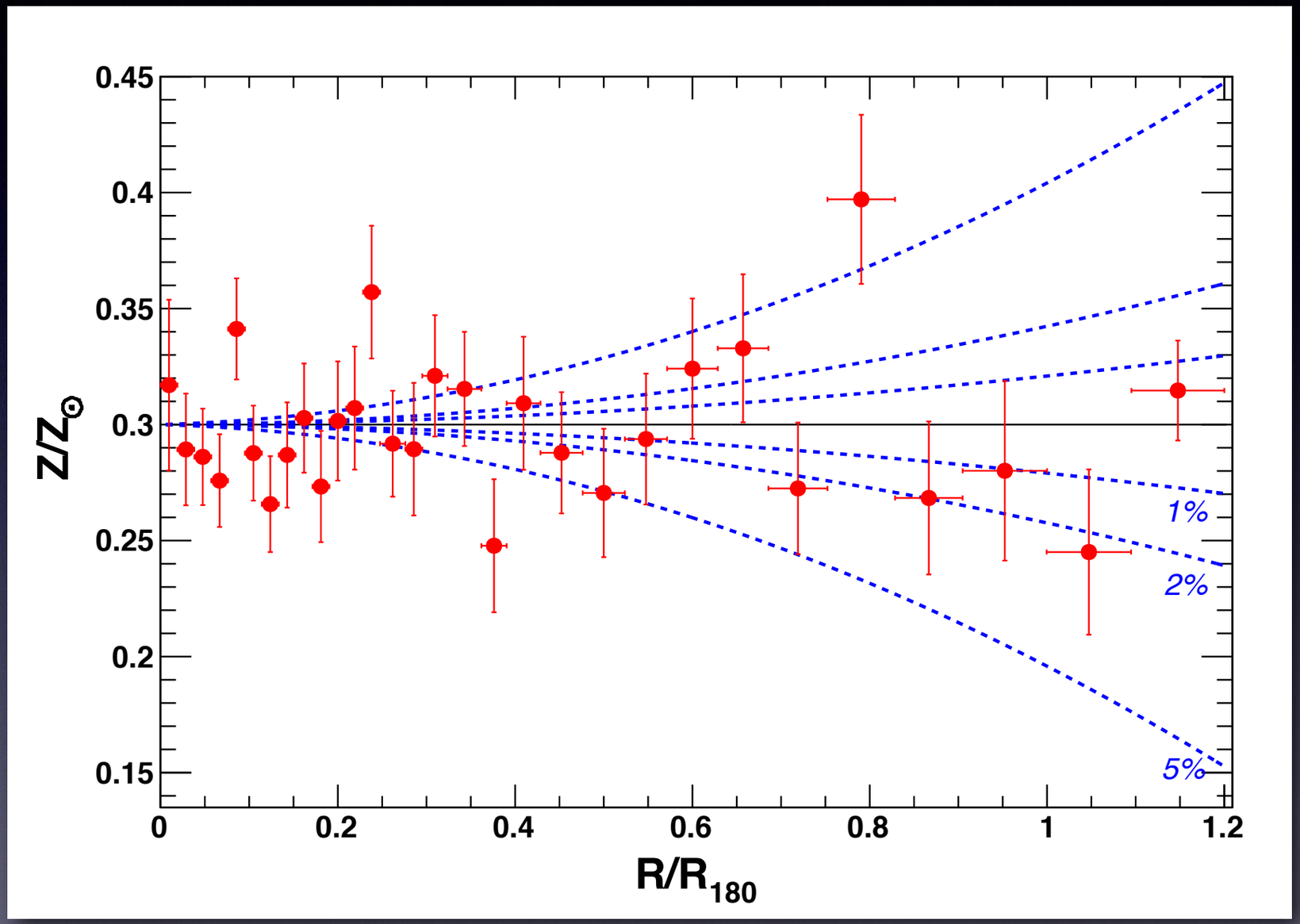


Arnaud et al 2001 (Abell 1795)

Temperature + abundance

Importance of background *reproducibility*

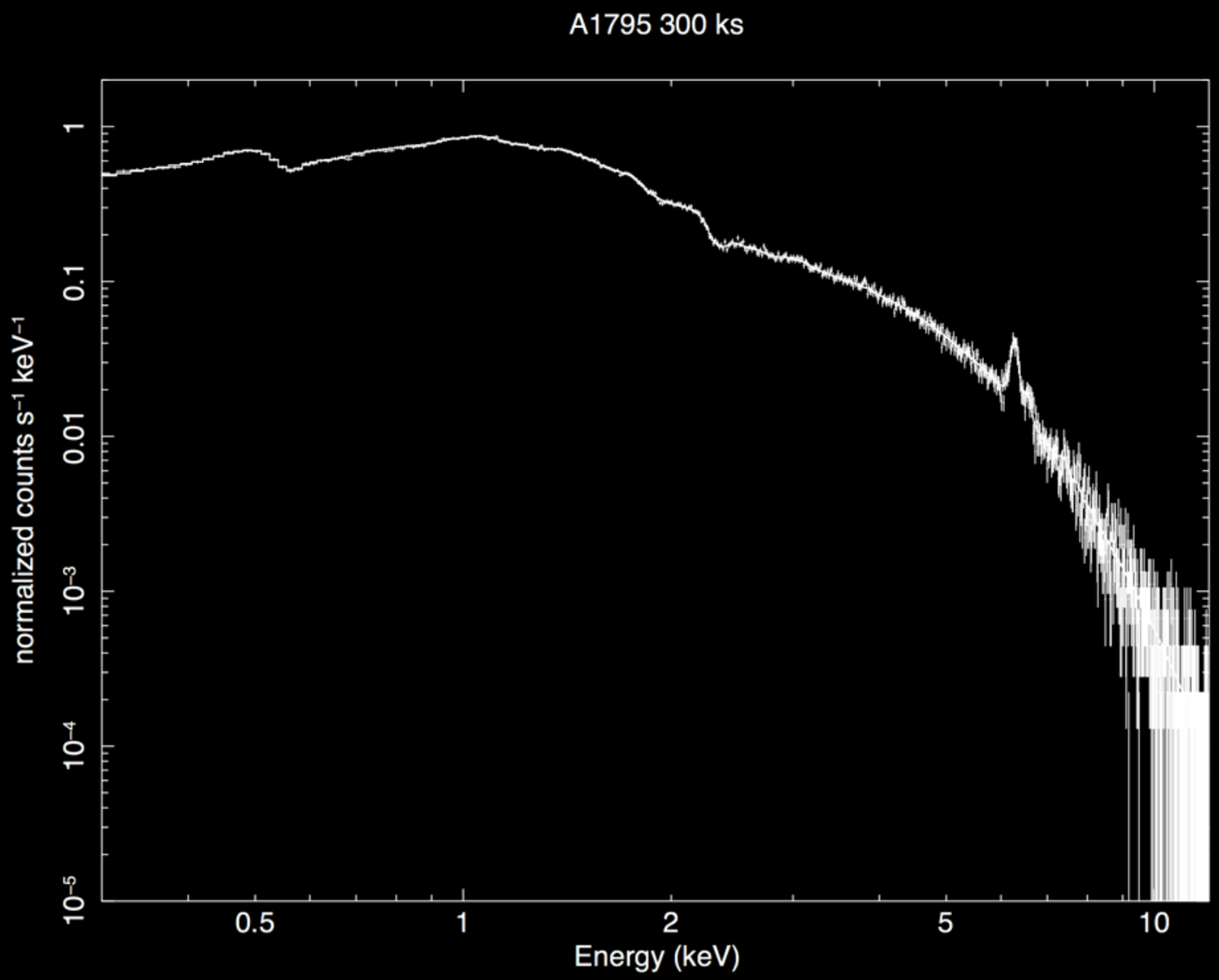
D. Eckert

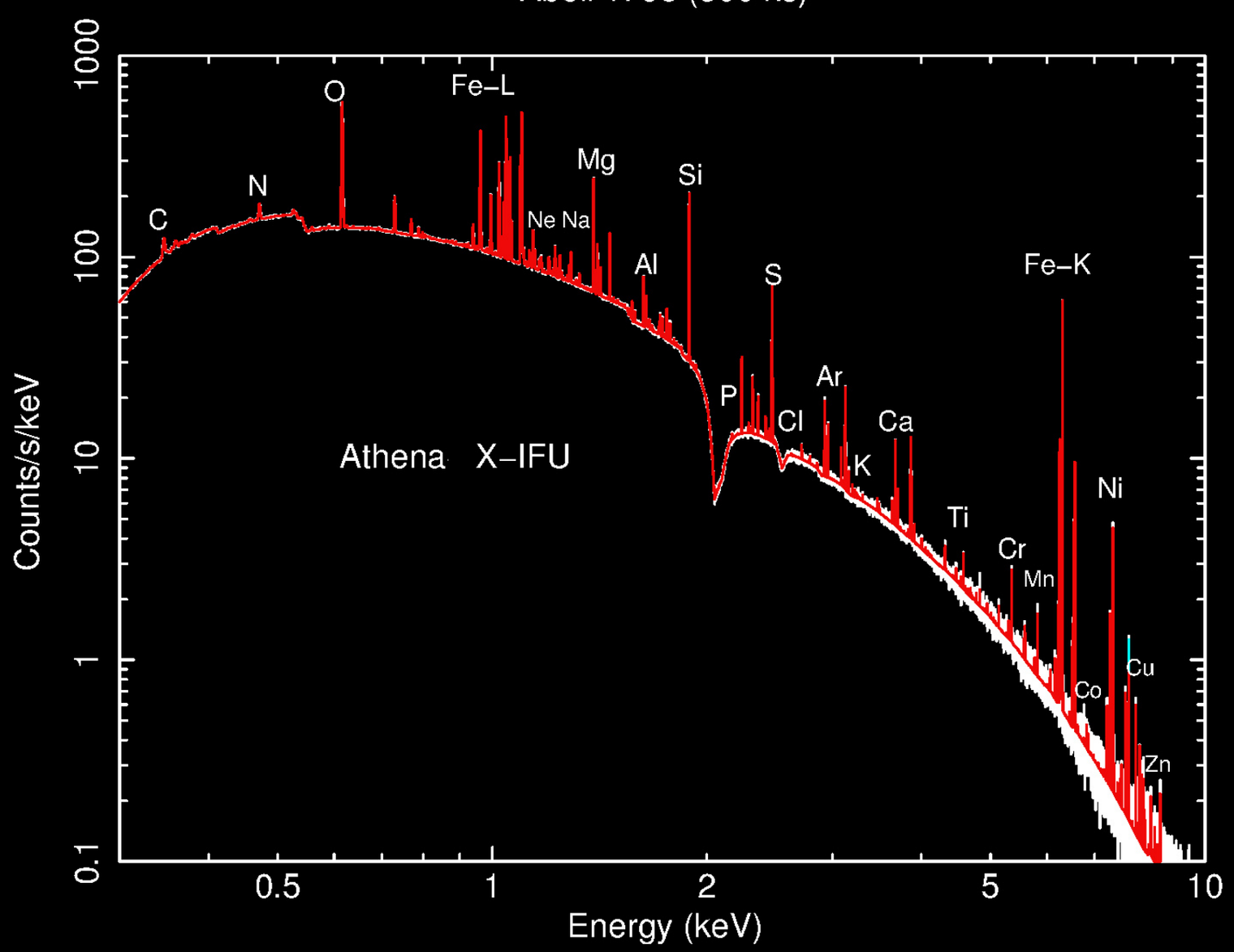


- Uncertainties in background reproducibility induce systematic uncertainties on the measurement of physical quantities

XMM-Newton EPIC MOS

Typical current CCD spectral resolution

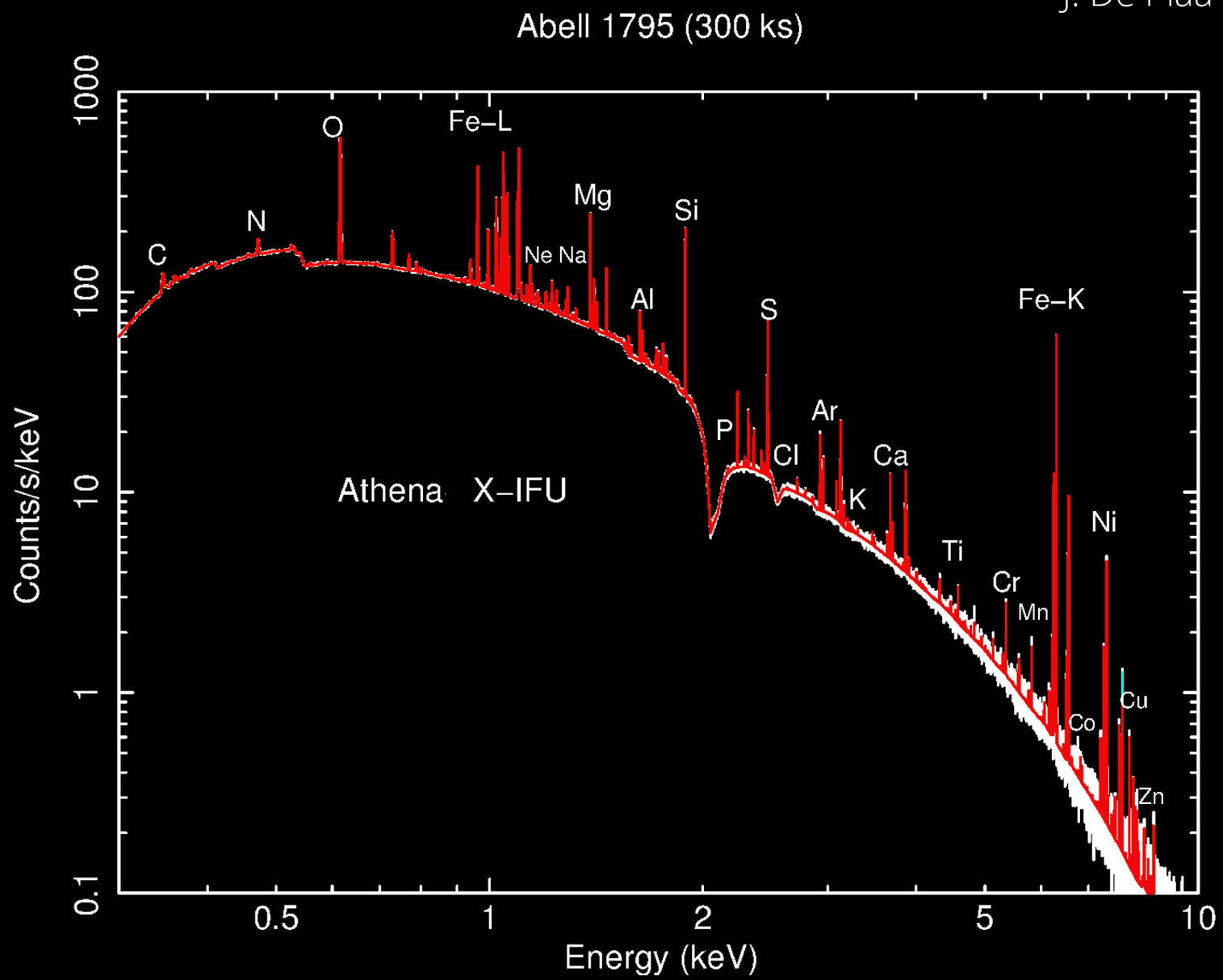




- TES sensor array / 2.5 eV resolution / 5’ diameter FoV

Abundance ratios

J. De Plaa



- z=0: abundance ratios yield fossil record of metal production due to different SN explosion mechanisms

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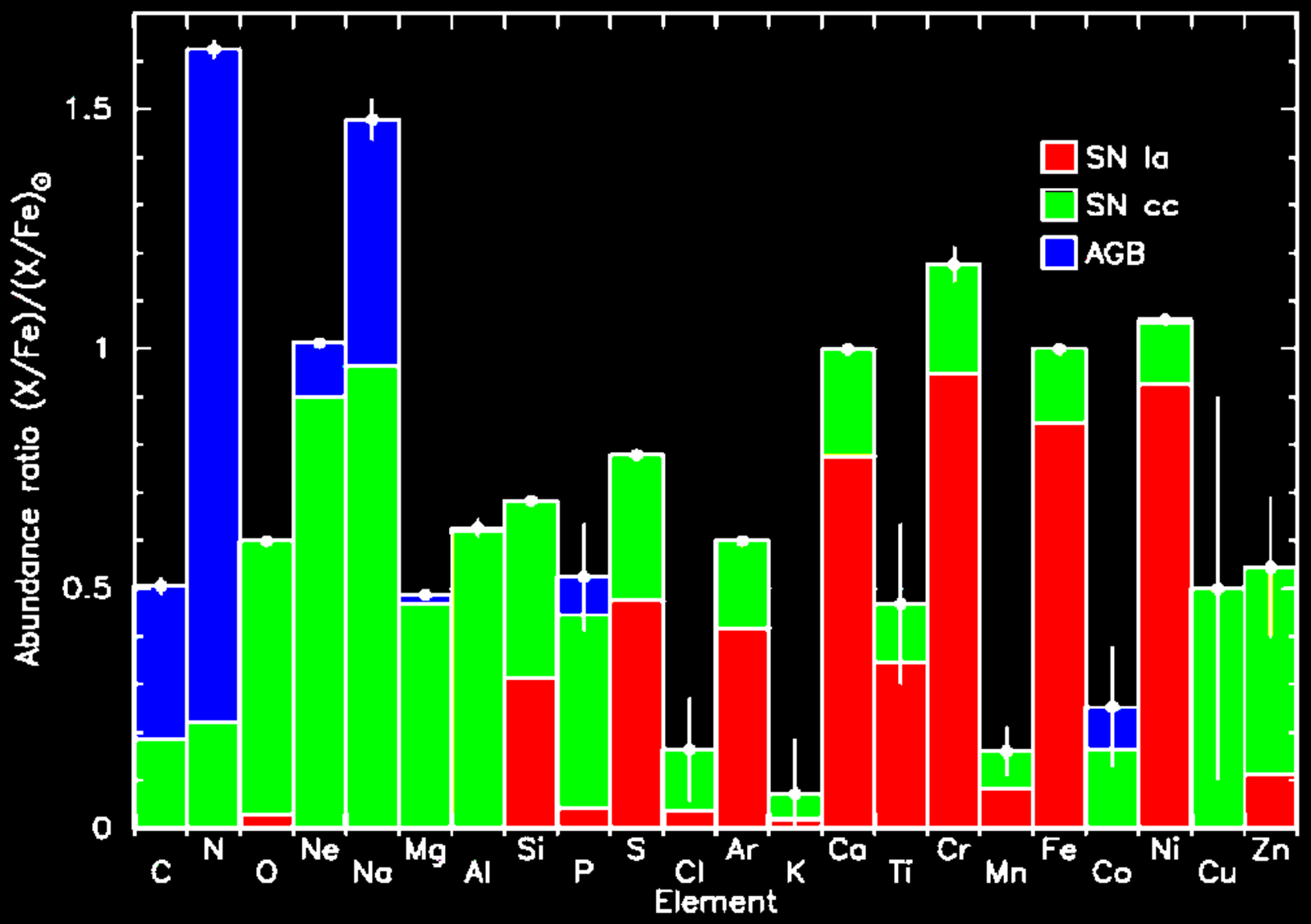

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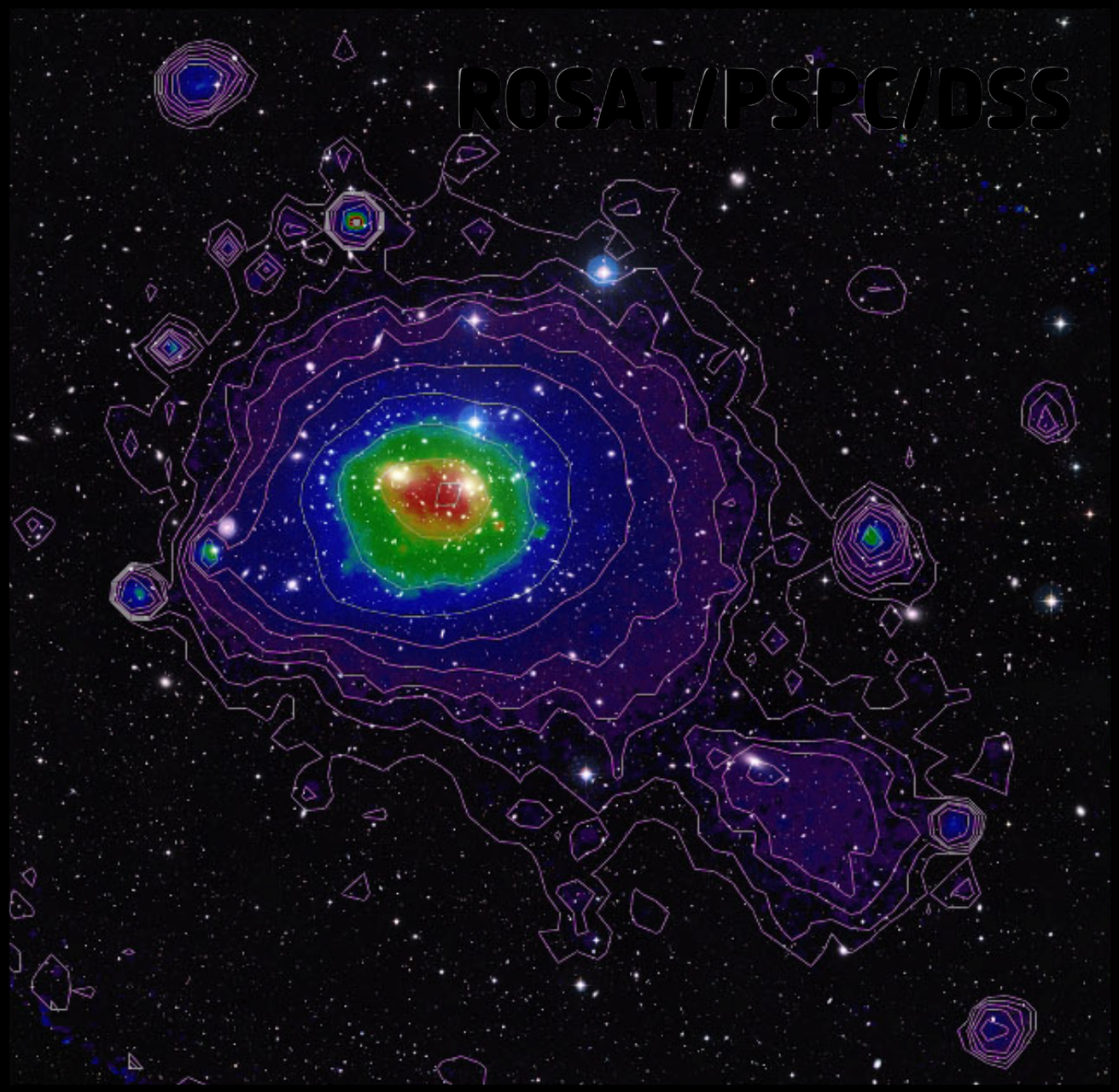
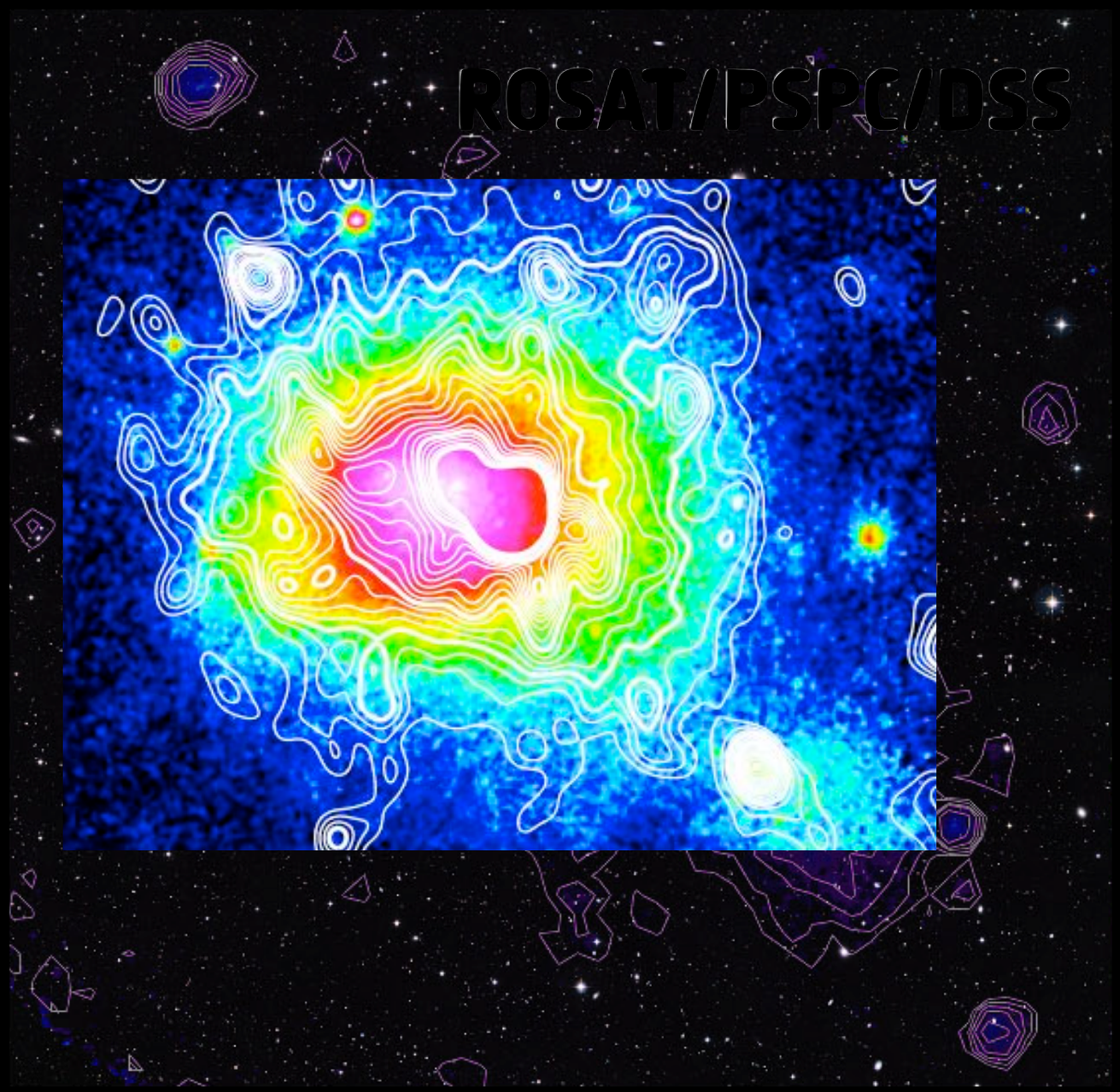
The halo-turbulence connection



X-IFU

The halo-turbulence connection



Brown & Rudnick 2010

X-IFU

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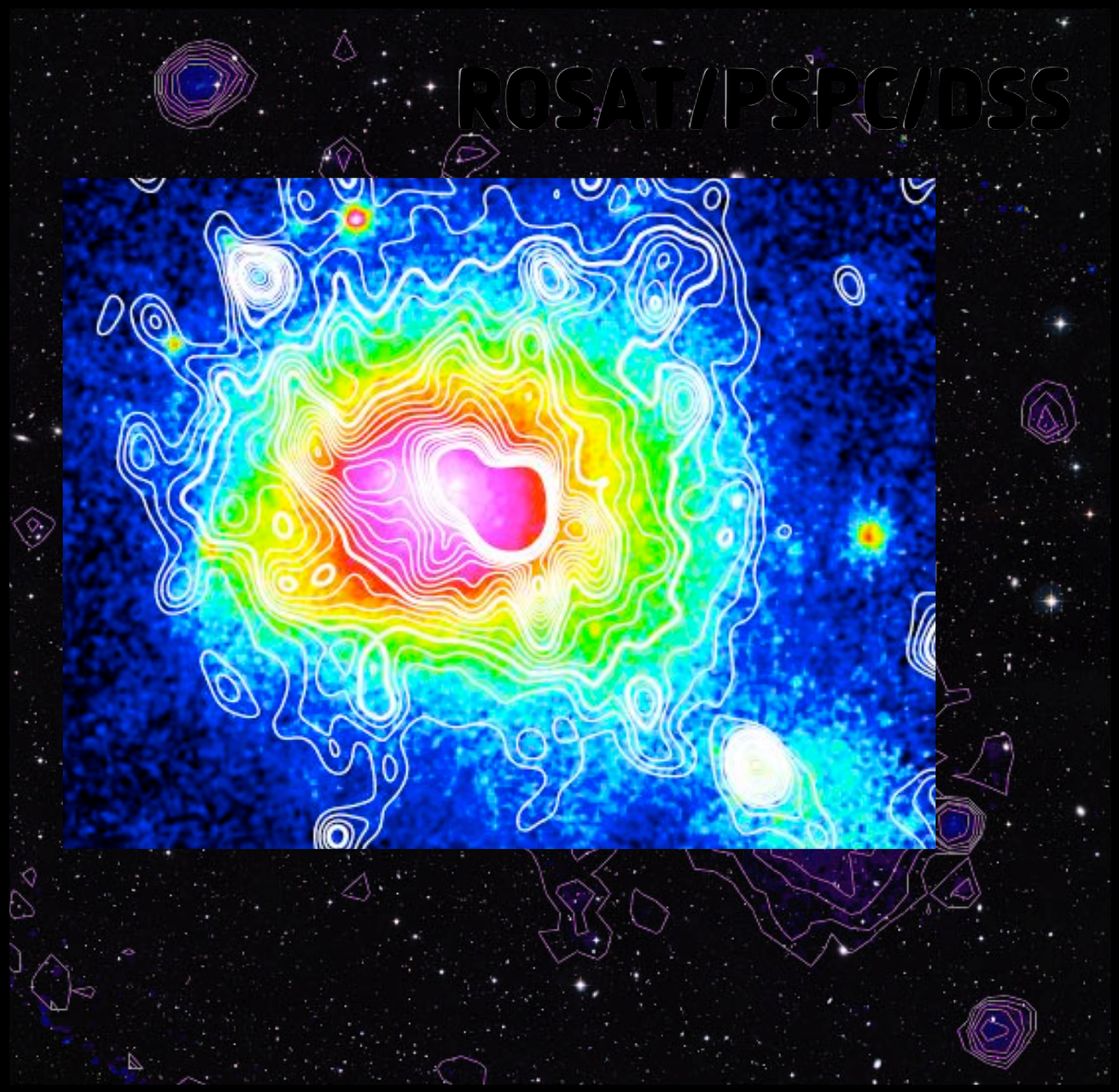
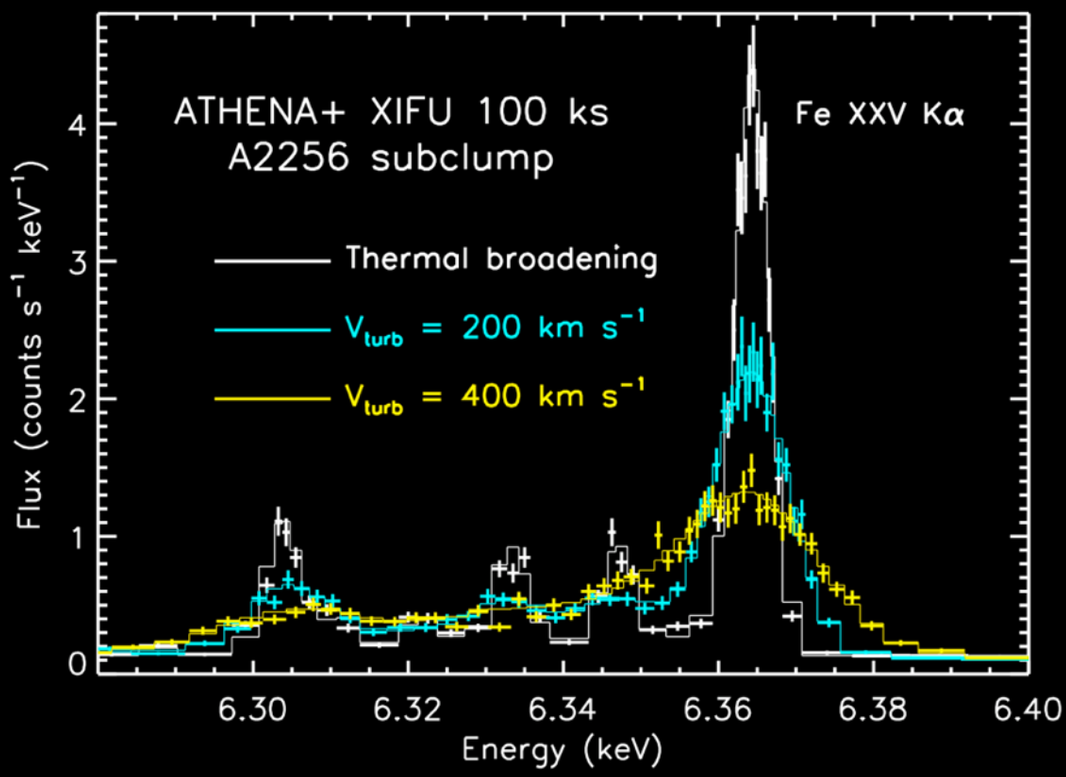


Brown & Rudnick 2010



J. Nevalainen

X-IFU

Conclusions

- Athena observations of nearby ($z < 0.5$) clusters
  - Thermodynamic properties of the outskirts
  - Characterisation of the accretion process
  - Sensitive measurements of line profiles and abundance ratios

- Recent TWG activities
  - Quantification of effect of potential A_{eff} decrease
  - Investigation of parameters affecting measurement of properties in the outer regions (principally the particle background level)