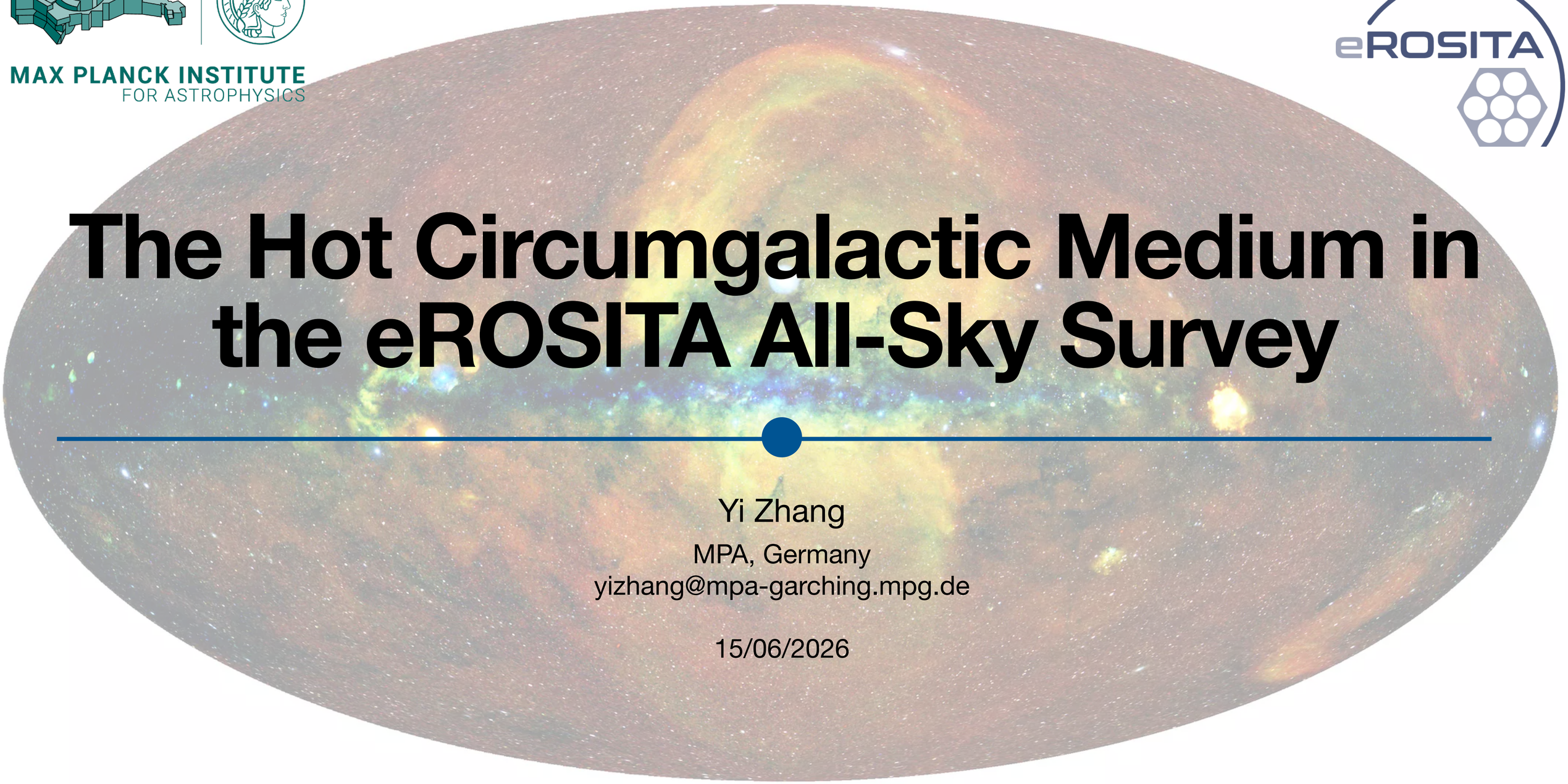
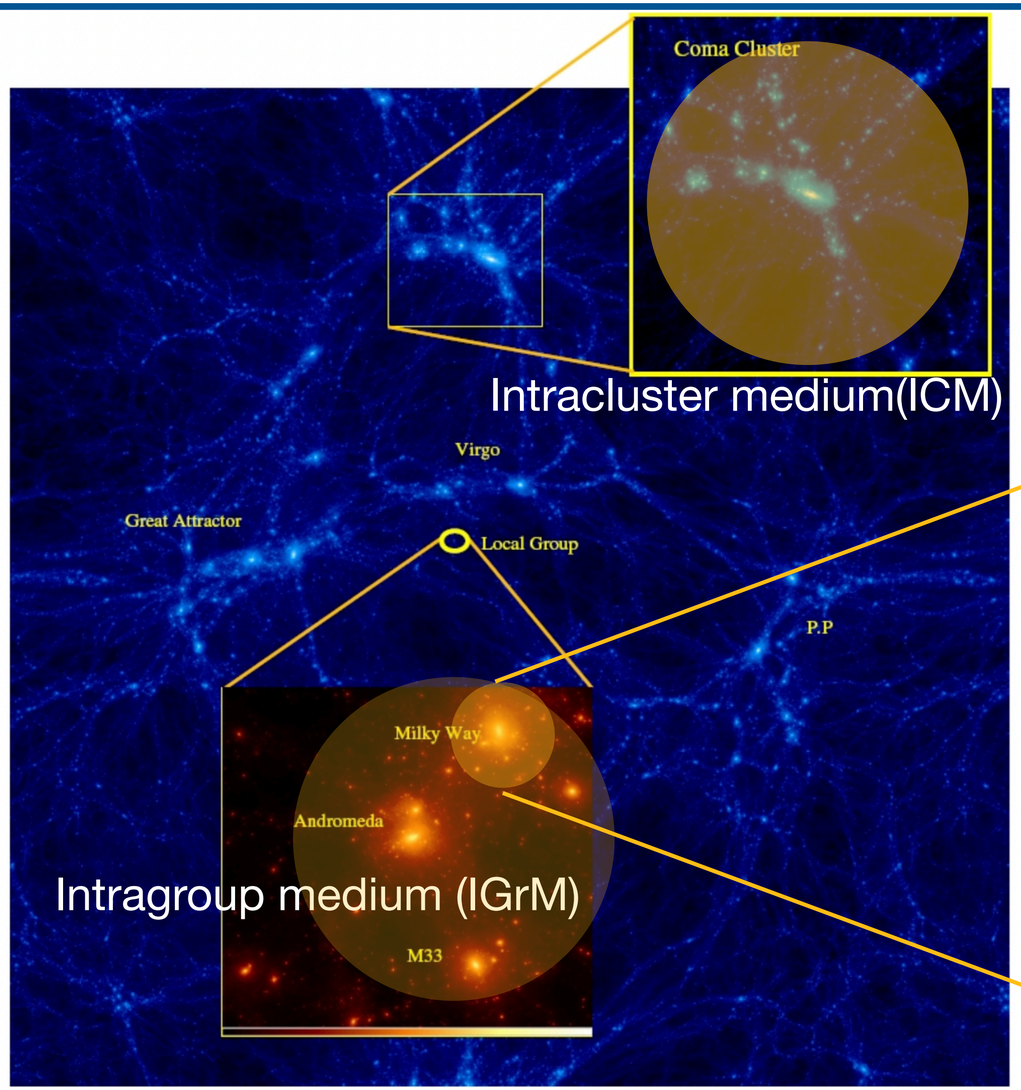


The Hot Circumgalactic Medium in the eROSITA All-Sky Survey

Yi Zhang
MPA, Germany
yizhang@mpa-garching.mpg.de

15/06/2026

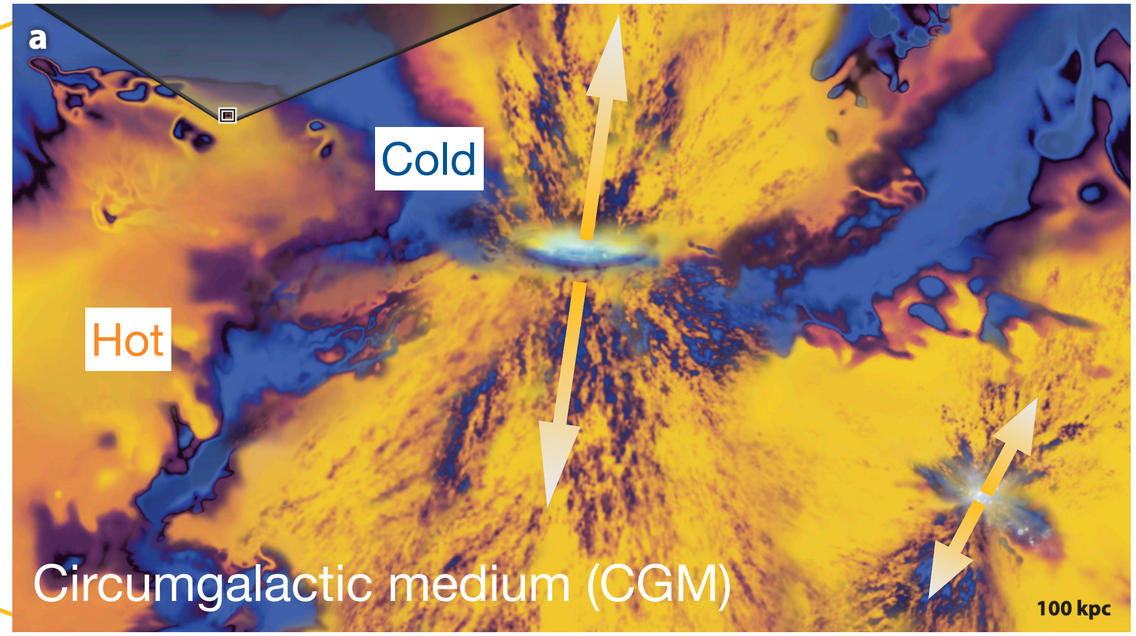
Galaxies and hot gas



Copyright:S. Gottlöber, G. Yepes, A. Klypin, A. Khalatyan (Clues)

Hot gas around galaxies:

- Diffuse ~ virial radius (100-1000s kpc)
- 10^6-10^7K, emits X-ray



Faucher-Giguere & Oh. 2023

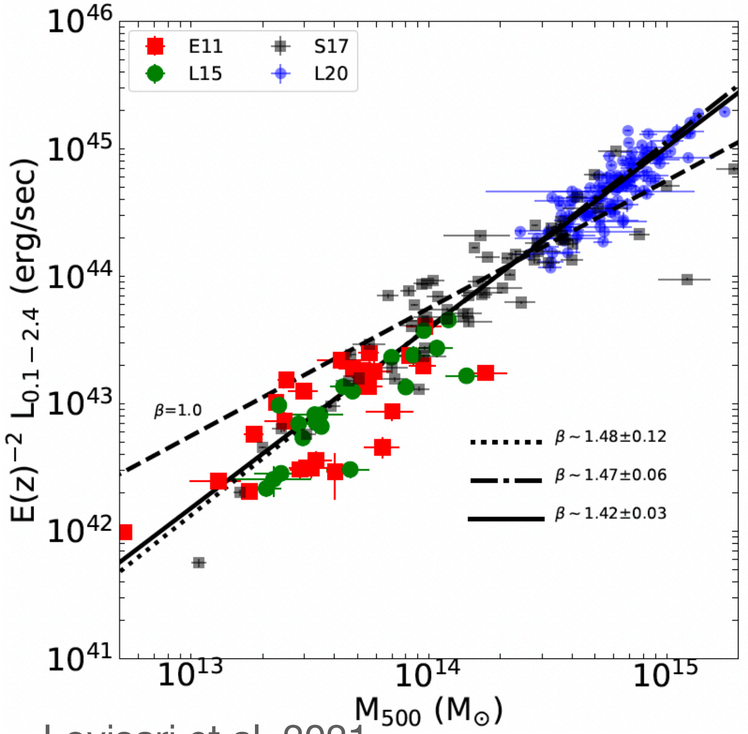
Yi Zhang yizhang@mpa-garching.mpg.de

Galaxies and hot gas

To heat gas:

- **Gravitational heat of accreted gas (~M_{halo})**

  Observed L_x-M_{halo}: slope=1.4-2.0
  Gravitation-only model: slope≈1.0



Lovisari et al. 2021

- **AGN or stellar feedbacks (~SFR, M_{star})**
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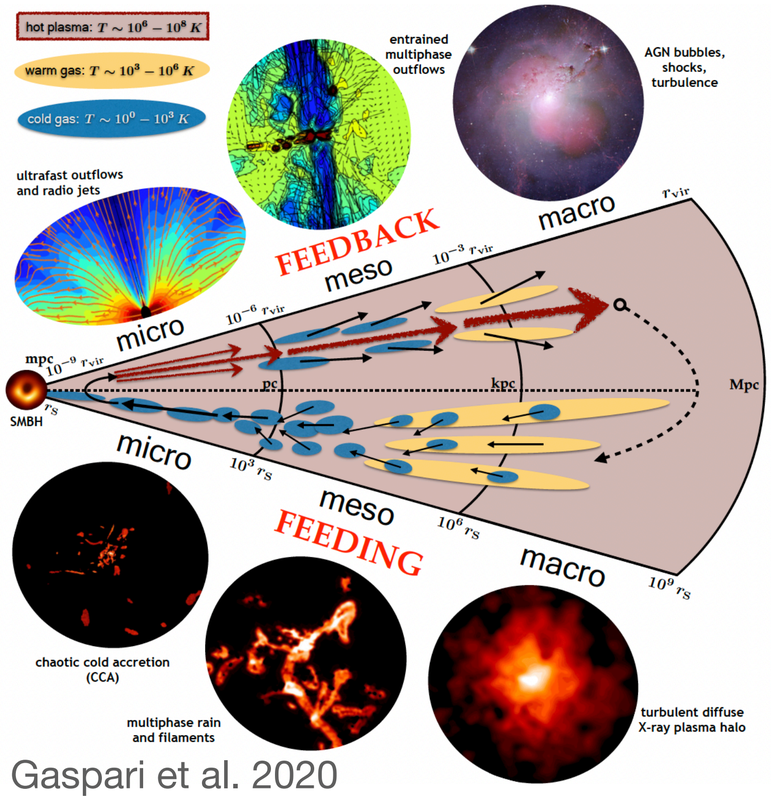

Gaspari et al. 2020

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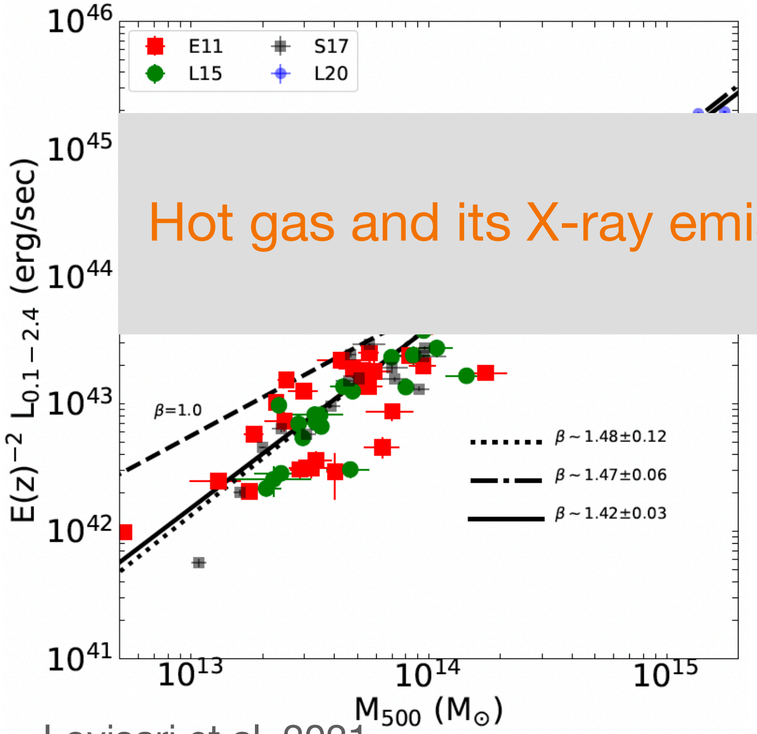

Lovisari et al. 2021

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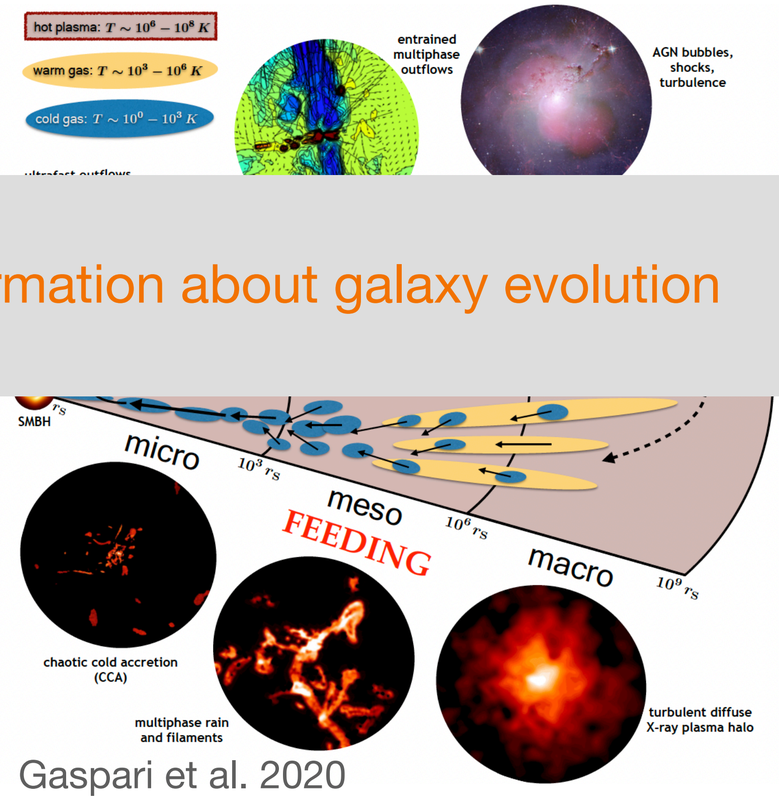


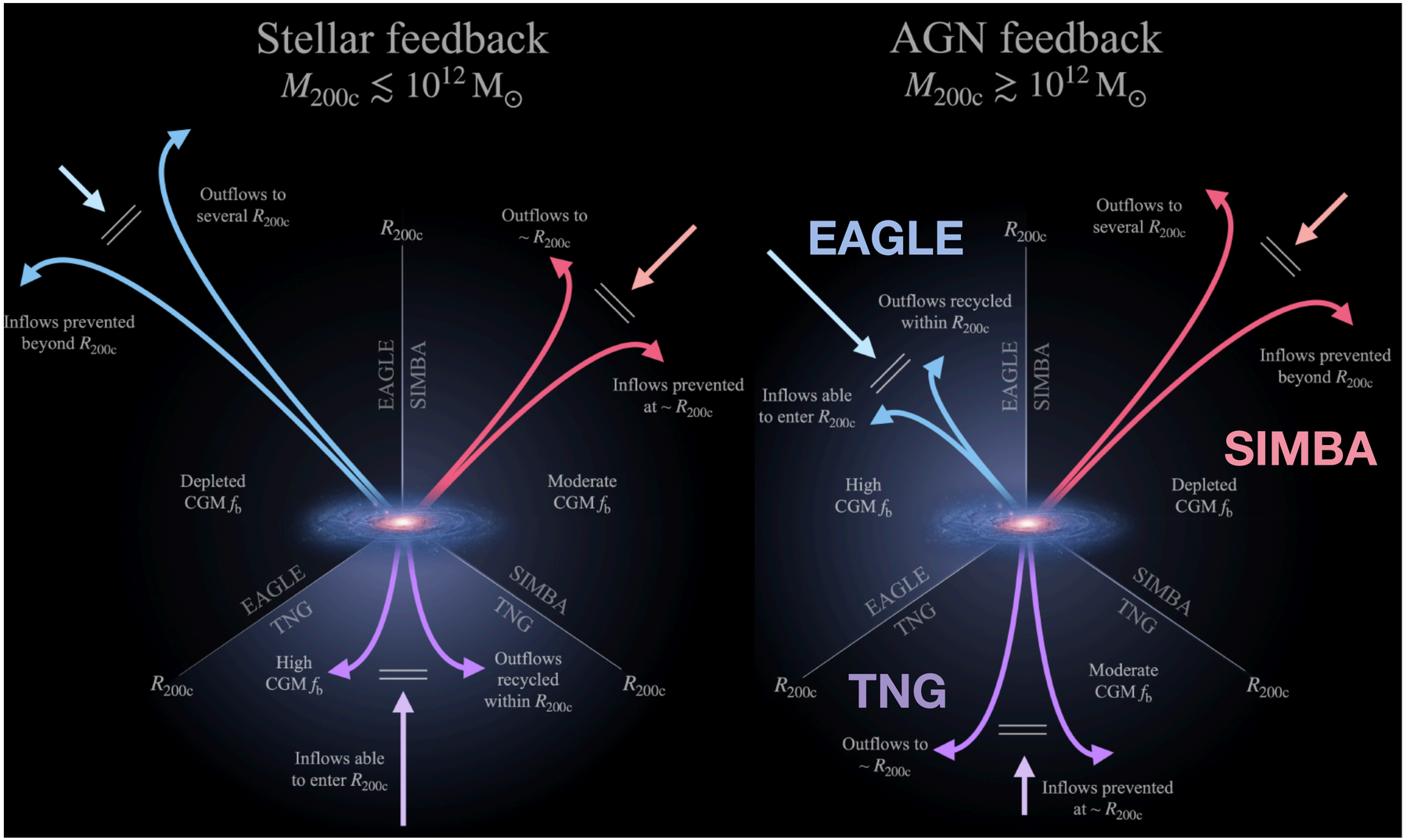
Gaspari et al. 2020

Hot gas and its X-ray emission imprint information about galaxy evolution

Yi Zhang yizhang@mpa-garching.mpg.de

Gas in simulations

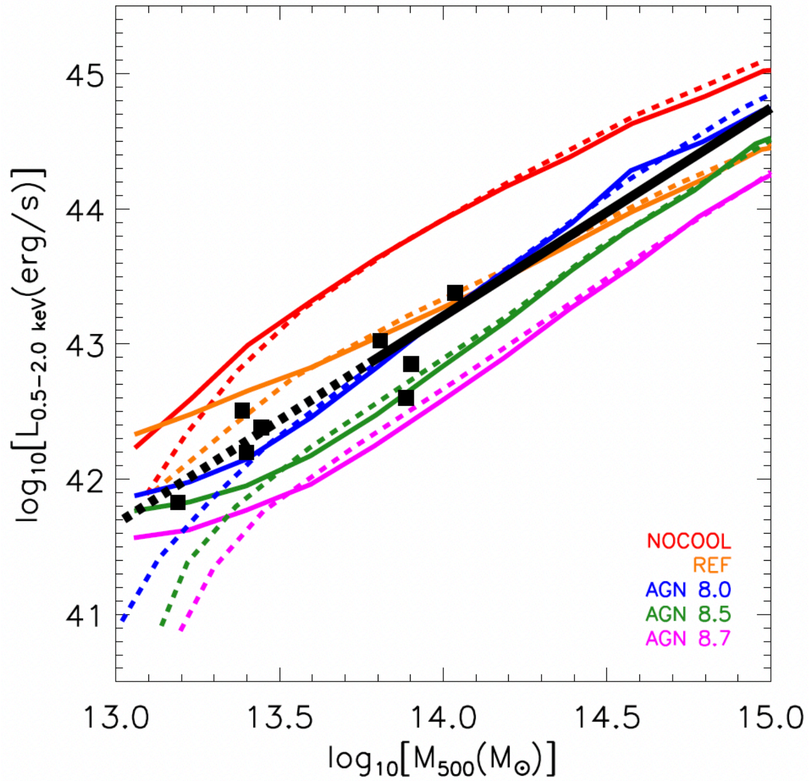
Simulations with different feedback models:



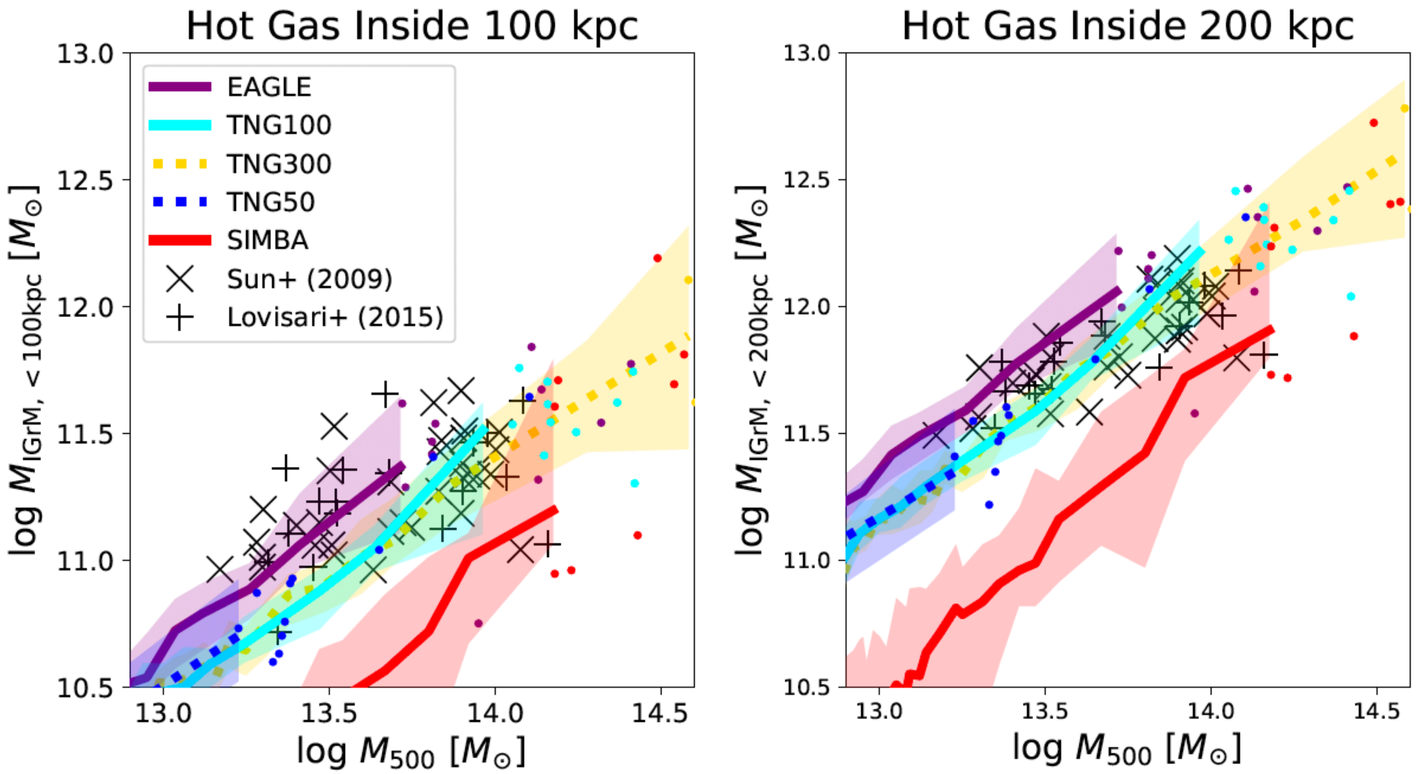
Wright et al. 2024

Hot gas in simulation

Comparing simulations to observations:



Le Brun et al. 2014

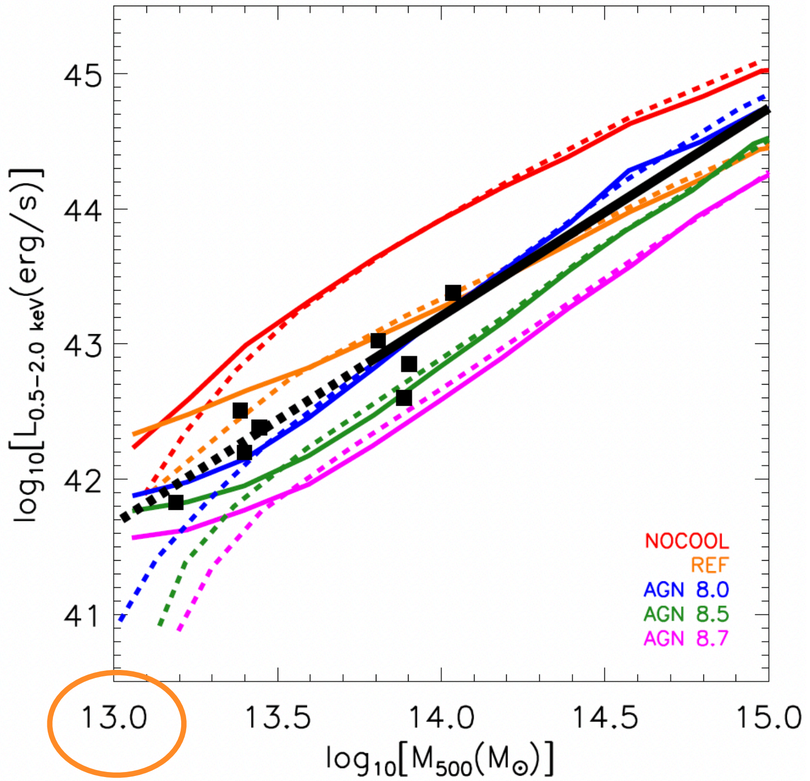


Oppenheimer et al. 2021

Hot gas in simulation

Comparing simulations to observations:

Only $M_{halo} > 10^{13}$ ($M_{star} > 10^{11}$)



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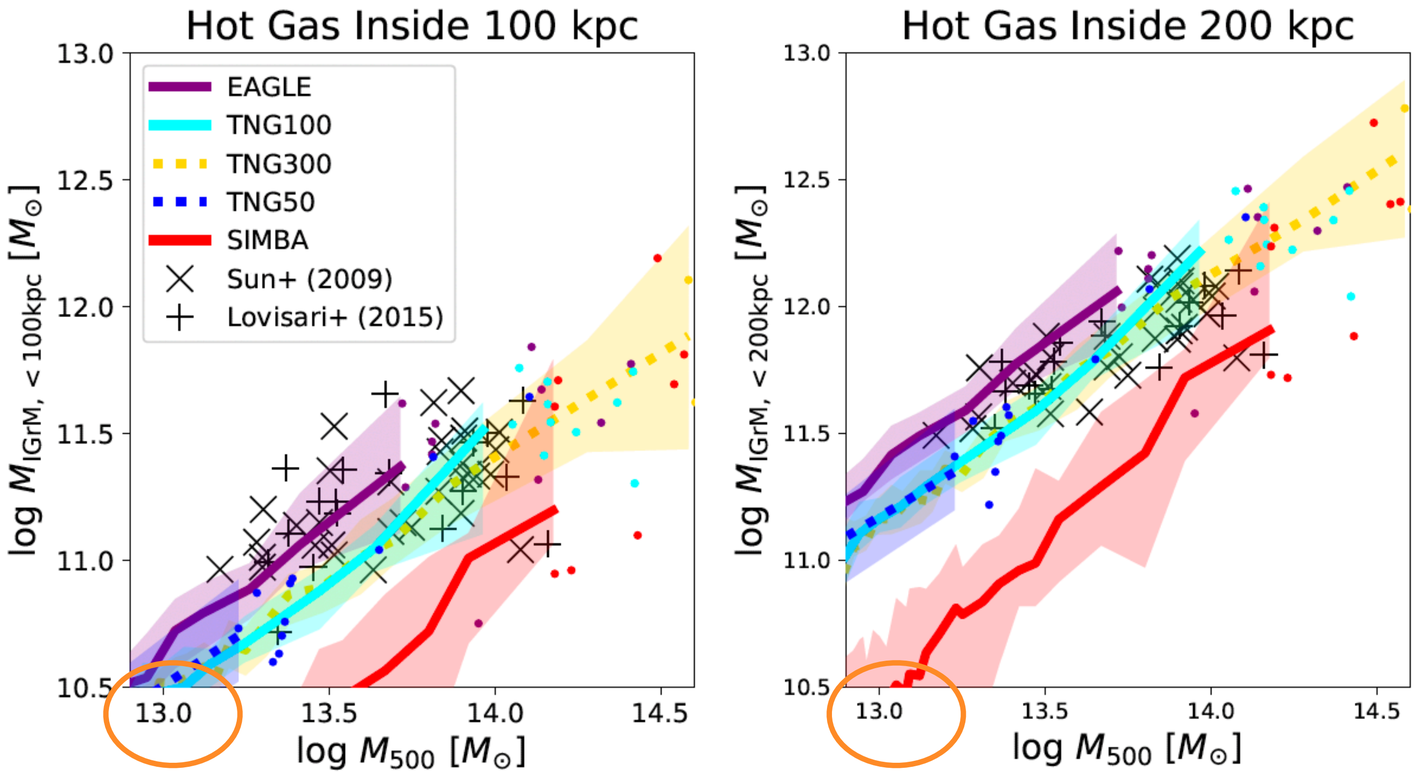
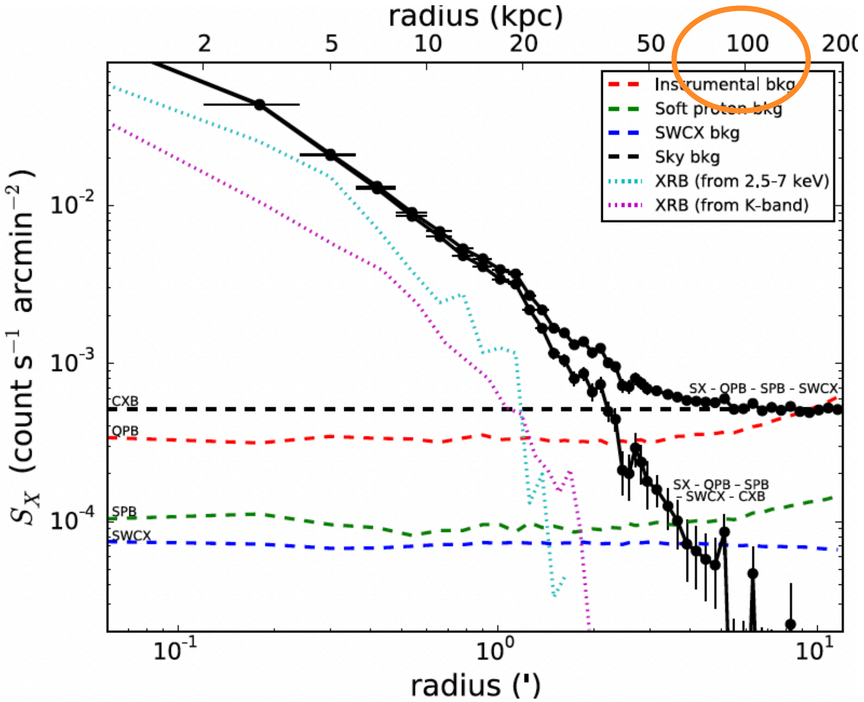


Oppenheimer et al. 2021

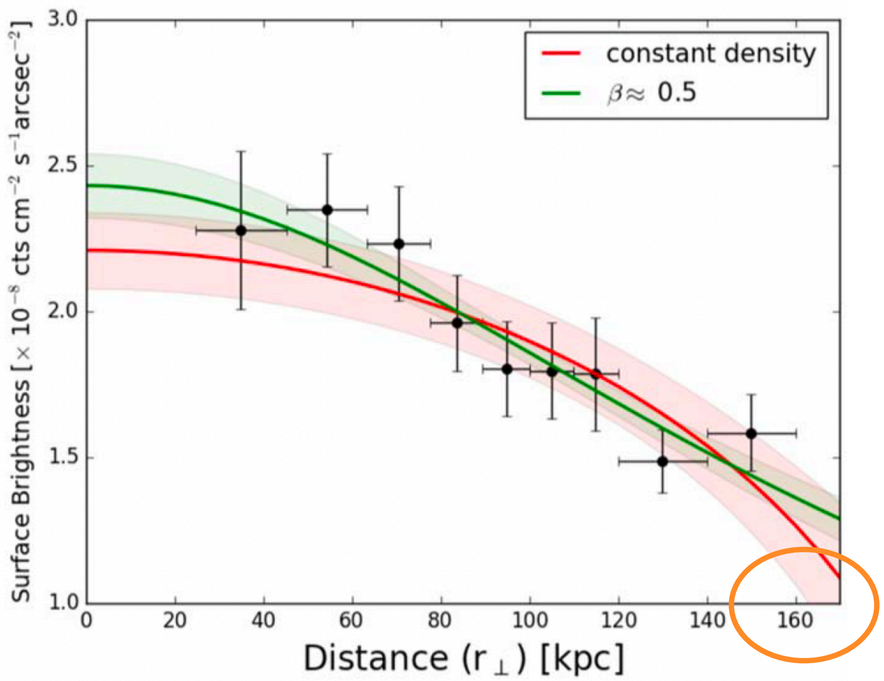
Detect hot CGM

- Use XMM-Newton, Chandra, Suzaku
  - Nearby massive galaxies (<50 Mpc, $M_{star}>10^{11}$ M_{solar} ~$M_{halo}=10^{13}$)
  - X-ray emission out to ~100 kpc <0.5 R_{vir}

Strickland et al. 2004; Tüllmann et al. 2006; Wang 2010; Li & Wang 2013a;Kim & Fabbiano 2013, 2015; Goulding et al. 2016; Forbes et al. 2017; Choi et al. 2015; Li & Wang 2013b; Wang et al. 2016; Kereš et al. 2009b,a; van de; Voort et al. 2016; Li et al. 2016; Bogdan et al.2017; Das et al. 2019; et al



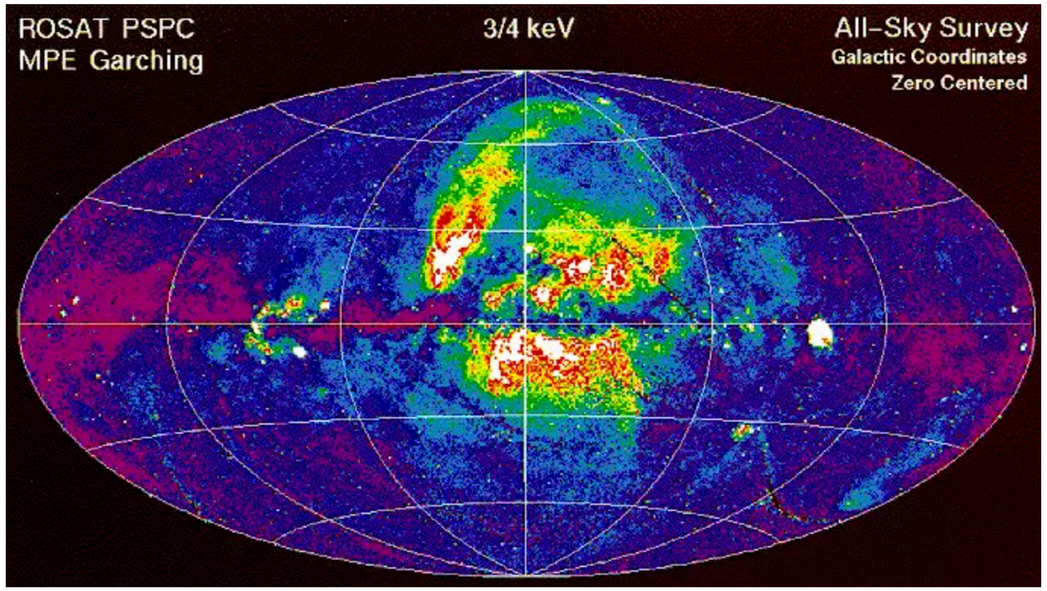
Anderson et al. 2016



Das et al. 2019

Detect hot CGM

- Use ROSAT
  - Mean t_{exp}=300s over sky



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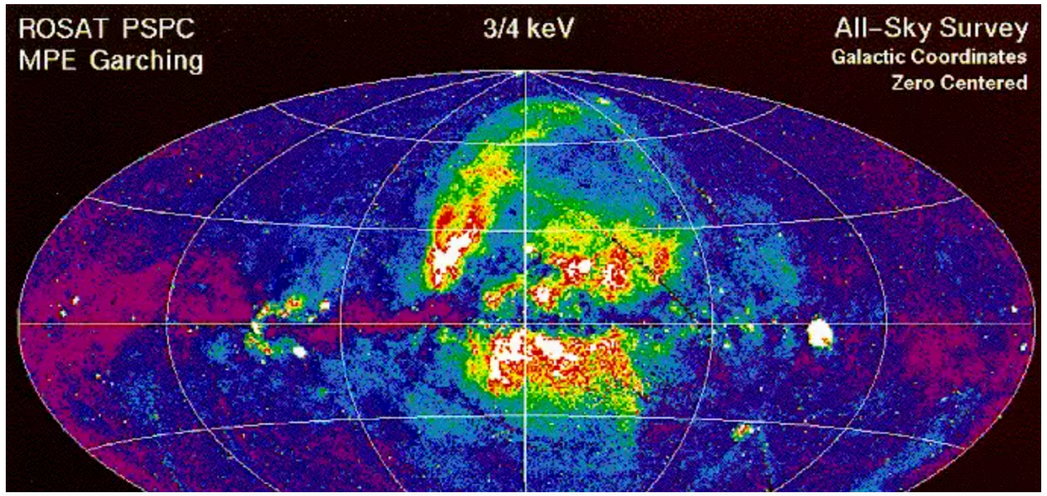

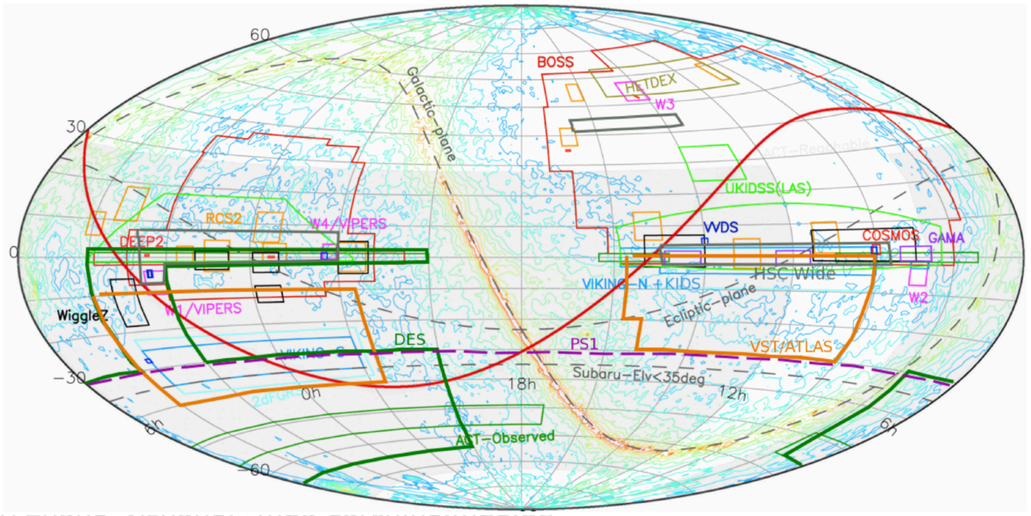

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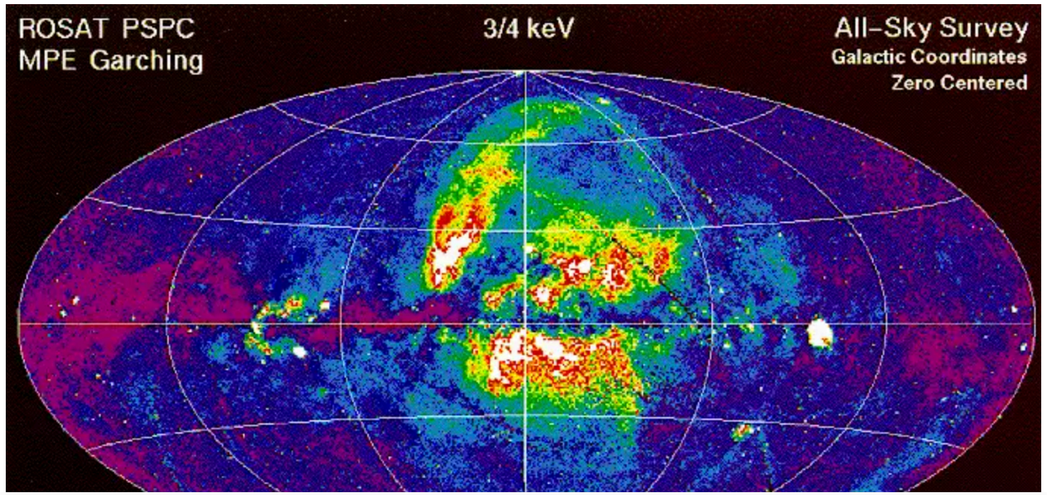

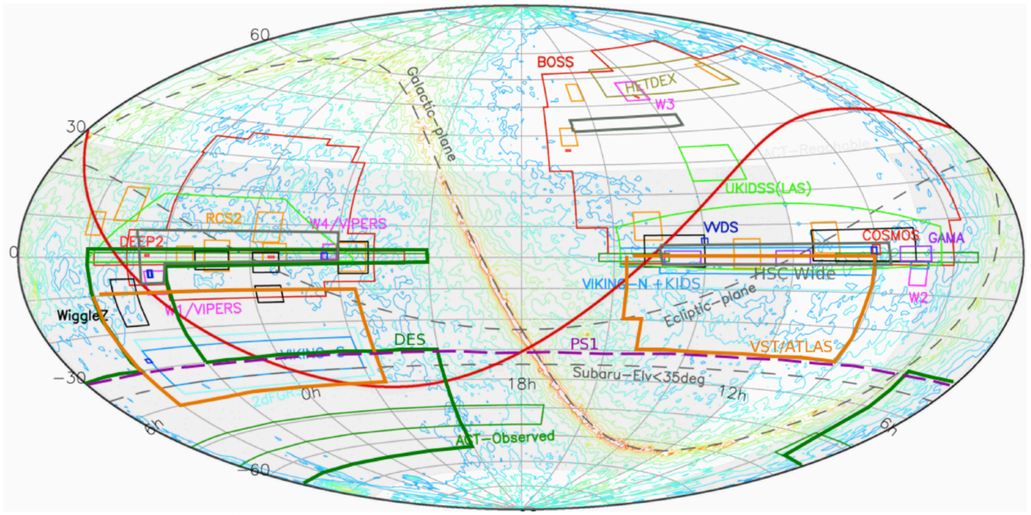

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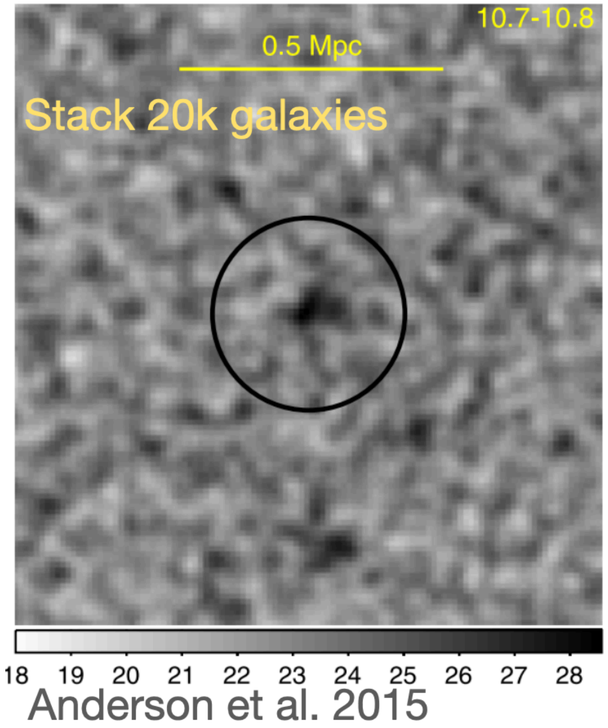

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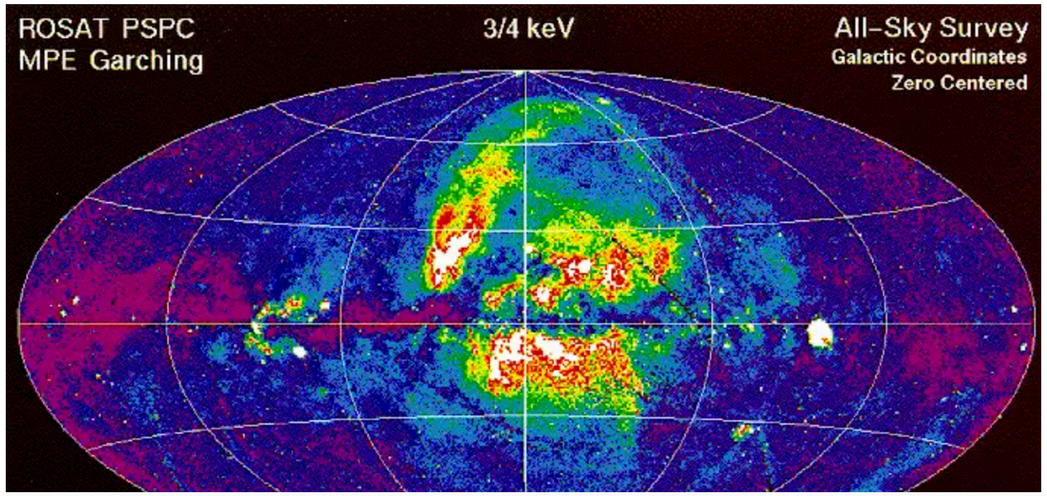

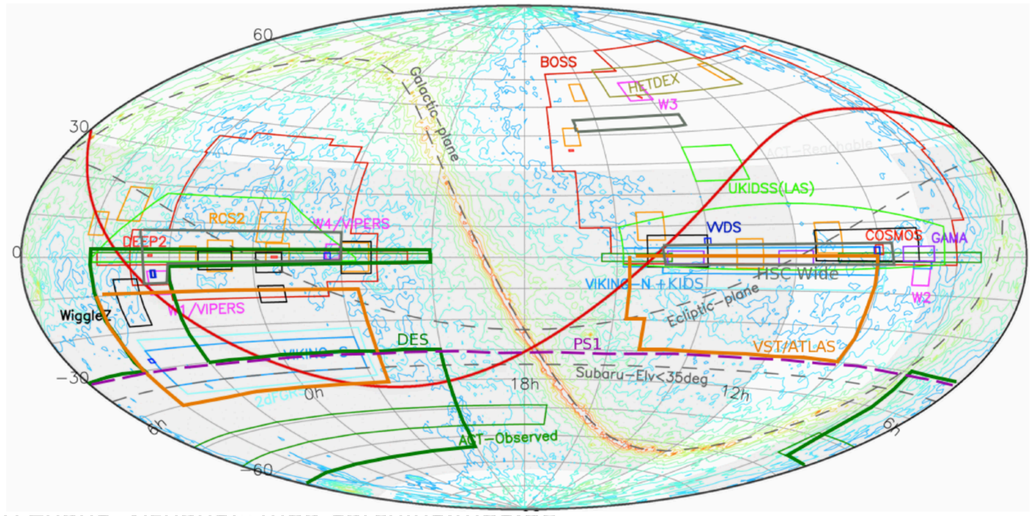

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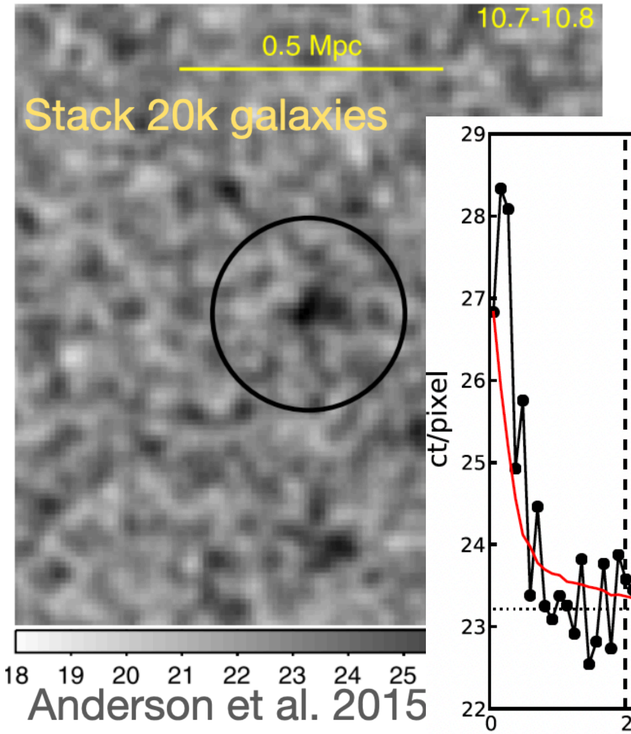

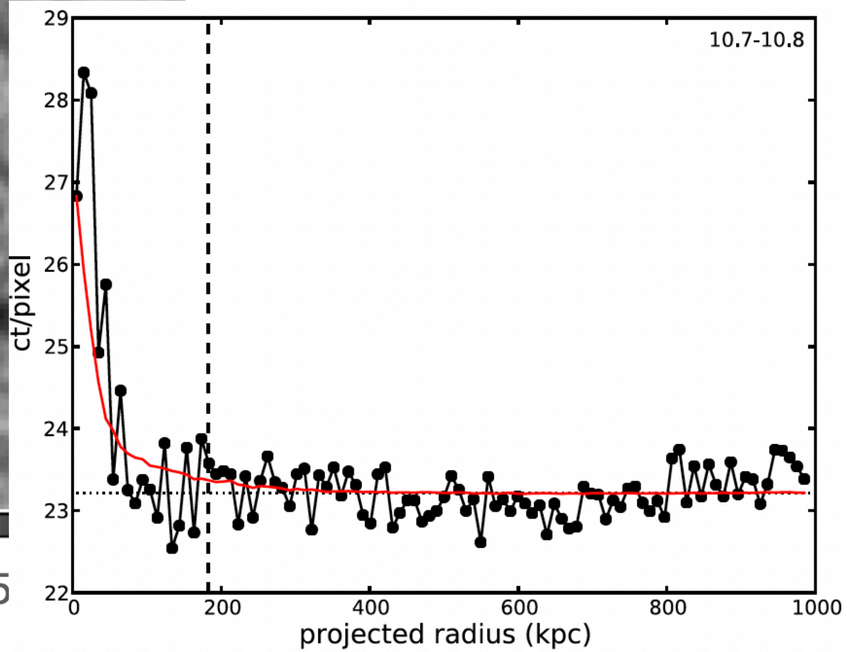

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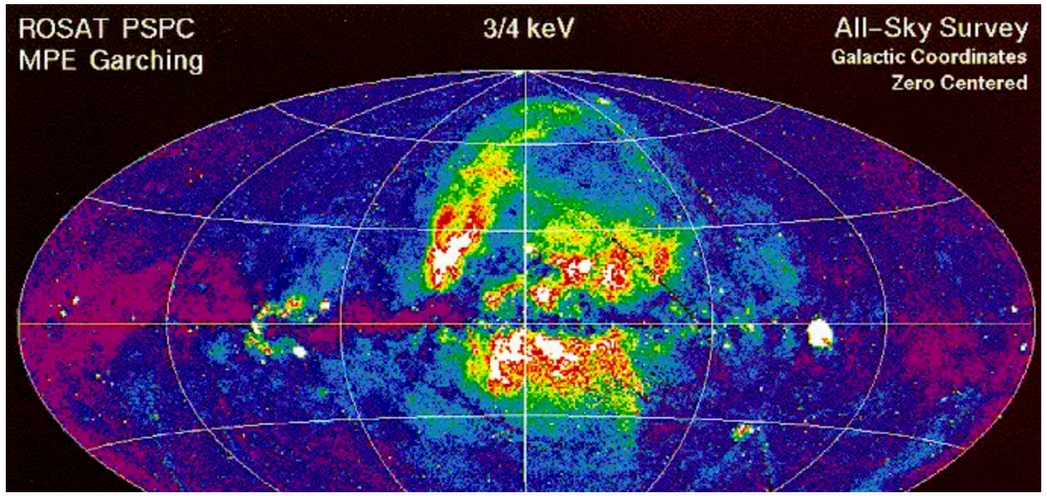

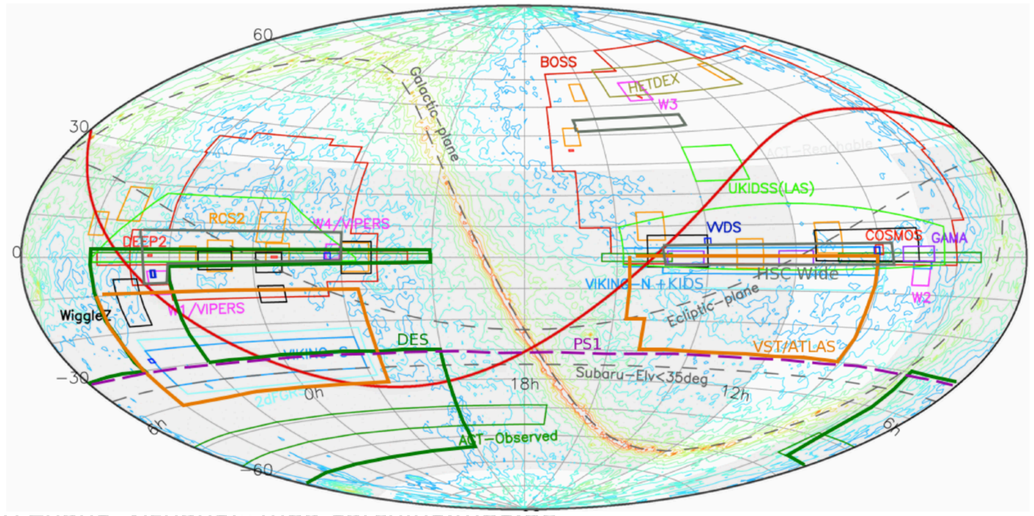

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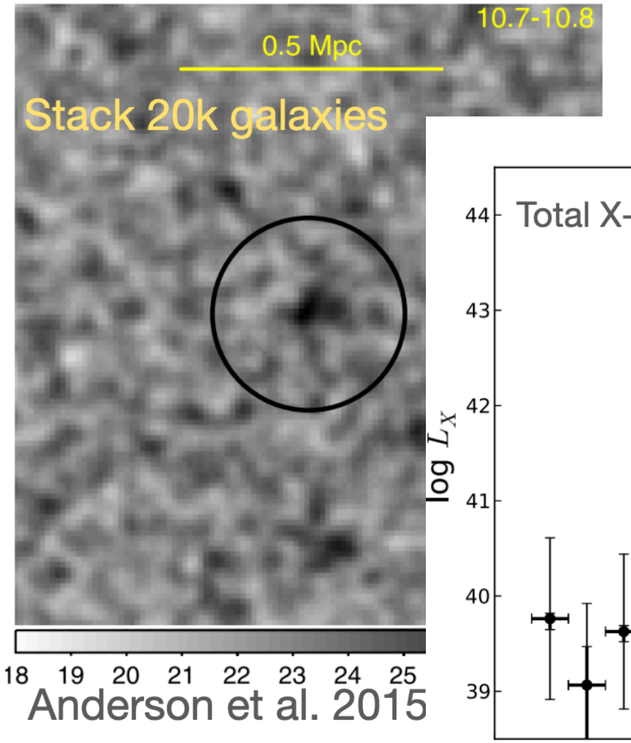

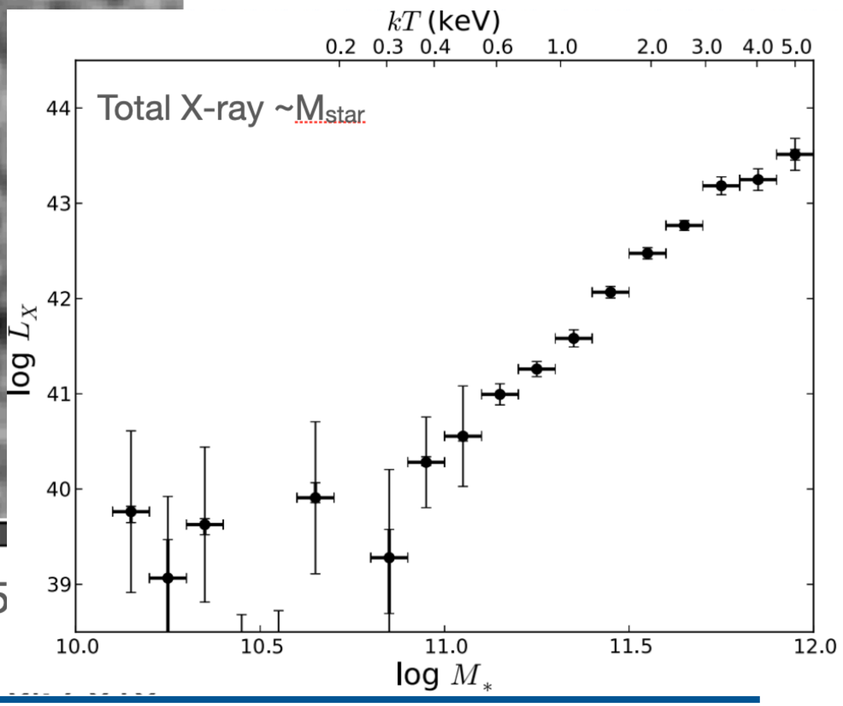

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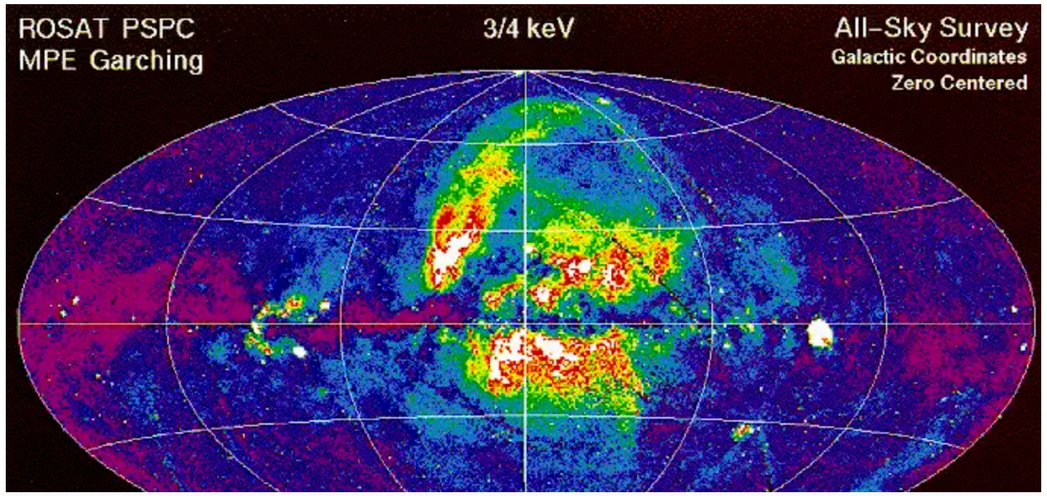

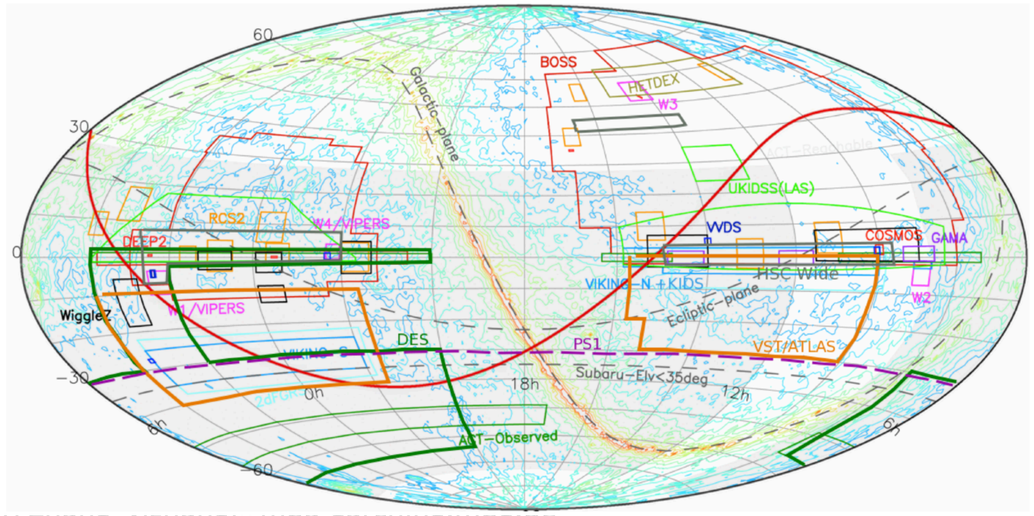

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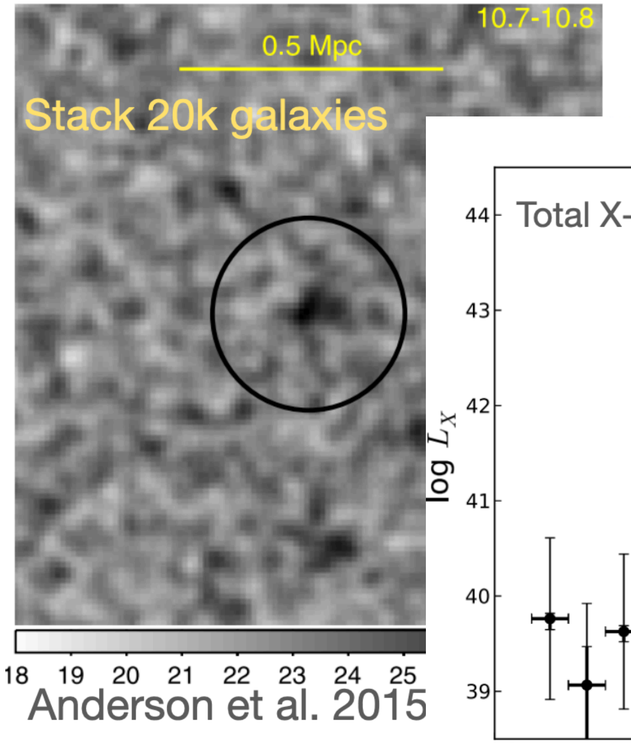

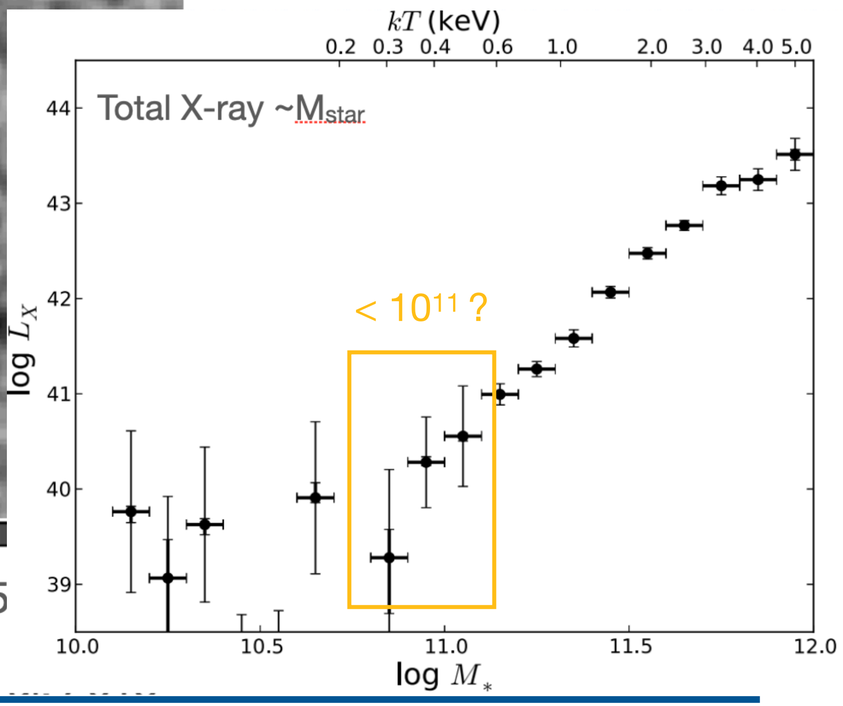

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- How bright and extended is the CGM around <10^{11} solar mass galaxies?
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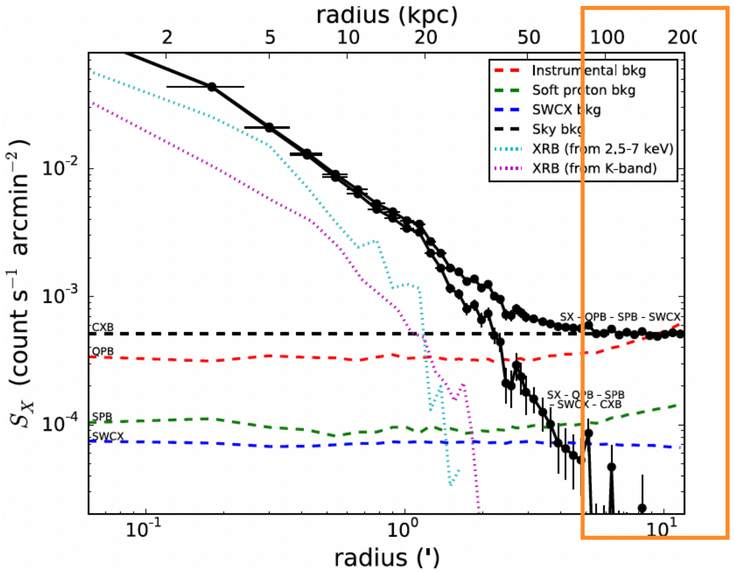
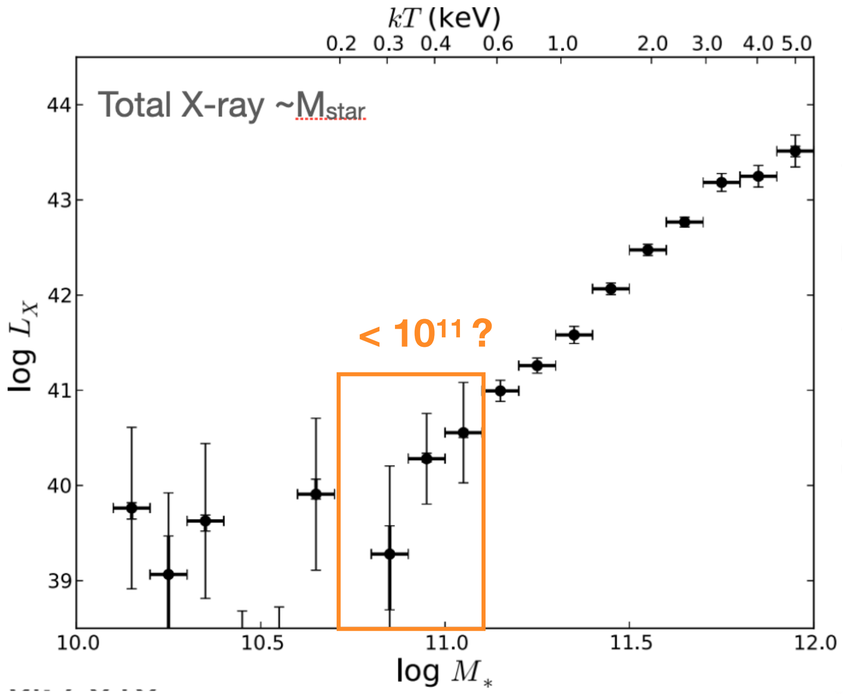
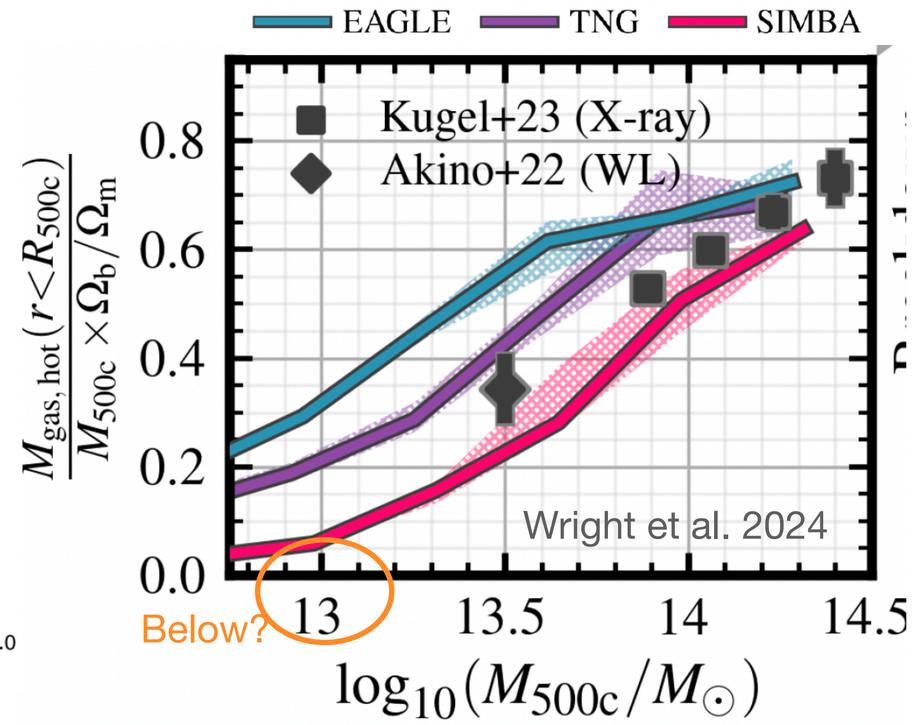
Emission beyond 0.5R_{vir} ?







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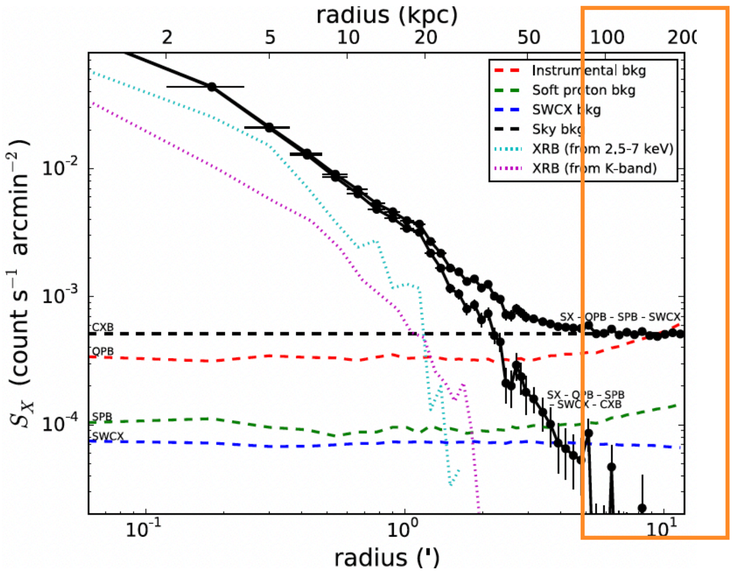
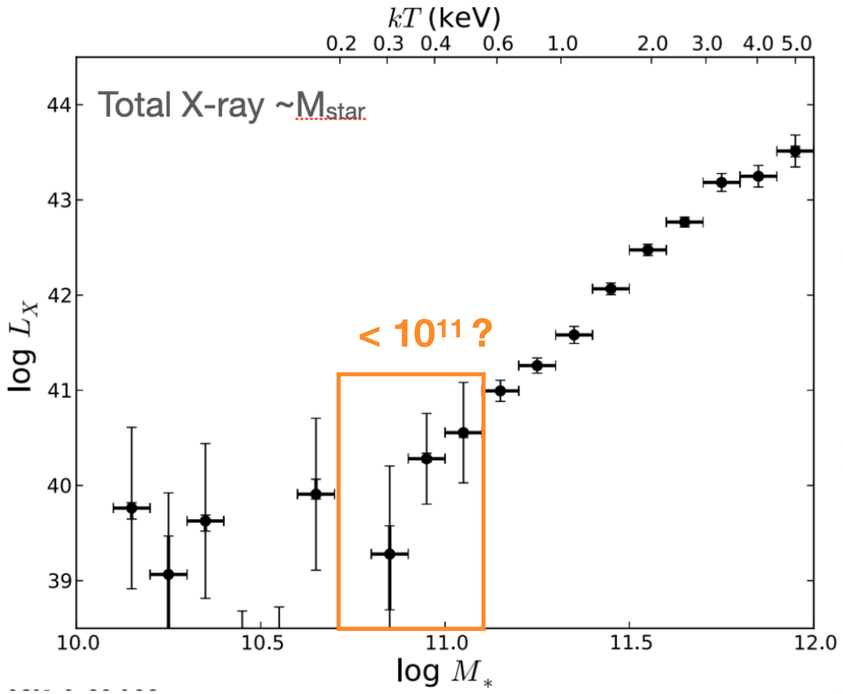
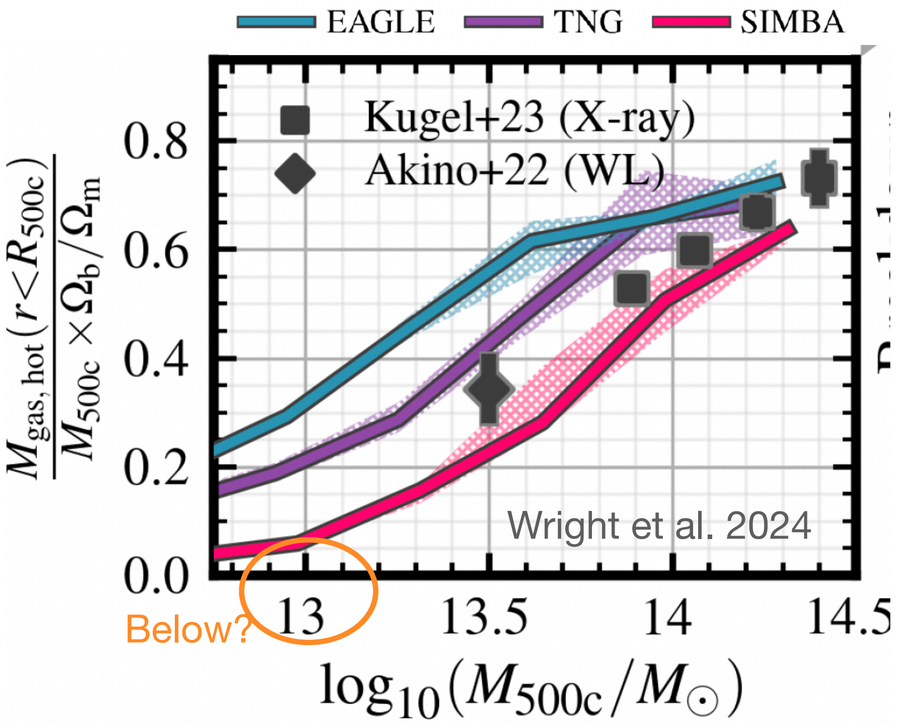


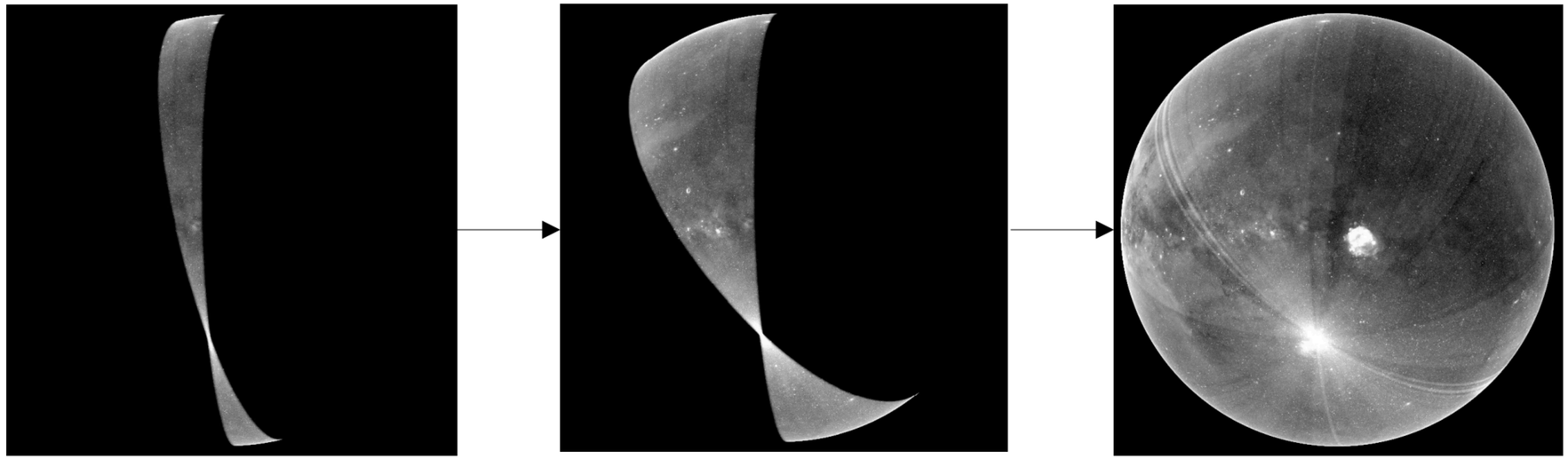




X-ray telescope: eROSITA

We use eROSITA, with 25 times better sensitivity than ROSAT

Observation plan: all sky survey, scan the sky every 6 months



After a few days | After a few weeks | After 6 months

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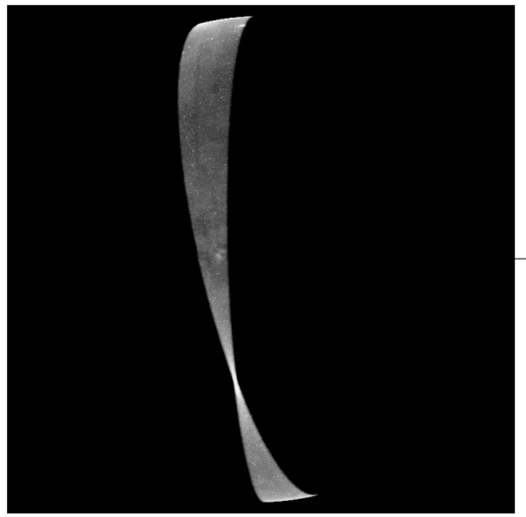

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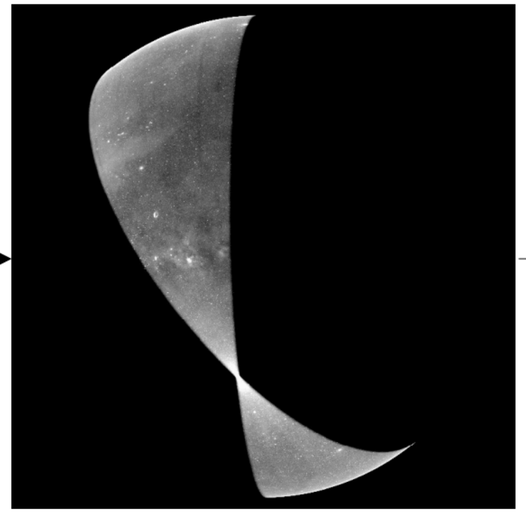

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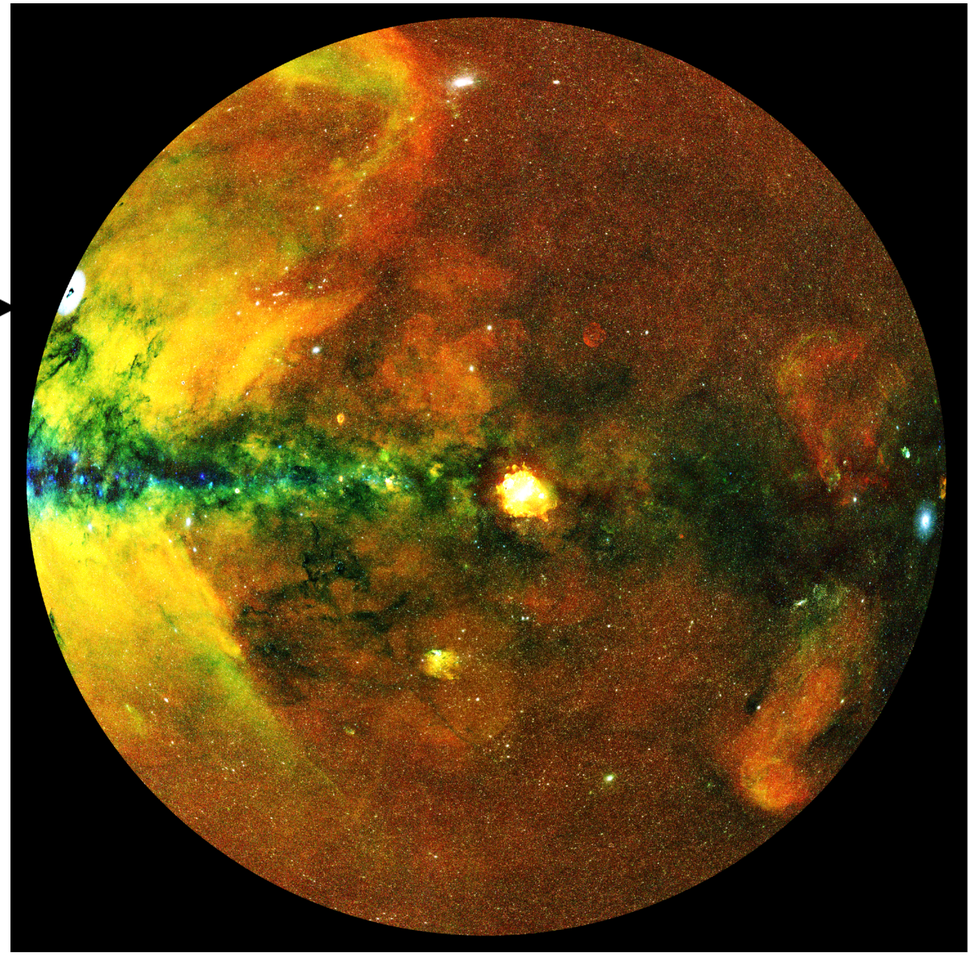
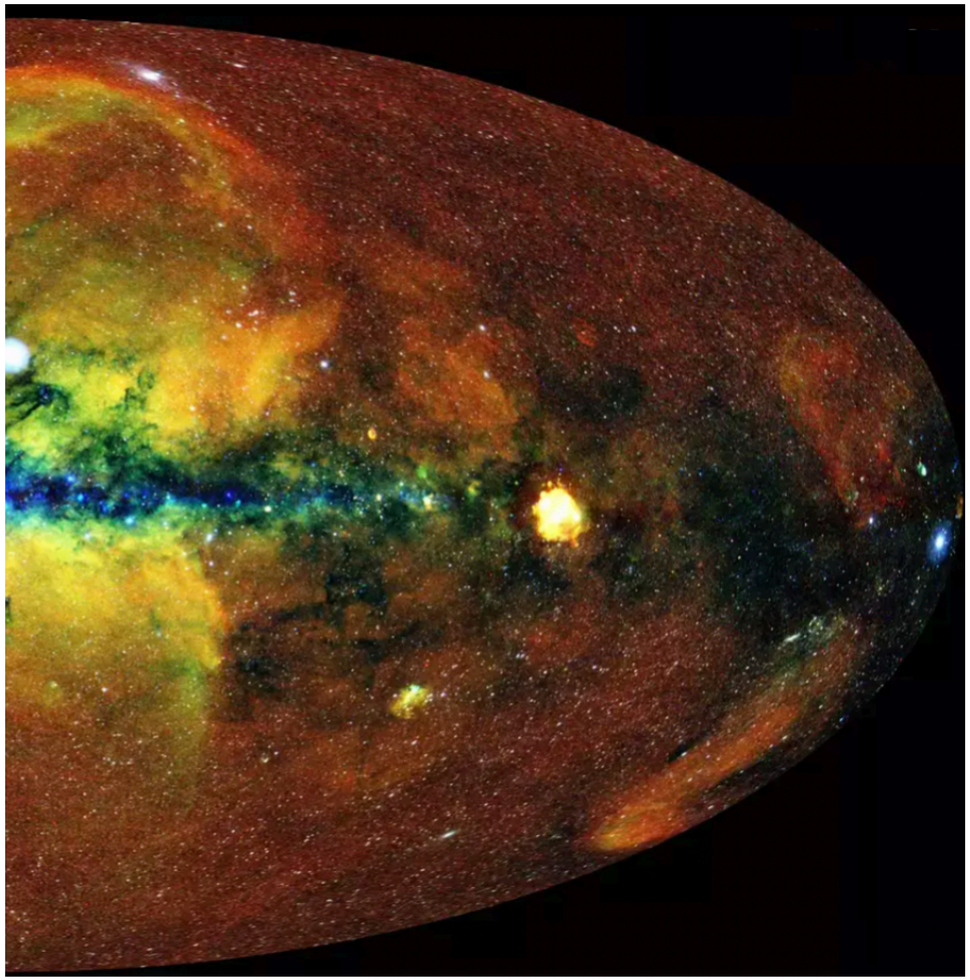


4.5 rounds of sky scans completed (eRASS:5), median t_{exp}≈600s.

Merloni et al. 2024

Stacking - eRASS:4 & SDSS

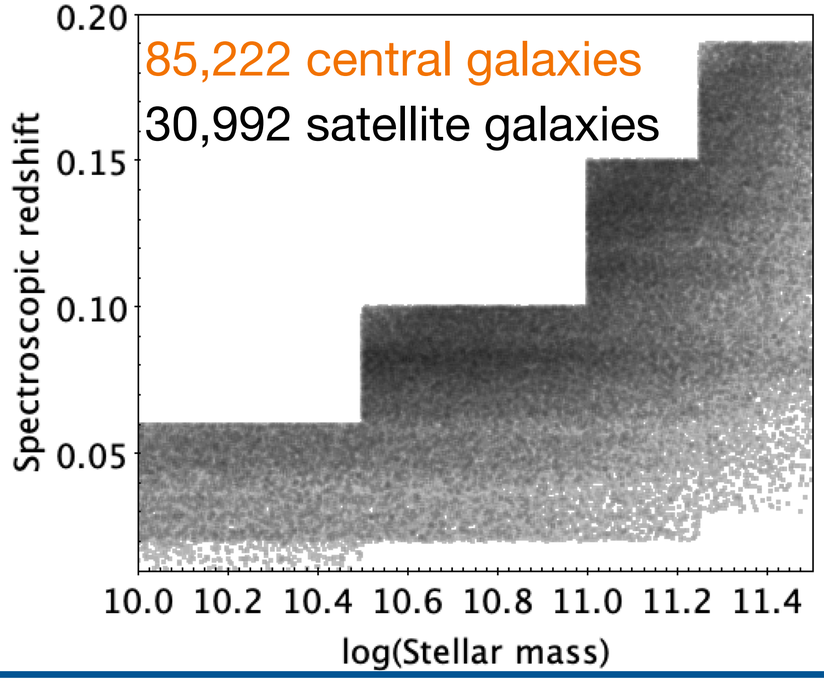
4 rounds of scans (eRASS:4)



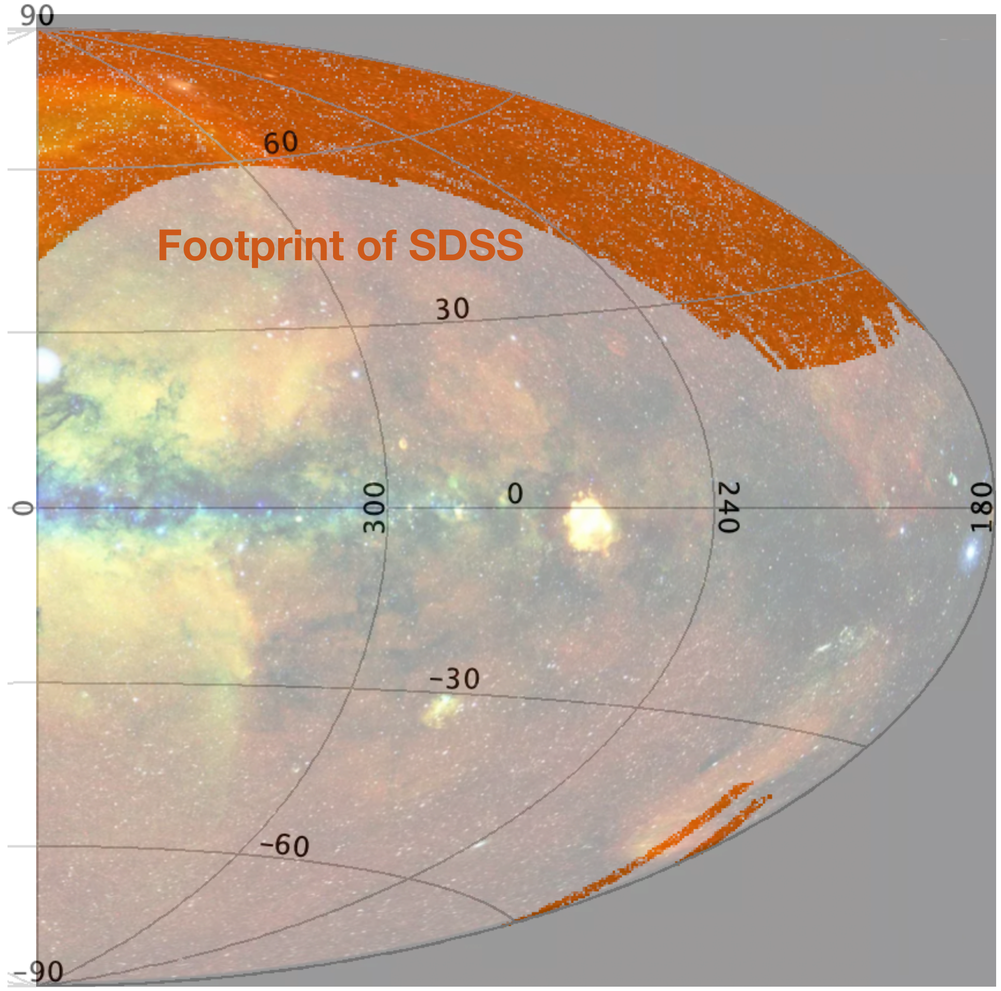
Stacking - eRASS:4 & SDSS

We take the SDSS DR7-main galaxy sample (r<17.77):

- Stellar mass and SFR from MPA-JHU catalog
- BPT diagram applied to identify AGN-hosting galaxy (MPA-JHU)
- Self-calibrated halo-based group finder -> central/satellite galaxy, halo mass (Tinker et al. 2021)
- Volume-limited galaxy sample



4 rounds of scans (eRASS:4)



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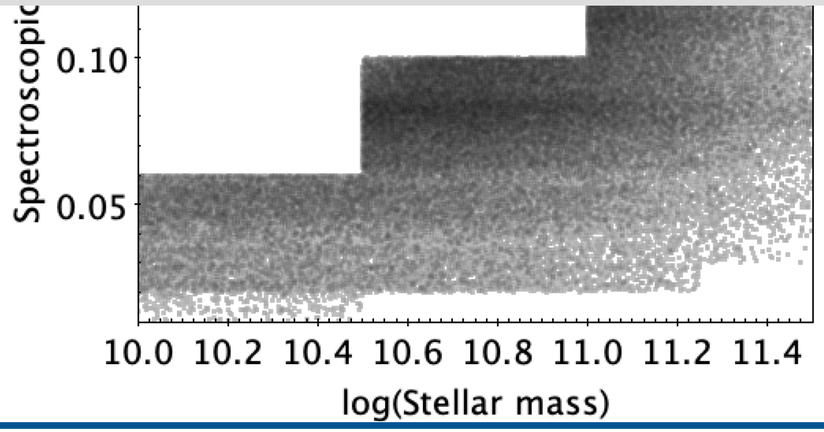
We measure the **mean** X-ray properties of galaxies in a M_{star} or M_{halo} bin



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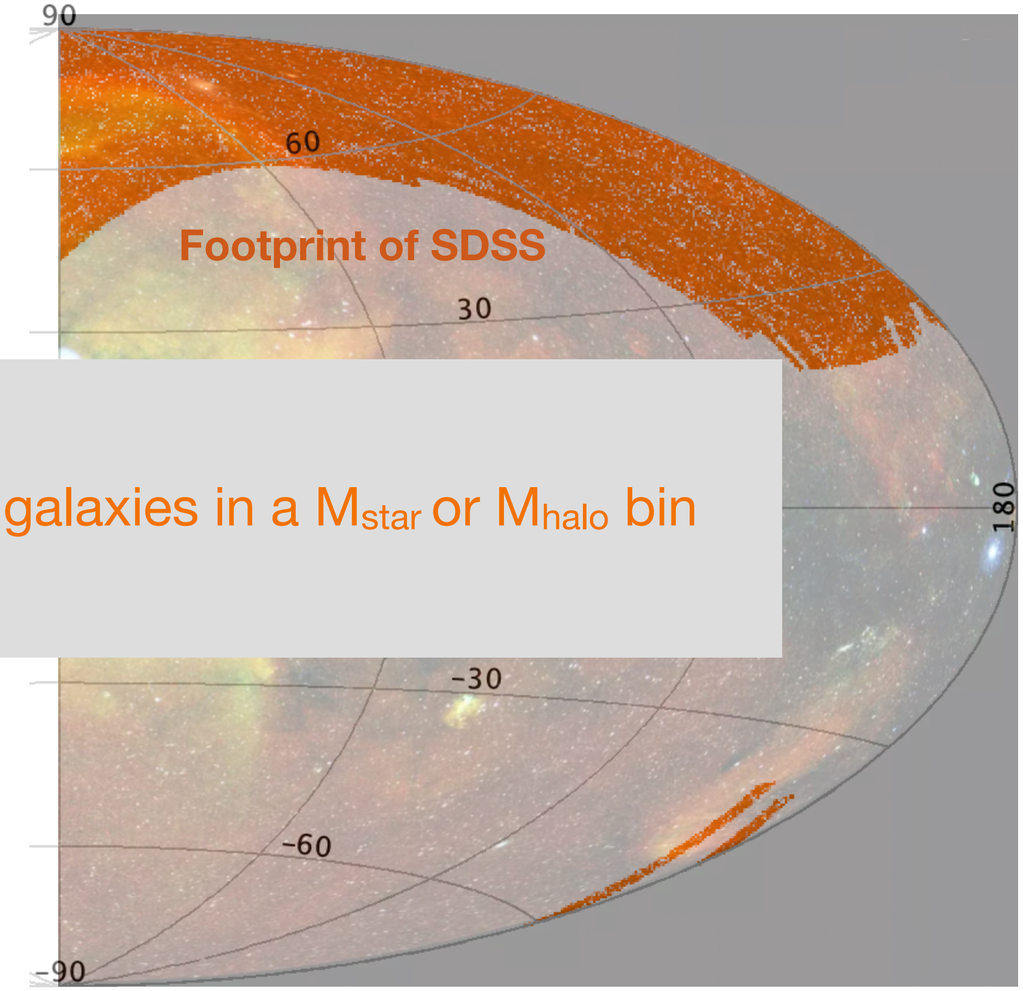
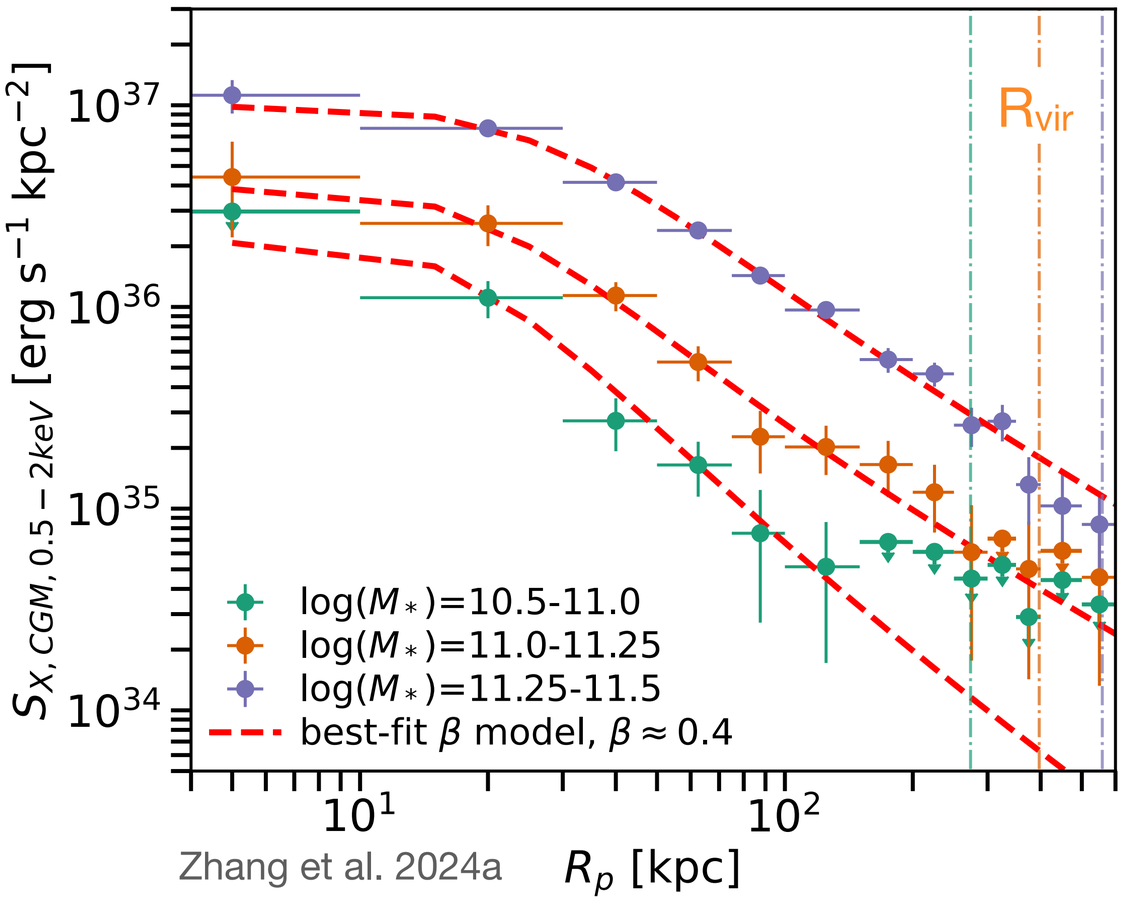


Results I: X-ray surface brightness profile of CGM

1.How bright and extended is the hot CGM?
2.How does it relate to galaxy properties?



- Mask detected X-ray sources + model undetected sources

  -> Obtain the hot CGM emission

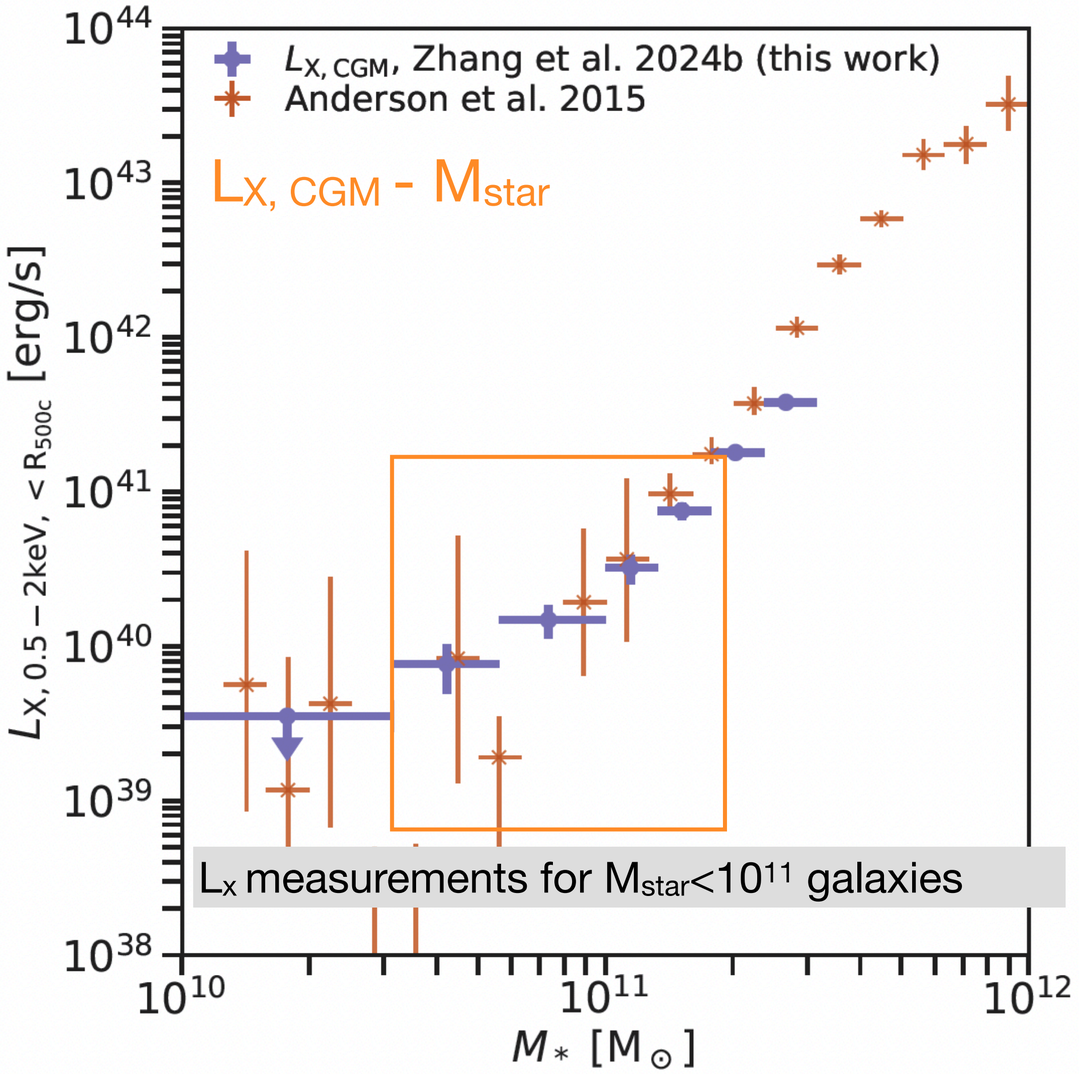
- We detect the extended hot CGM X-ray emission to R_{vir}

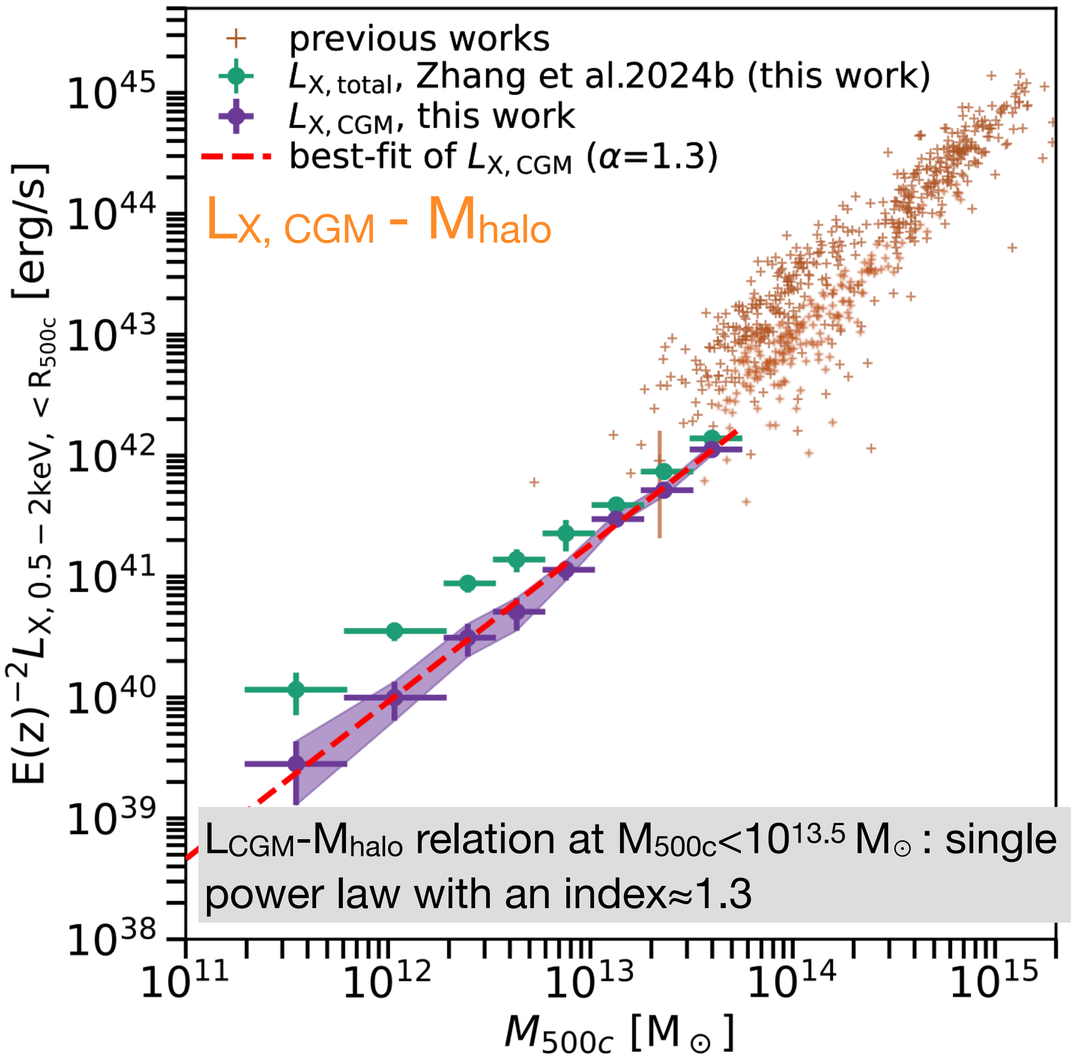
  Fit with a beta model: beta≈0.4, $S_x \sim r^{-1.4}$

Yi Zhang yizhang@mpa-garching.mpg.de

Results II-I: $L_{X,\,CGM}$ - M_{star}, M_{halo}

1.How bright and extended is the hot CGM?
2.How does it relate to galaxy properties?





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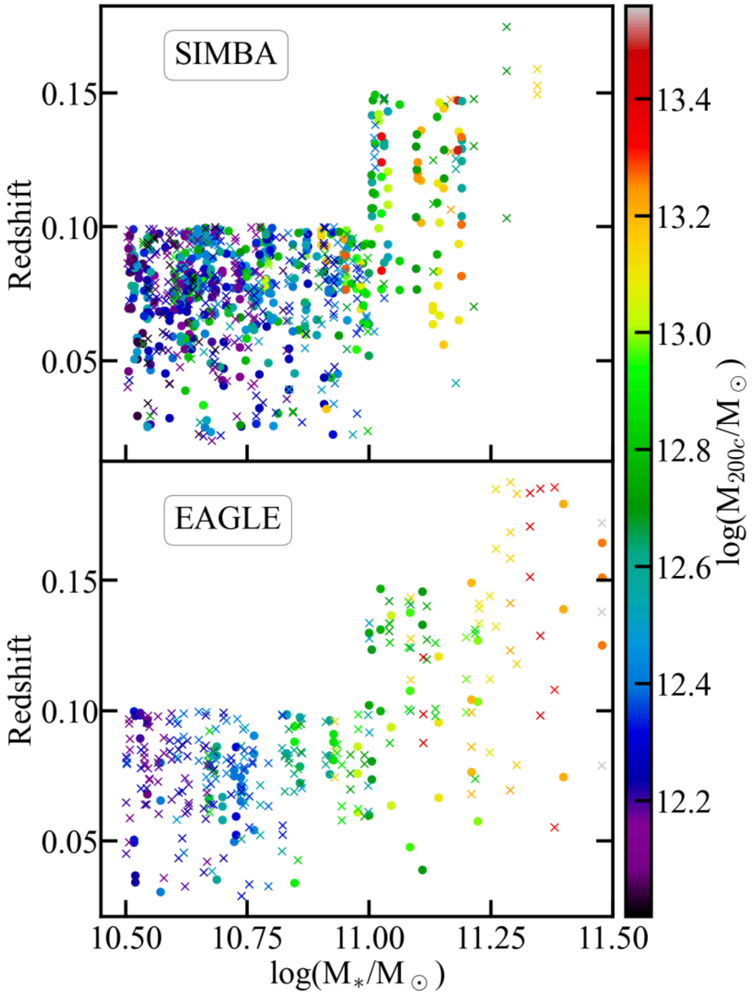
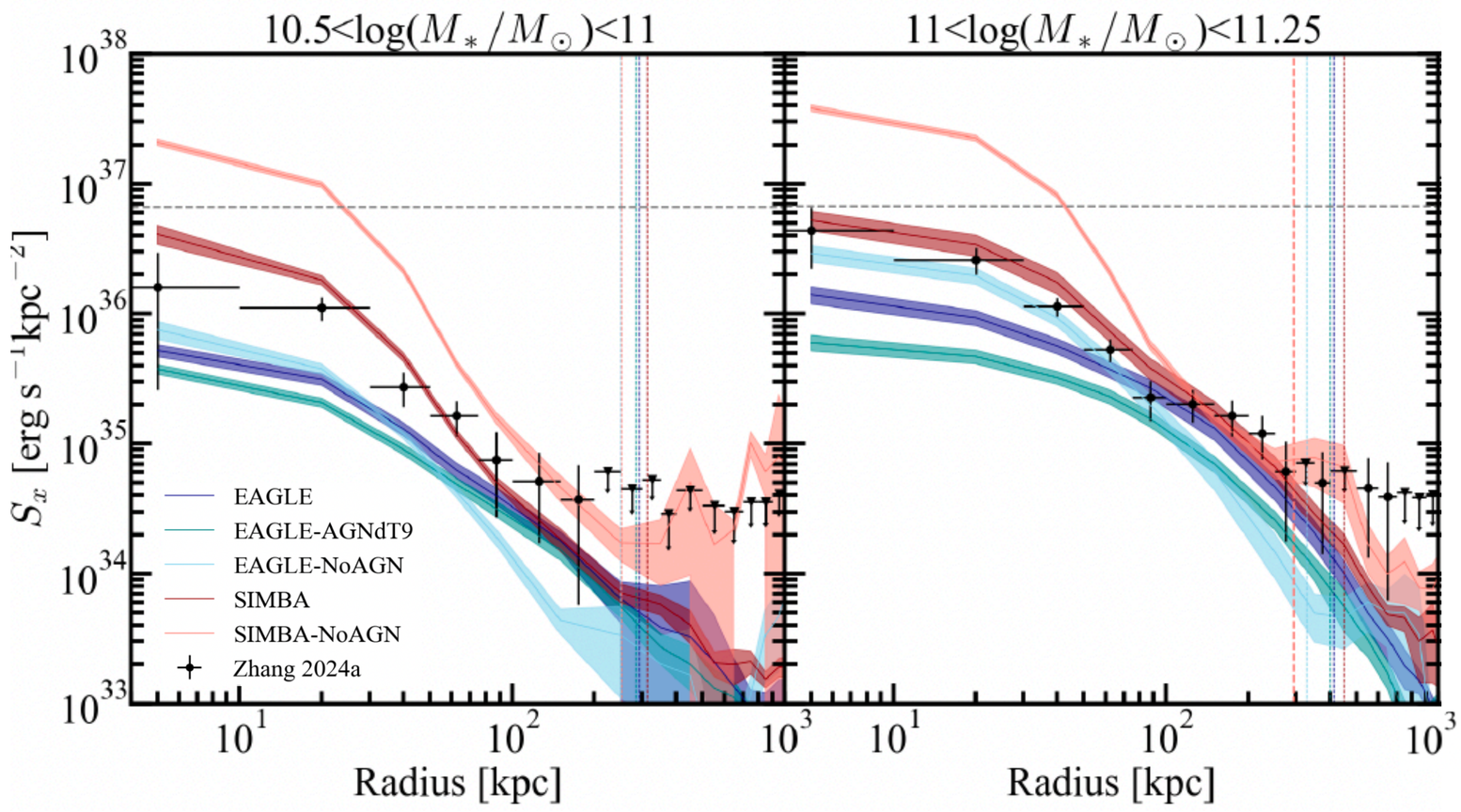
Comparison to simulations (thermal origin of X-ray)



Grayson et al. 2025:

Build galaxy samples in simulations with the same M_{star} and redshift distribution as the observations.



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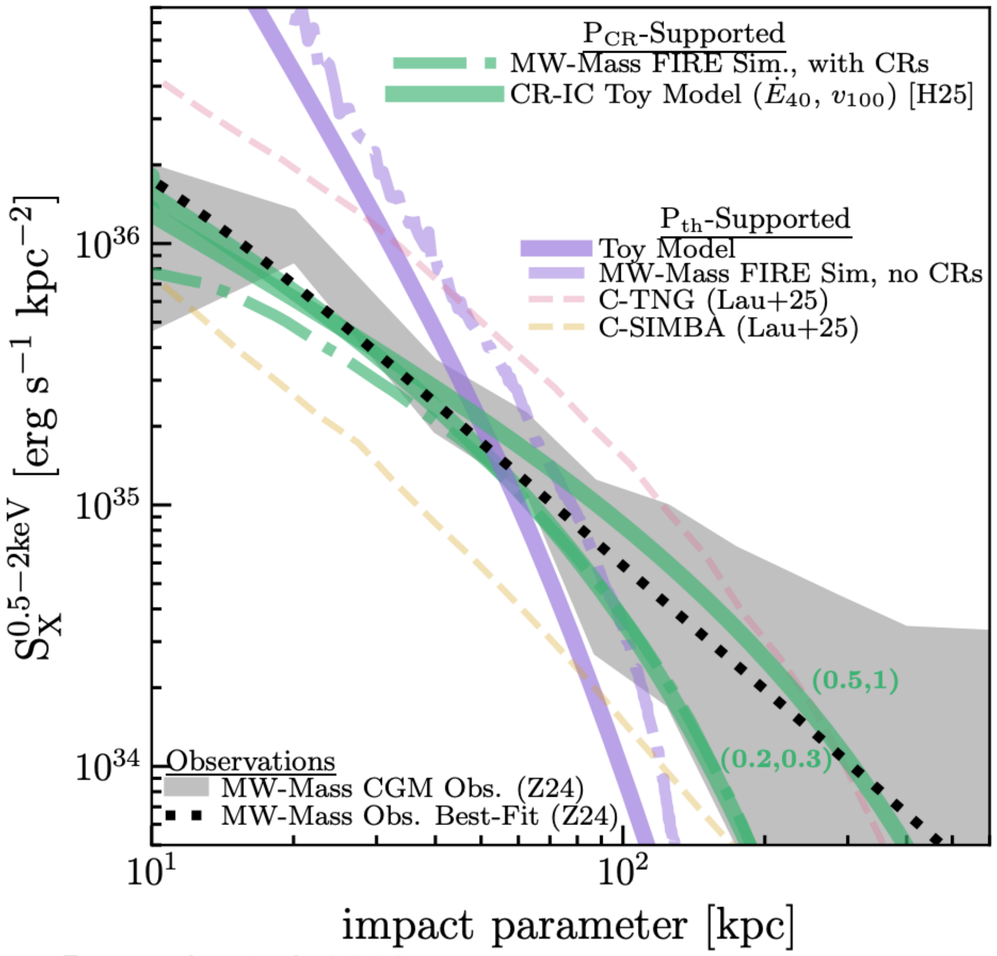
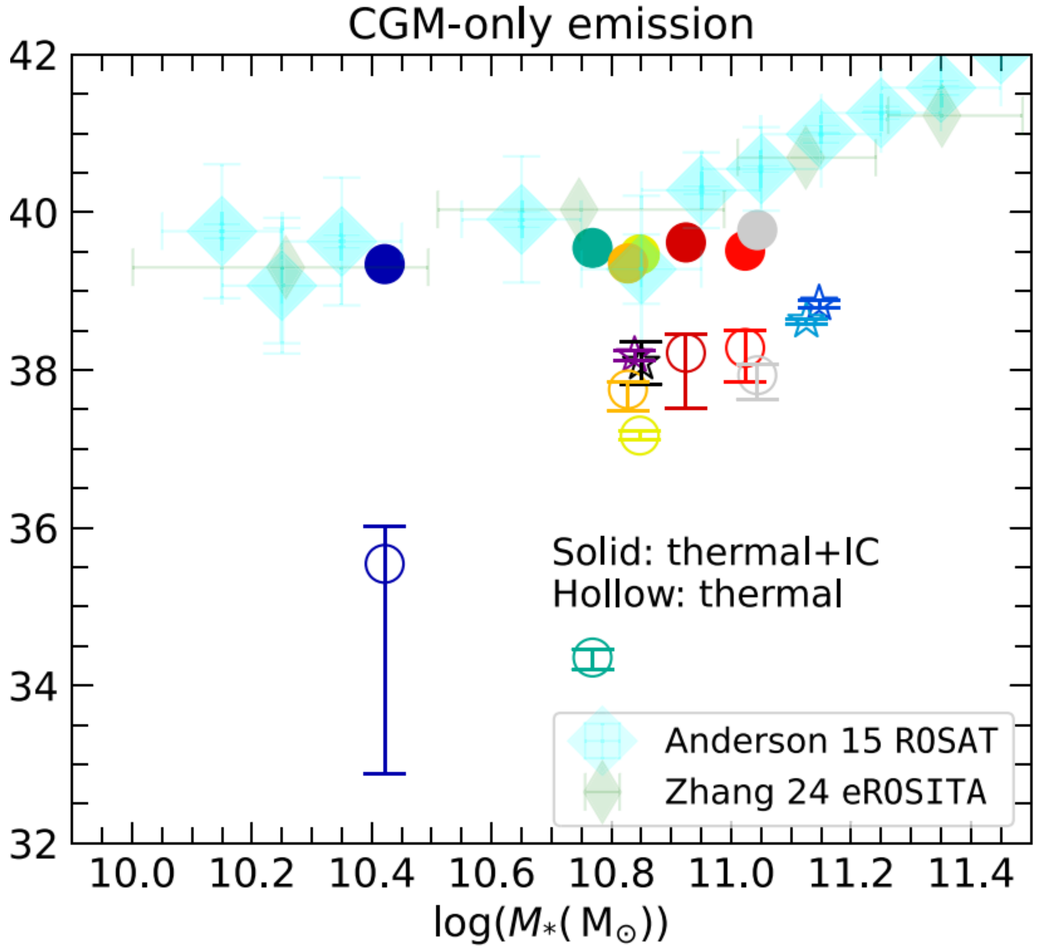
Comparison to simulations (non-thermal origin of X-ray)

Thermal X-ray can not explain the observed profile slope, cosmic ray + CMB non-thermal X-ray is necessary



Ponnada et al. 2026



Hopkins et al. 2025; Lu et al. 2025

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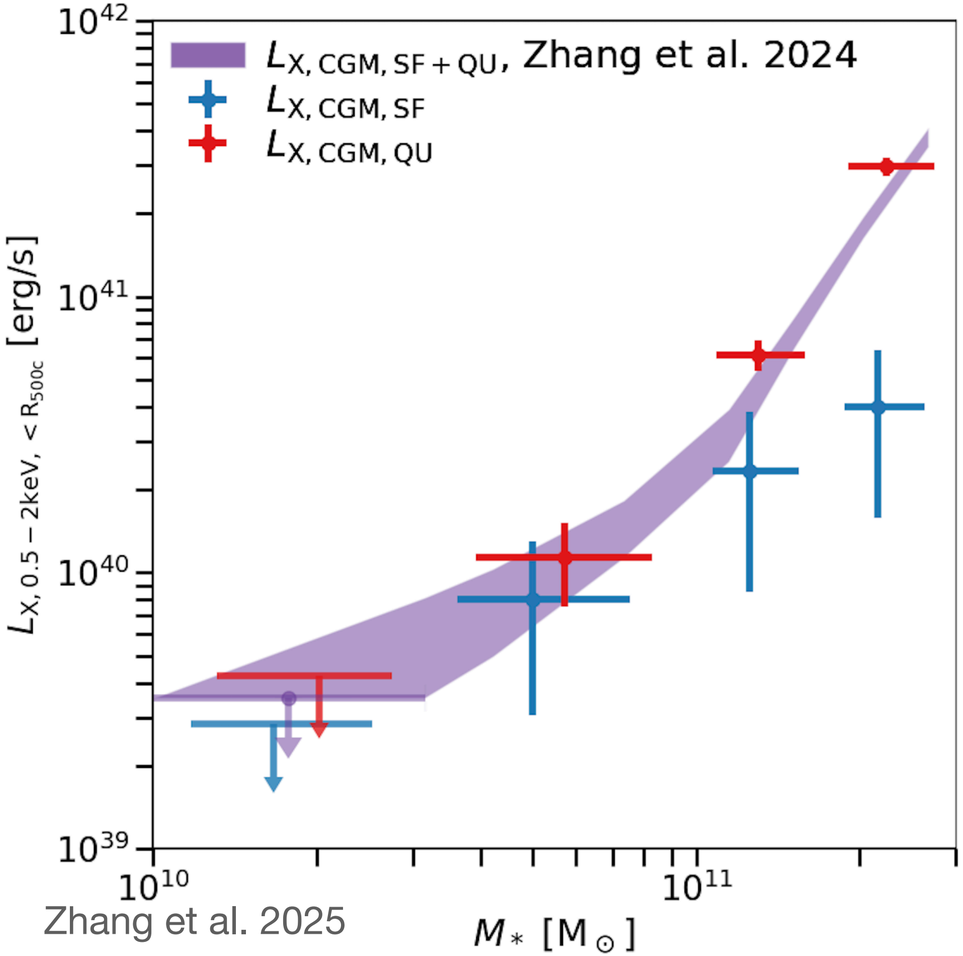
Results II-II: $L_{X,\,CGM}$ of star-forming and quiescent galaxies

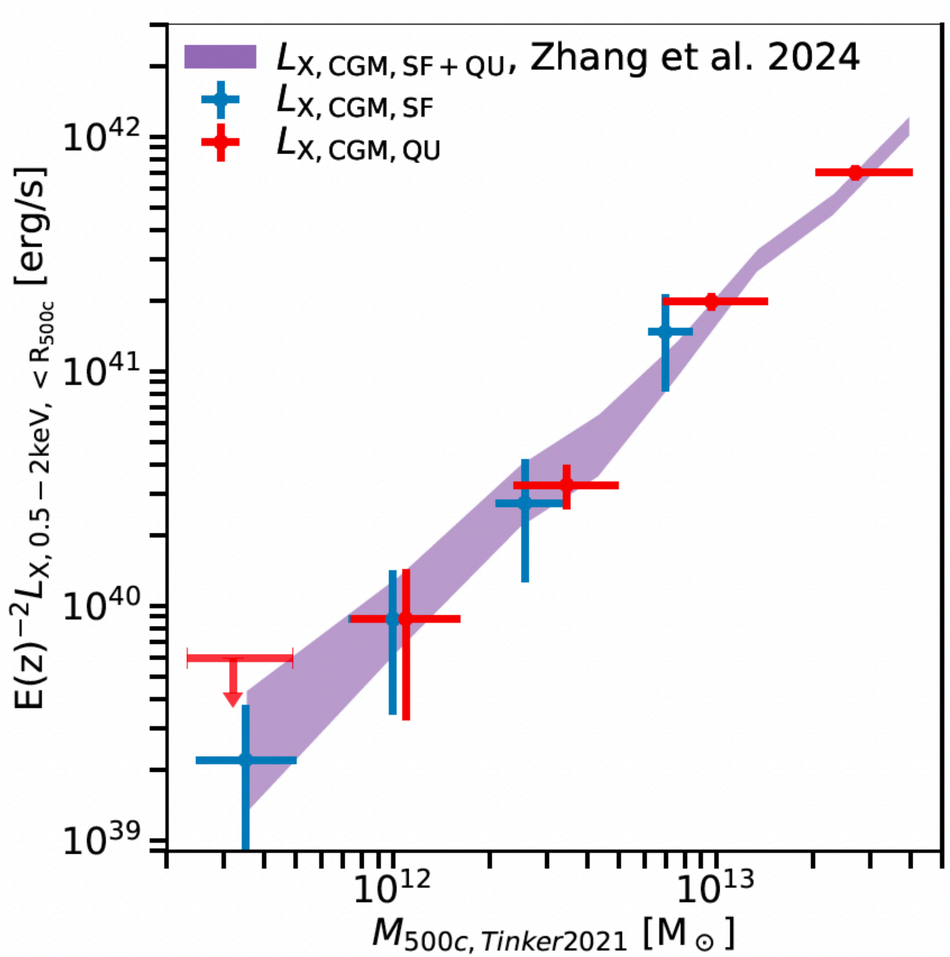
1.How bright and extended is the hot CGM?
2.How does it relate to galaxy properties?

$L_{X,\,CGM}$ - M_{star}



Zhang et al. 2025

$L_{X,\,CGM}$ - M_{halo}



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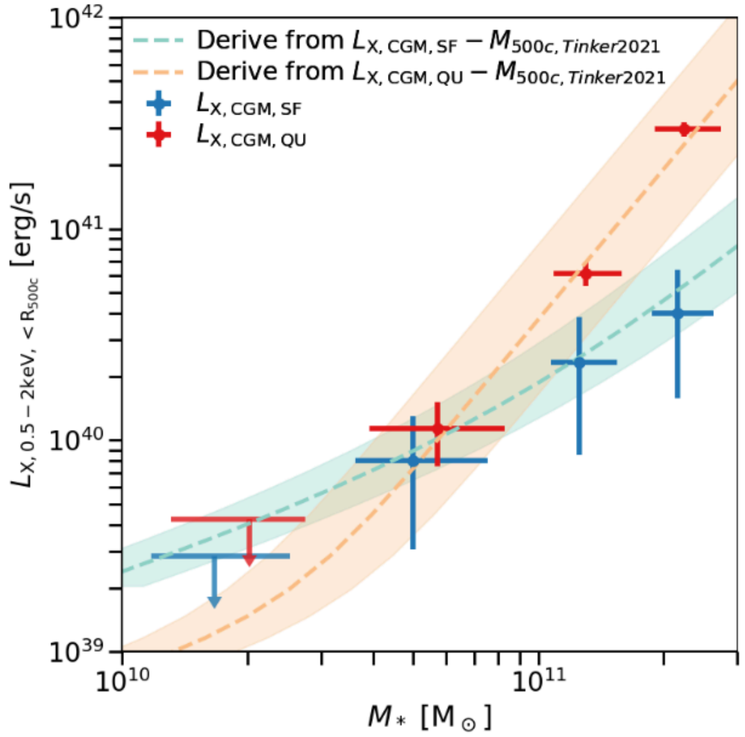
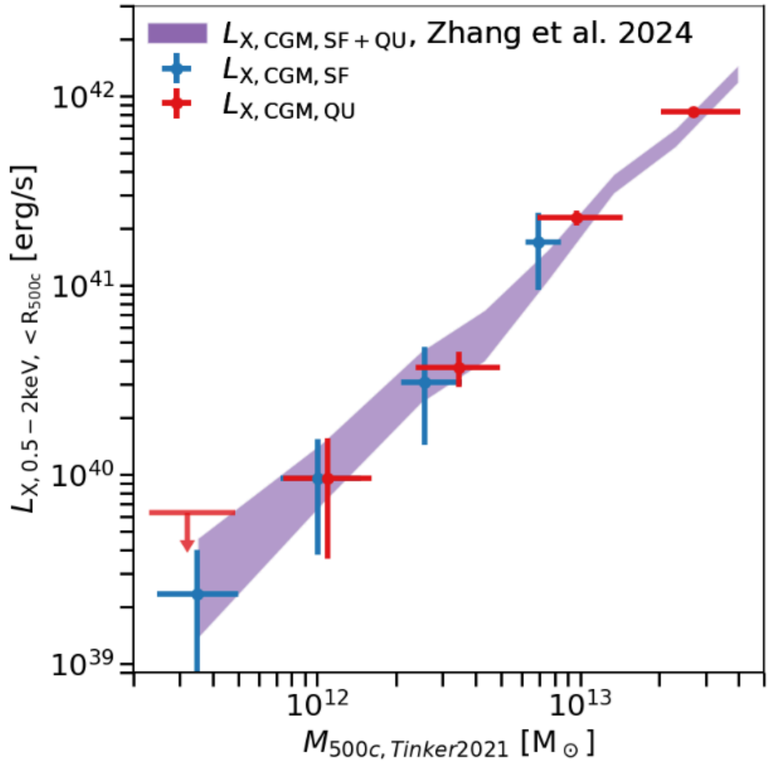
What causes quenching?

1.How bright and extended is the hot CGM?
2.How does it relate to galaxy properties?
3.Constraints on galaxy evolution models?

Lx~$M_{stellar}$



Lx~M_{halo}



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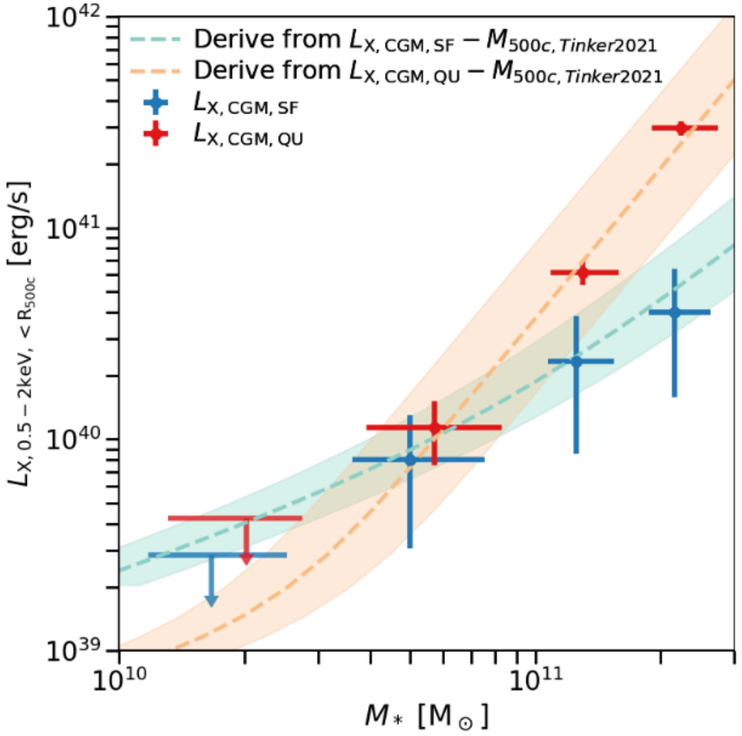
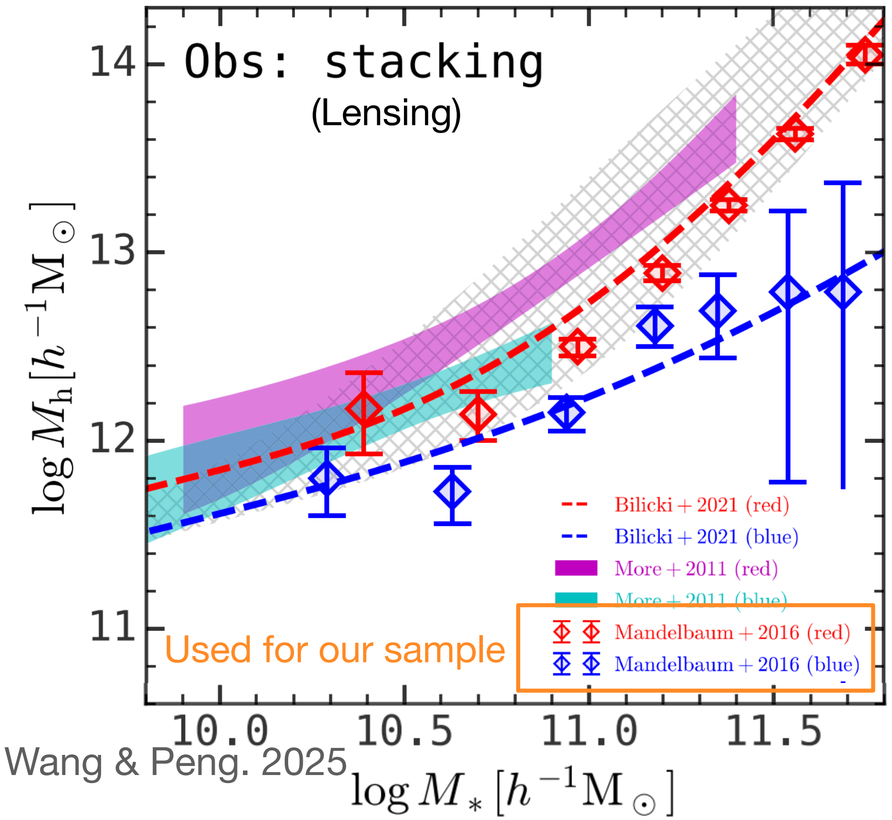
What causes quenching?

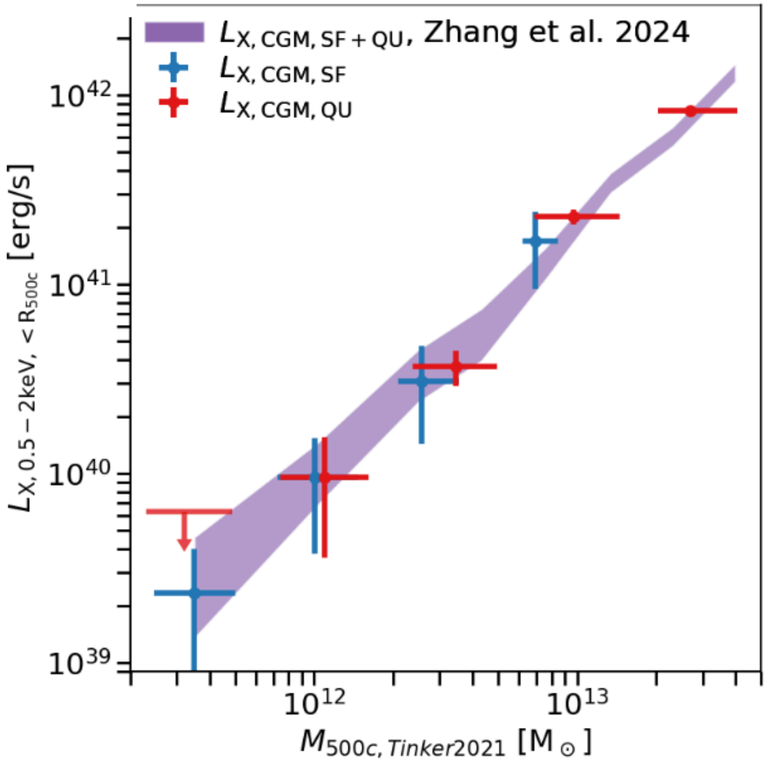
1.How bright and extended is the hot CGM?
2.How does it relate to galaxy properties?
3.Constraints on galaxy evolution models?

Lx~$M_{stellar}$ + Different M_{halo}-$M_{stellar}$ of SF/QU = Lx~M_{halo}





Wang & Peng. 2025



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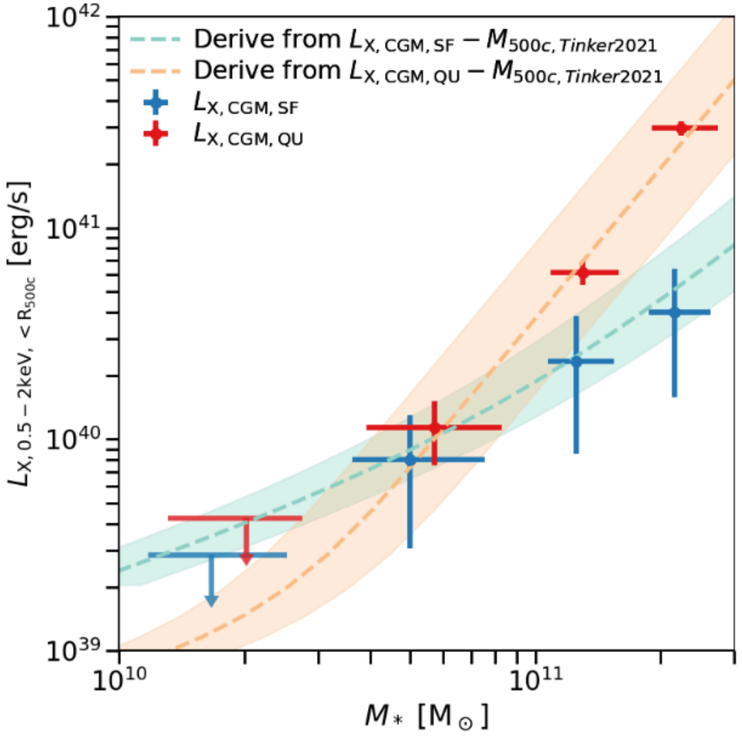
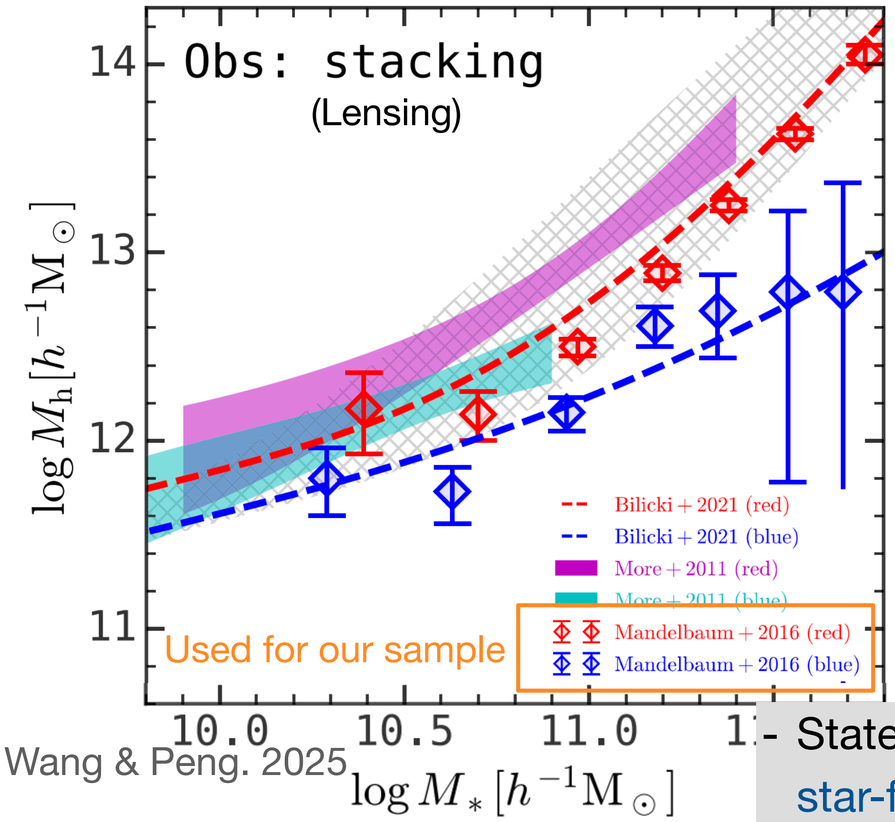
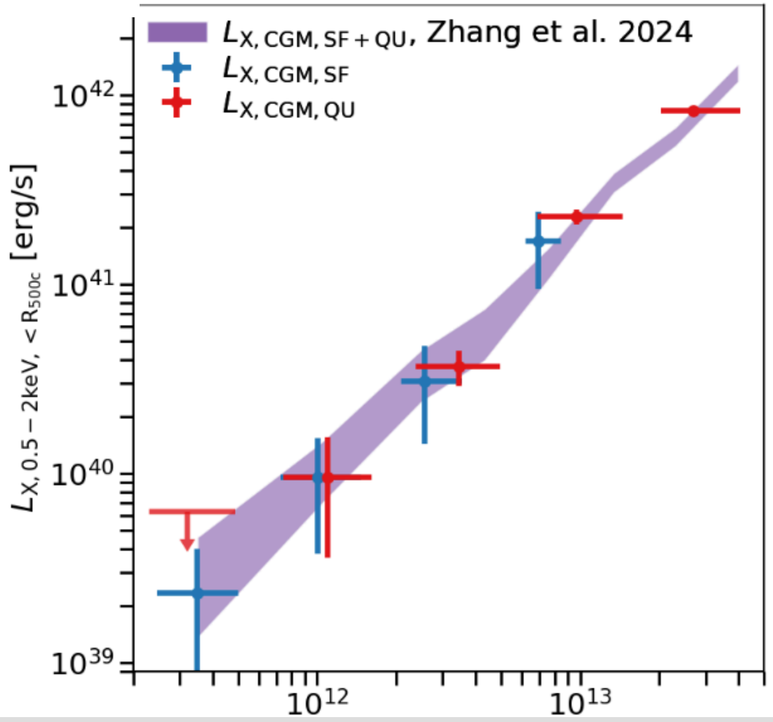




Wang & Peng. 2025



- State of the art, $L_{X,\,CGM}$ -M_{halo} is identical for star-forming and quiescent galaxies.
- If halo mass anchors the hot gas, what is the role of feedbacks?

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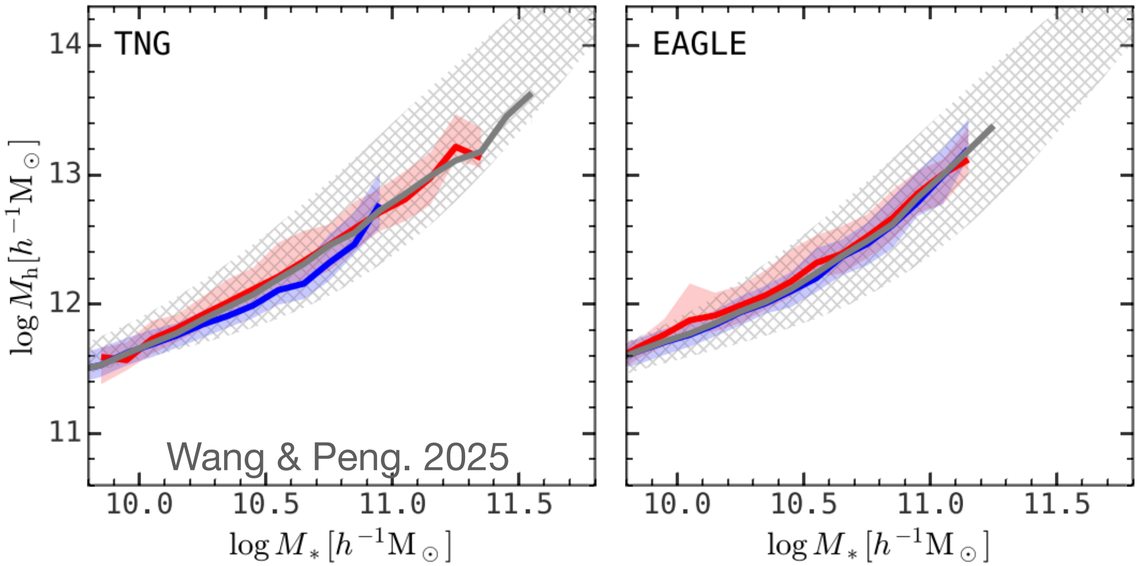
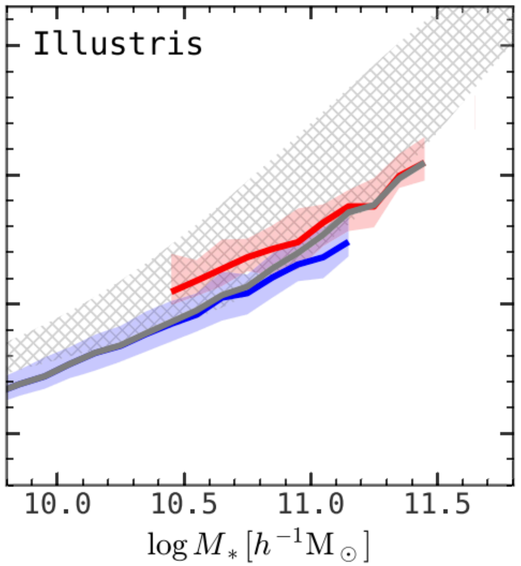
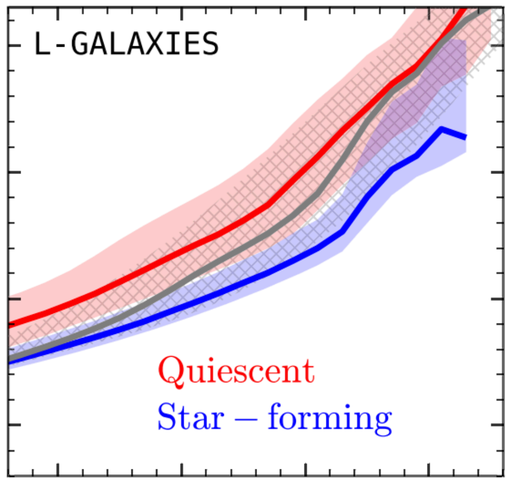
What causes quenching?

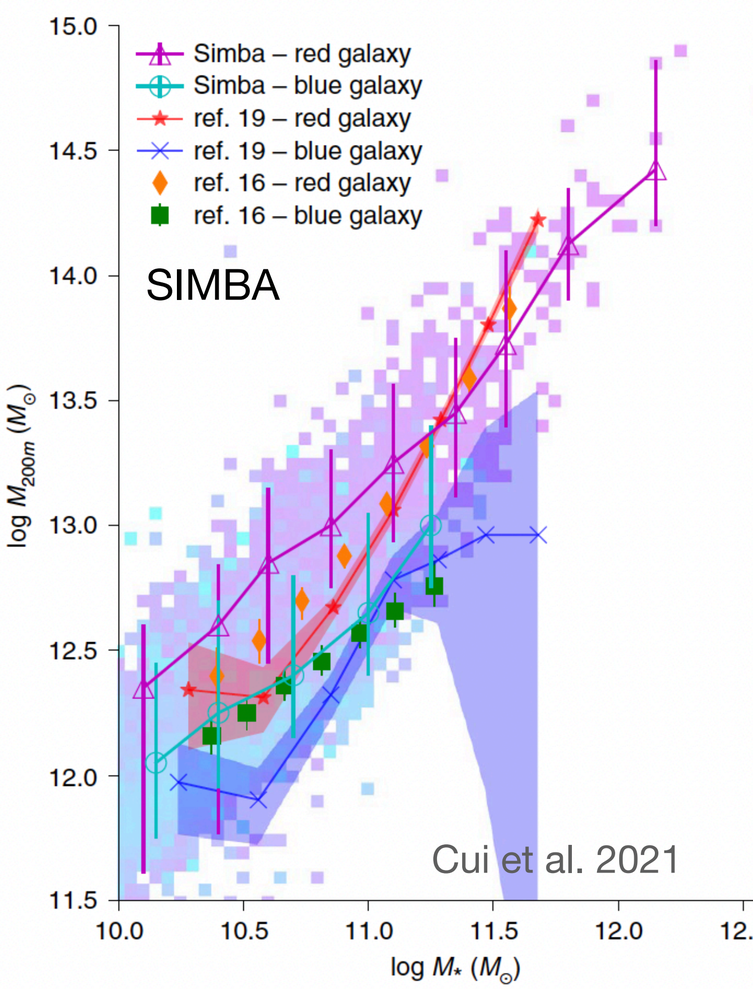
Some simulations predict same M_{halo}-$M_{stellar}$ for SF/QU:



Some predict different M_{halo}-$M_{stellar}$ for SF/QU:







- Are the merging history and galaxy environment more important than current models?

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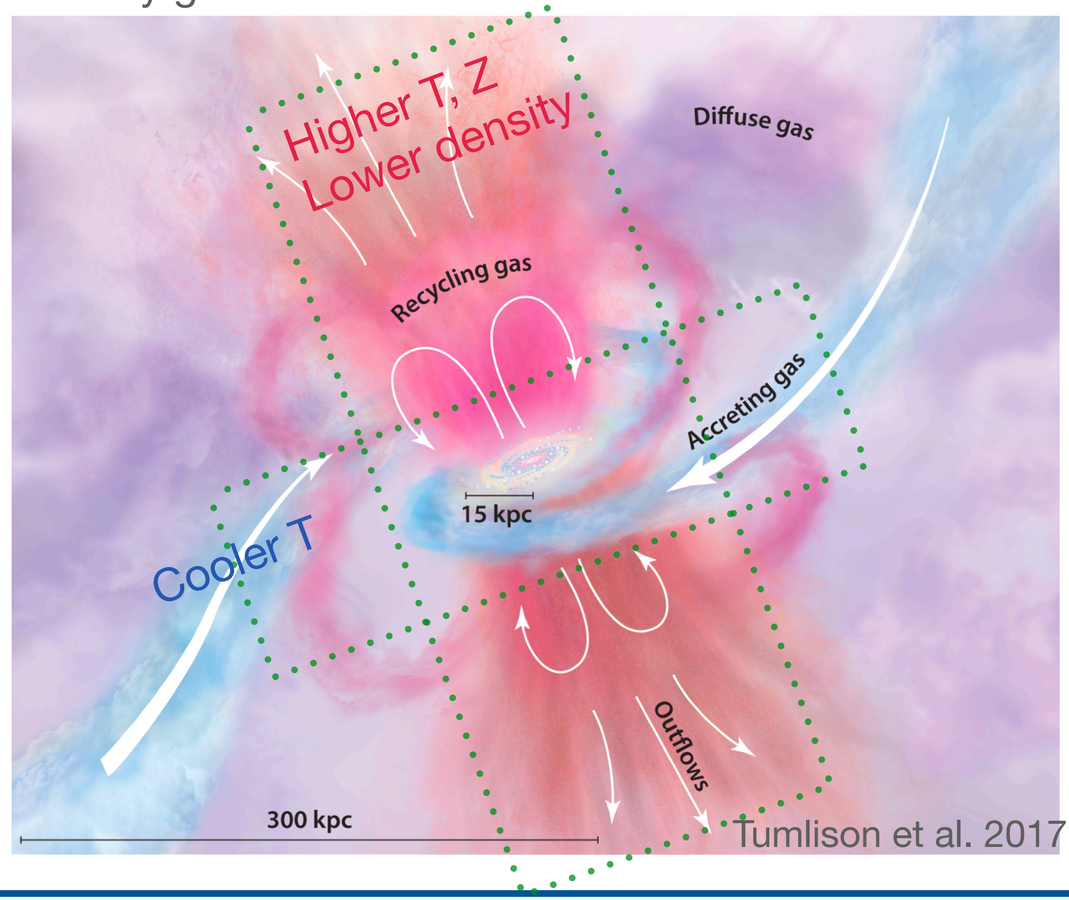
Results II-III: Not enough proof for anisotropic CGM

Anisotropy:

- Major axis: accretion; cooler and denser gas.
- Minor axis: AGN/stellar wind; hot, high metallicity, low-density gas.



Tumlison et al. 2017

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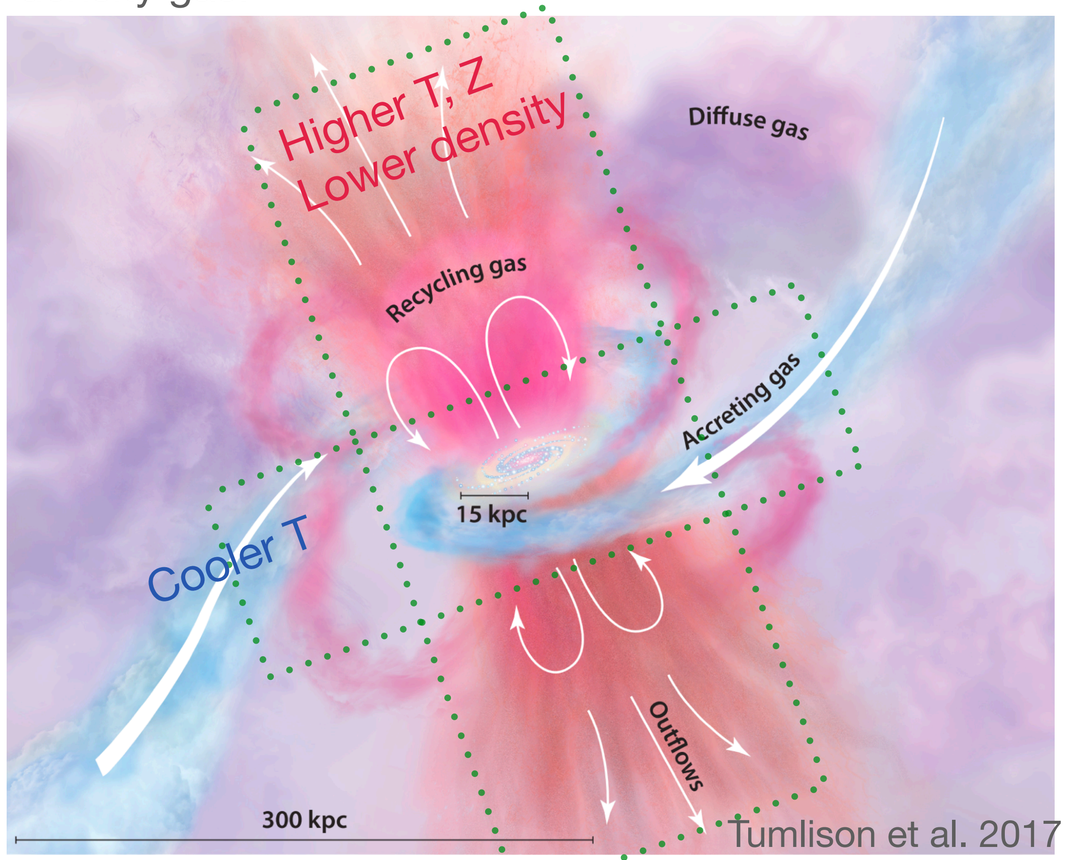
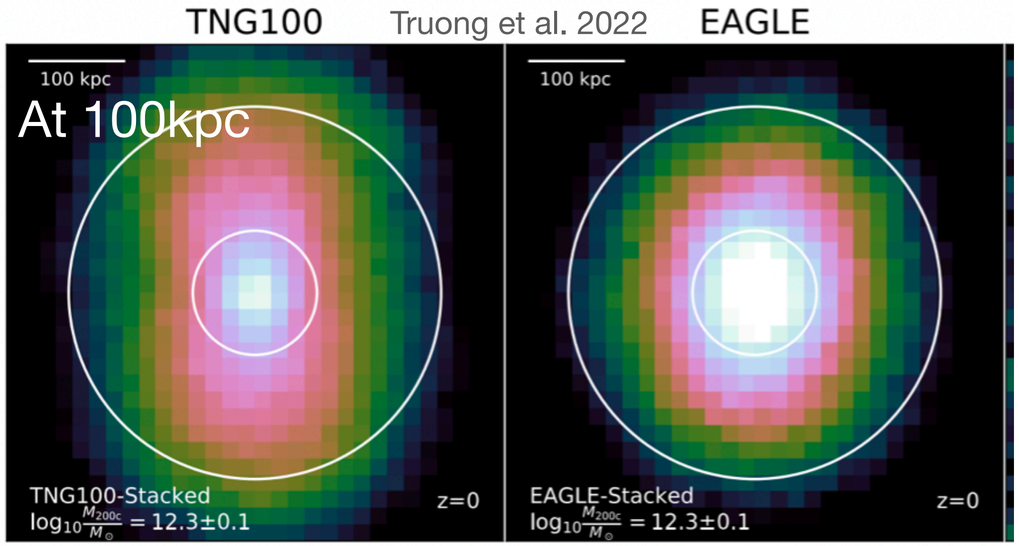
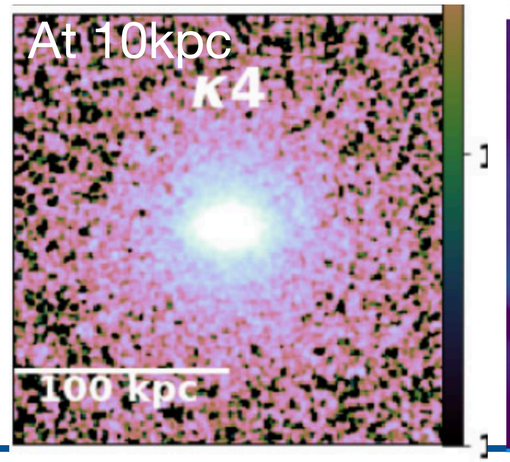


Tumlison et al. 2017

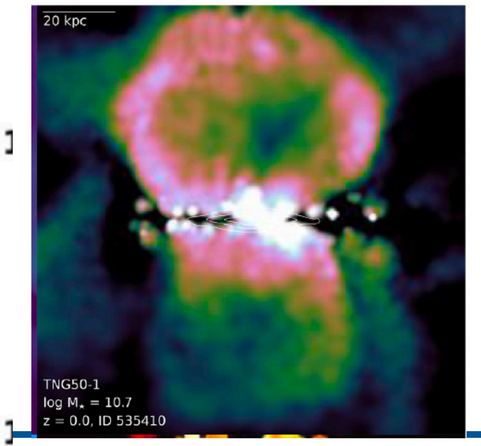


Truong et al. 2022

Different predictions from TNG, EAGLE, SIMBA…



Nica et al. 2022



Pillepich et al. 2021

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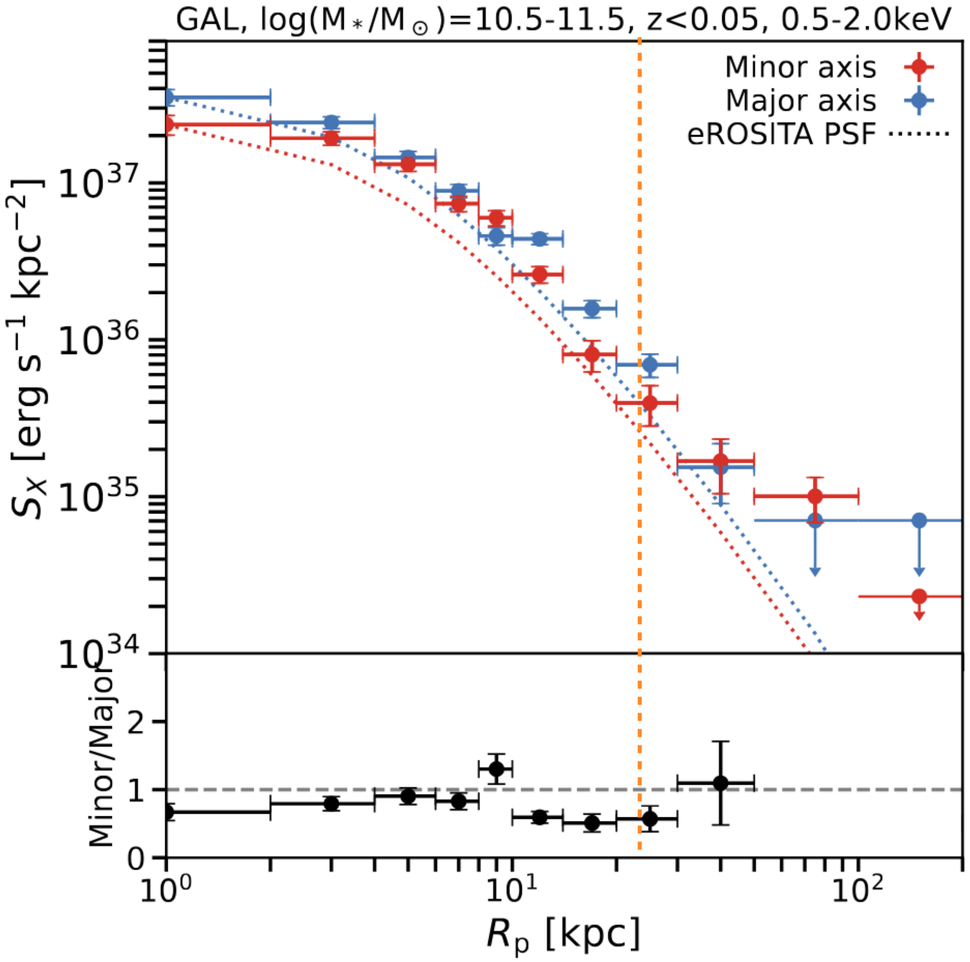
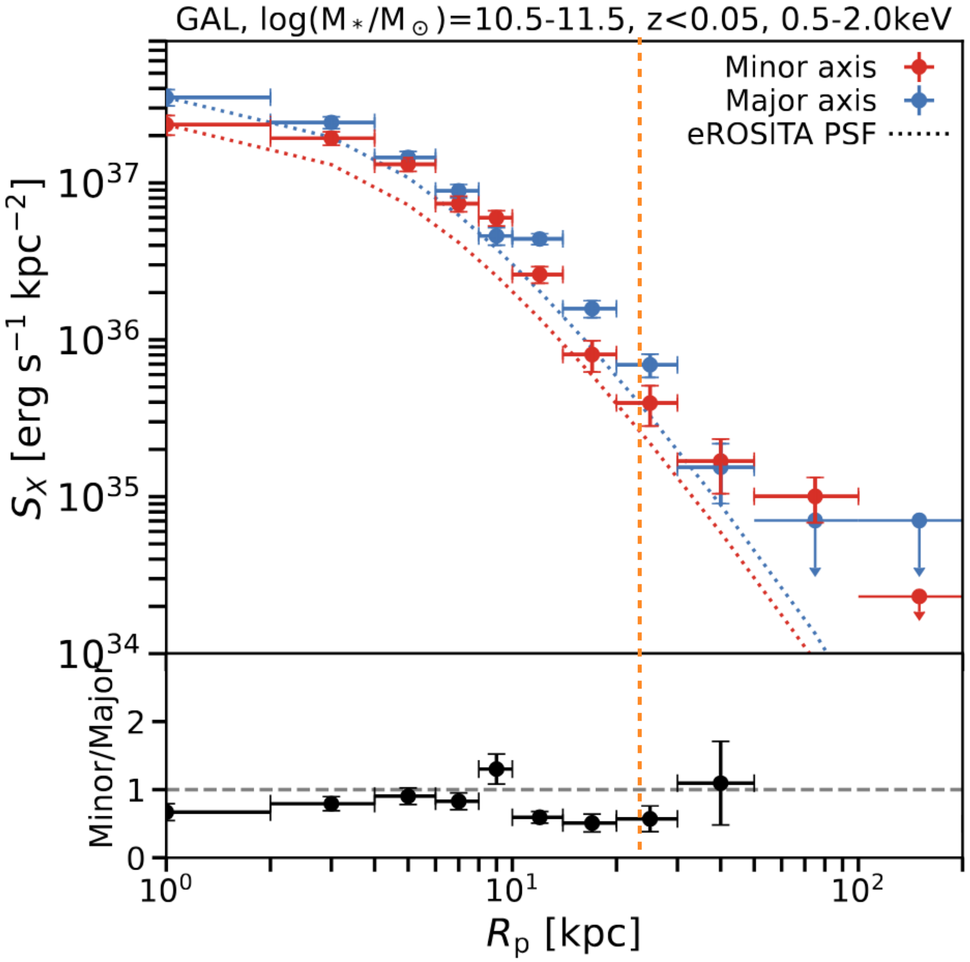
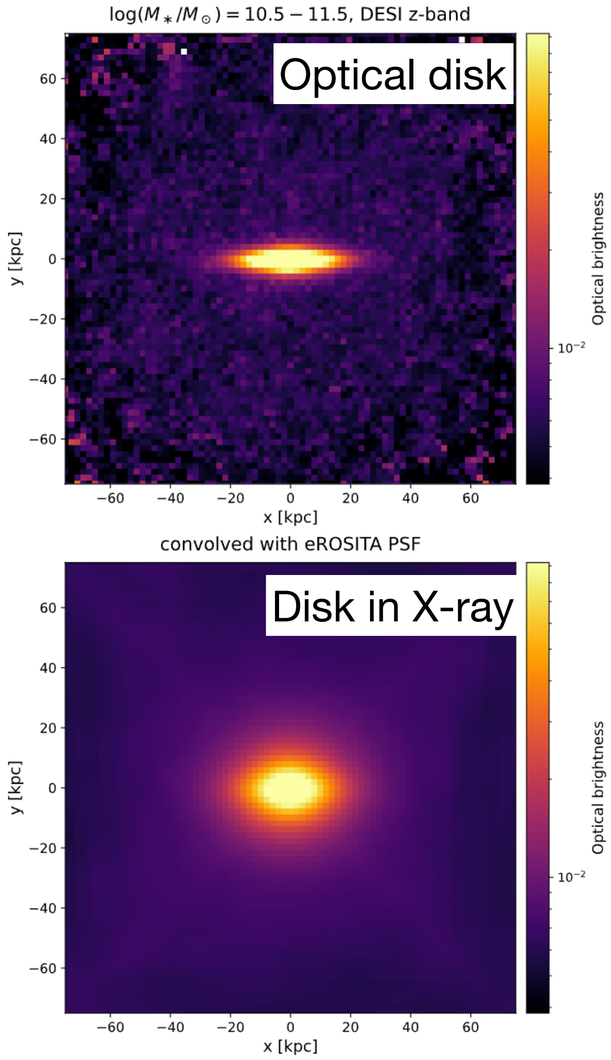
Results II-III: Not enough proof for anisotropic CGM

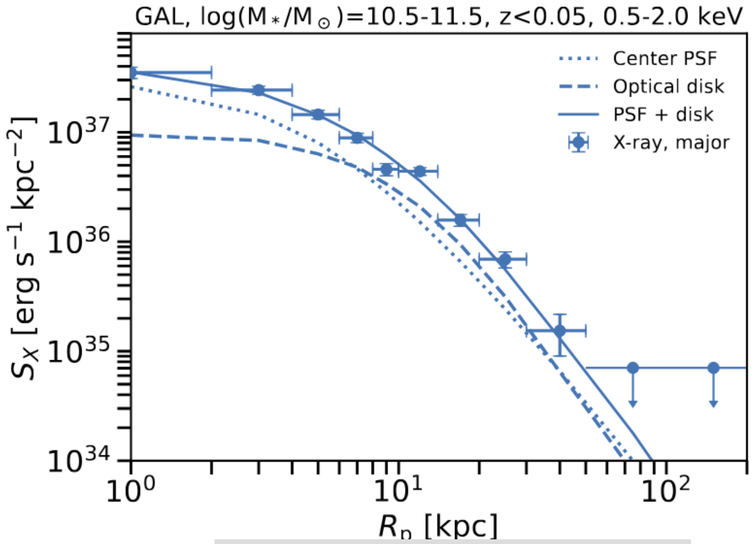


Zhang et al. in prep

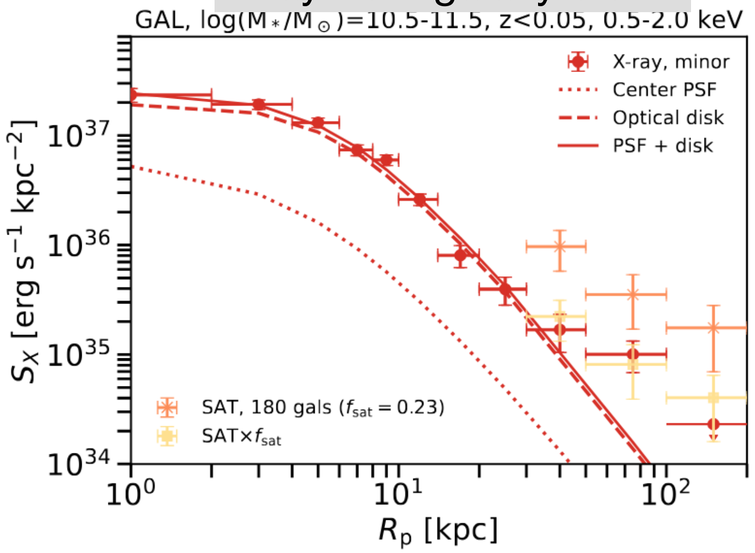
Results II-III: Not enough proof for anisotropic CGM







X-ray from galaxy disk



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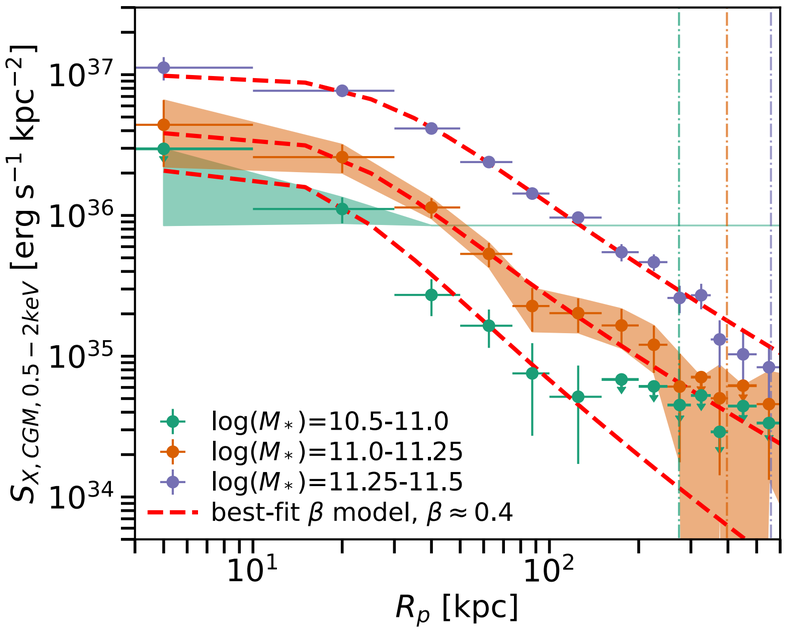
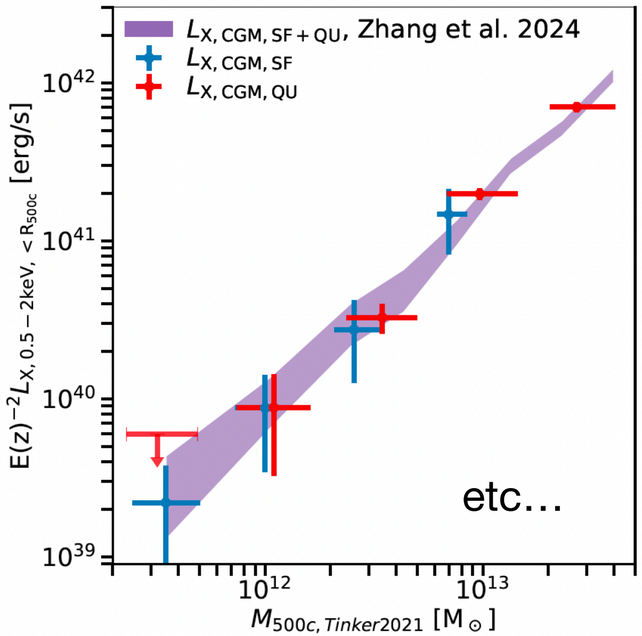
Summary

For galaxies with log(M_{star})=10.5-11.5, log(M_{halo})=12.5-14.0, redshift <0.2:





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