

Mapping the hidden drivers of galaxy evolution

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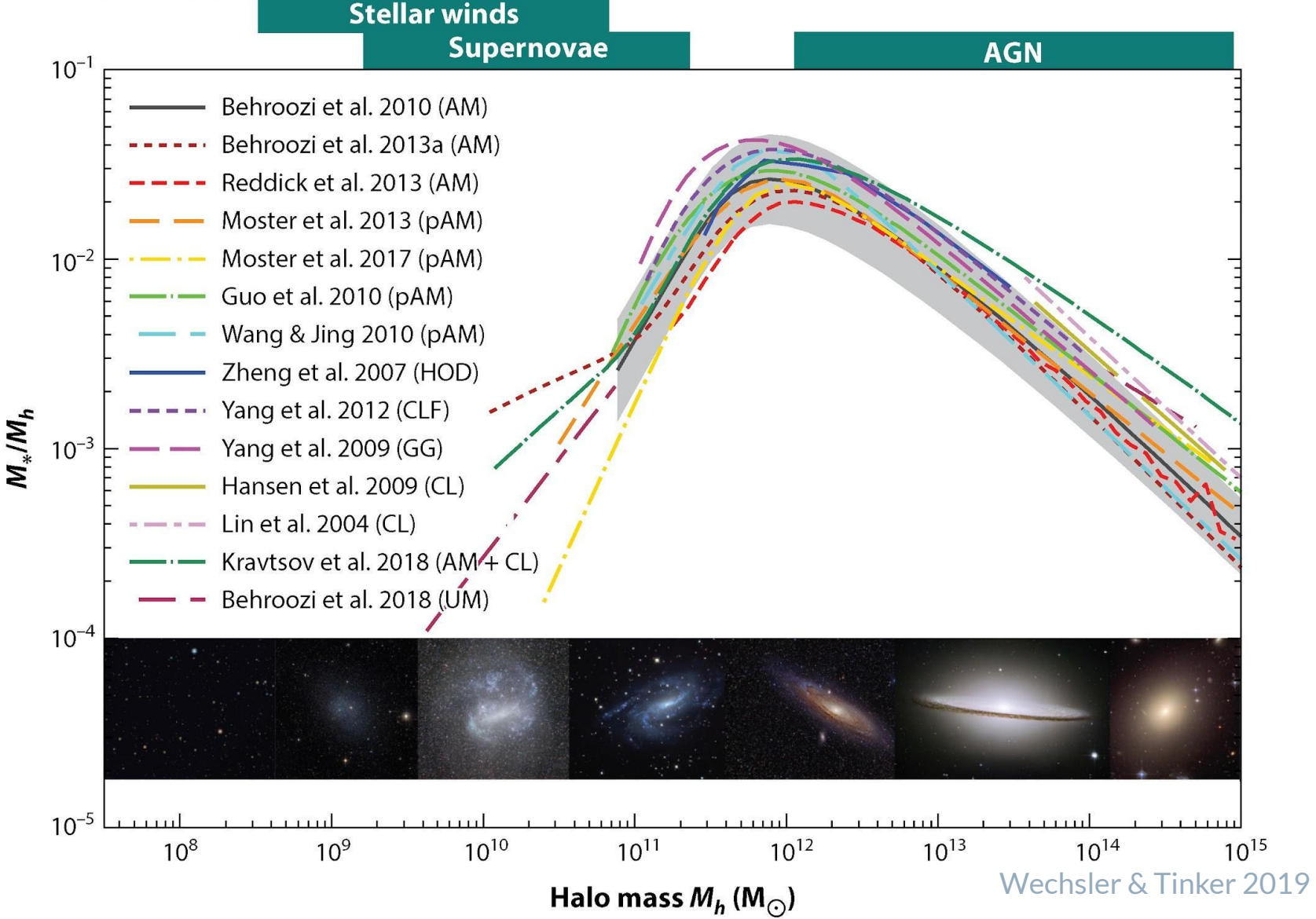
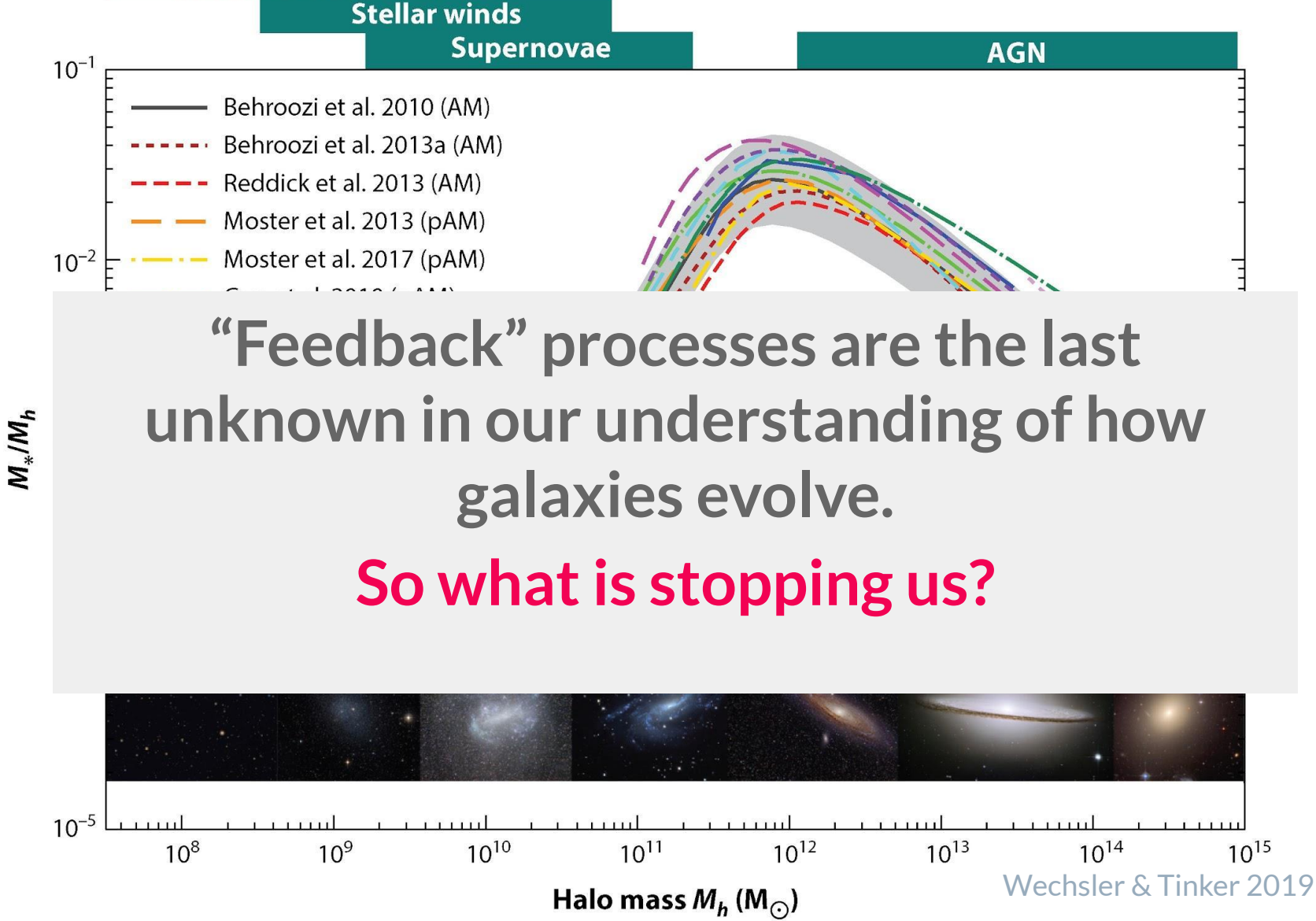
M106
X-ray
optical
radio
IR


NGC1399
X-ray
optical



Wechsler & Tinker 2019



"Feedback" processes are the last unknown in our understanding of how galaxies evolve.

So what is stopping us?

Wechsler & Tinker 2019

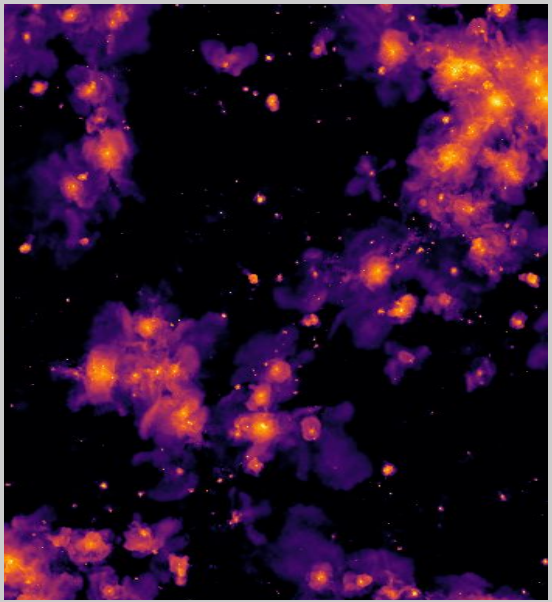
Hot and diffuse gas is the hidden agent of feedback processes



gas in galaxies
~100pc - ~10 kpc

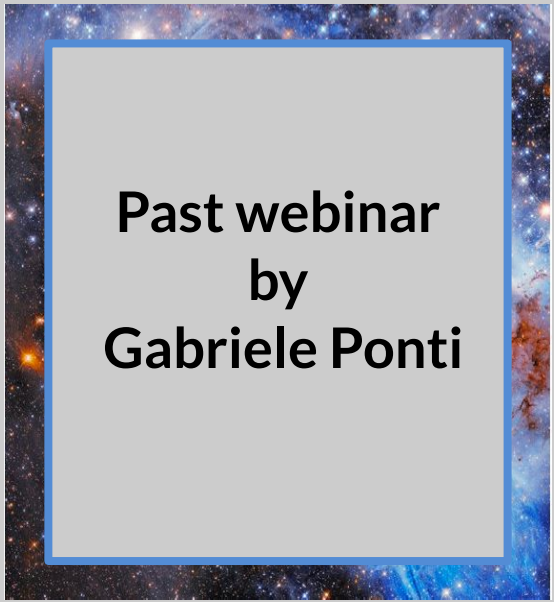


gas around galaxies
10s - 100s kpc

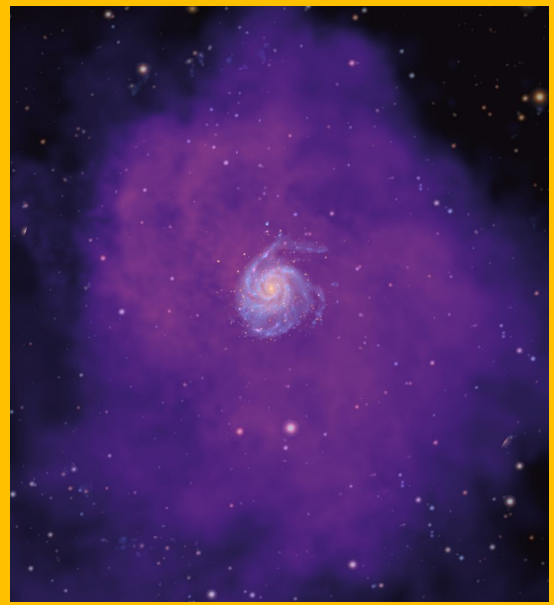


gas beyond galaxies
>> 100 kpc

Hot and diffuse gas is the hidden agent of feedback processes



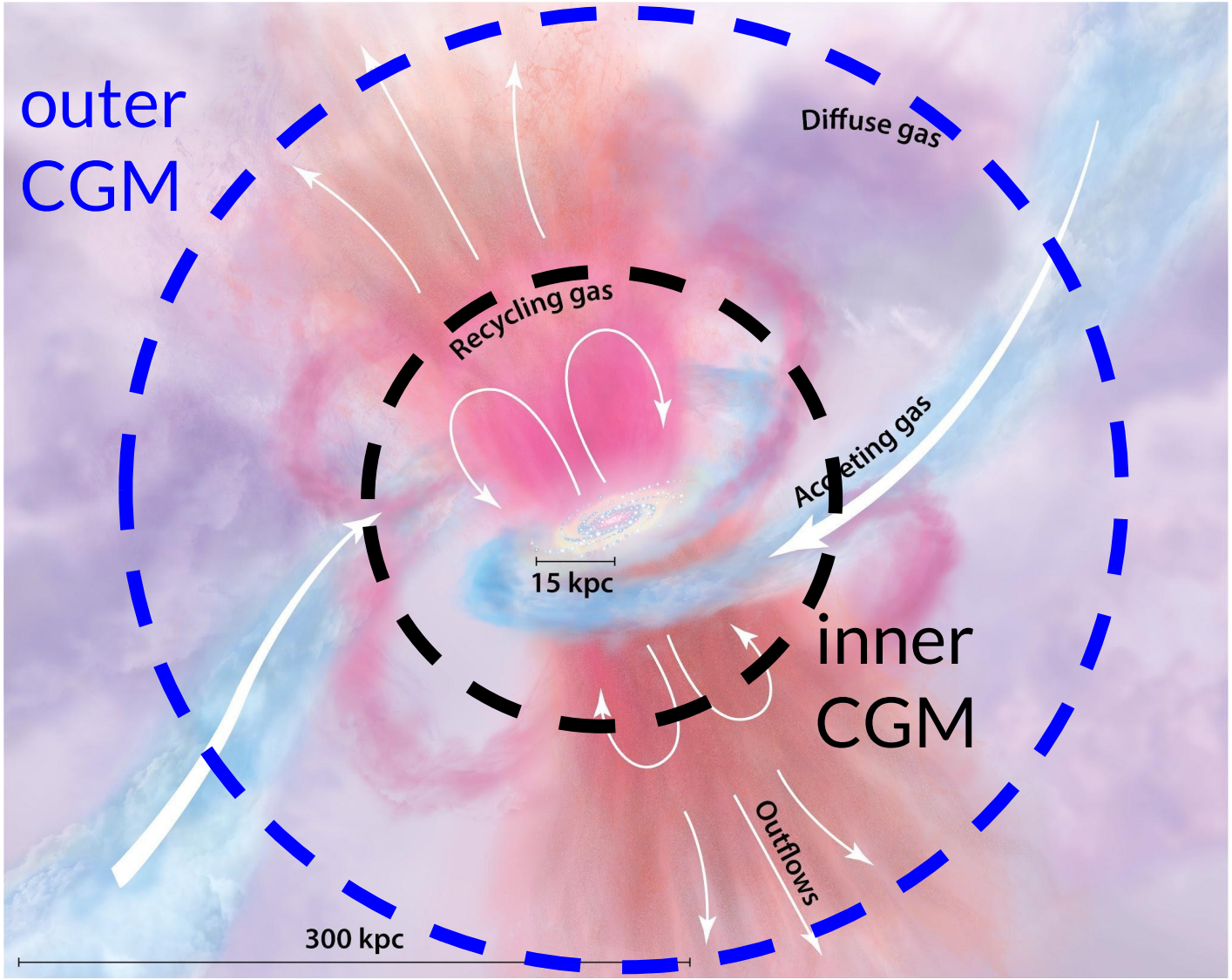
gas in our Galaxy
~100pc - ~10 kpc



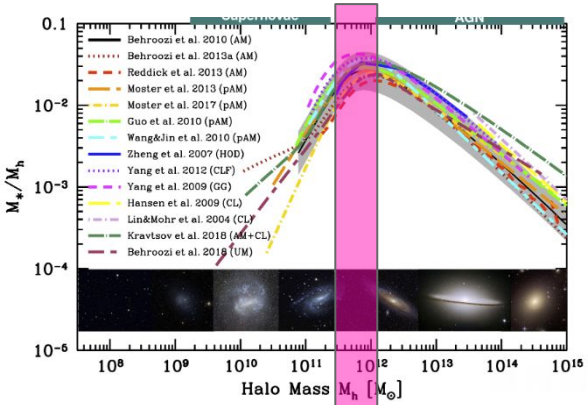
gas around galaxies
10s - 100s kpc

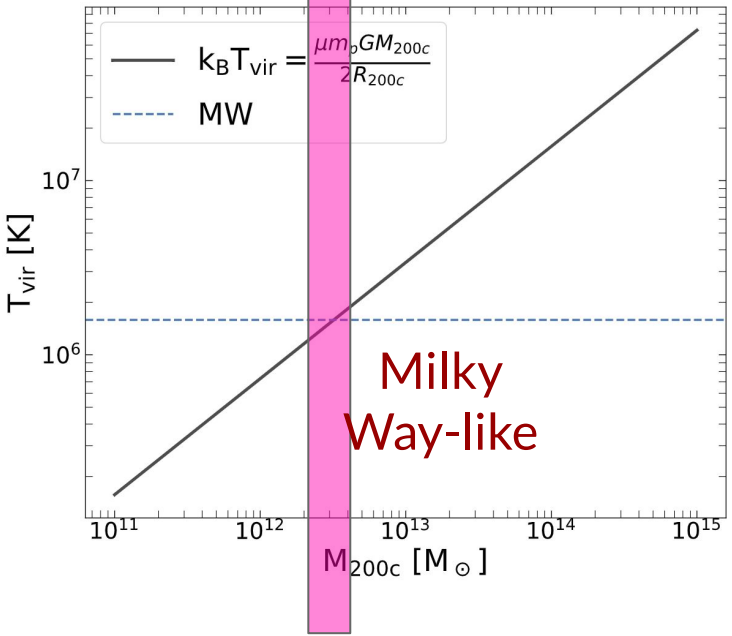


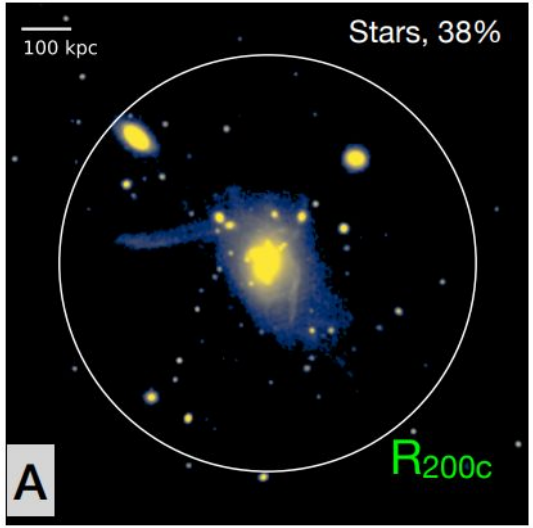
gas beyond galaxies
>> 100 kpc

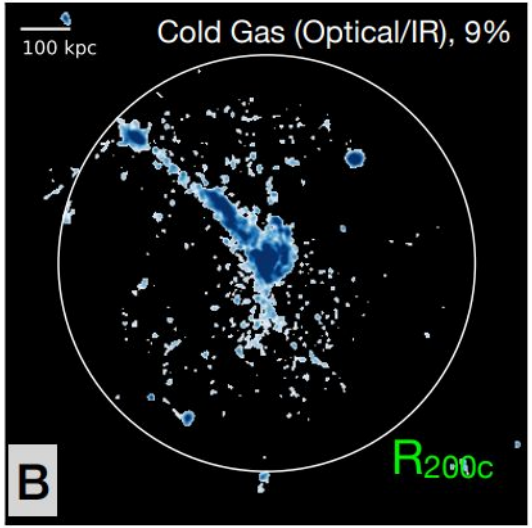


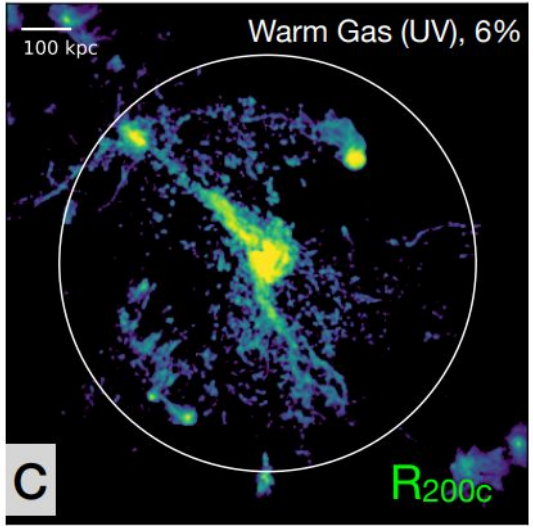
Tumlinson &
Werk 2017

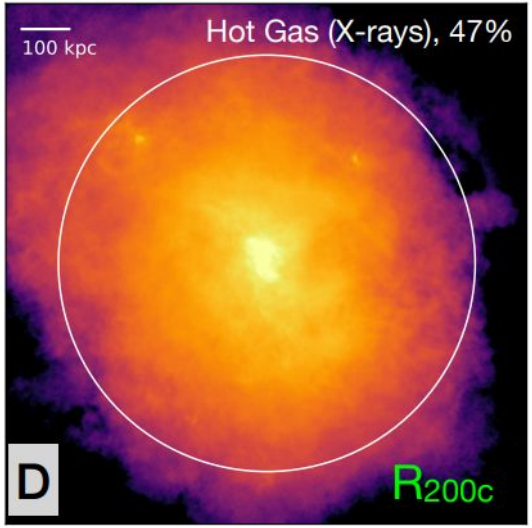






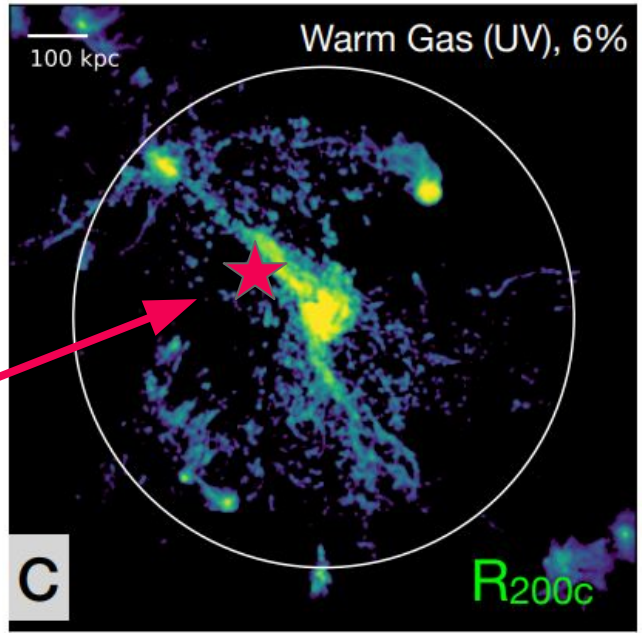


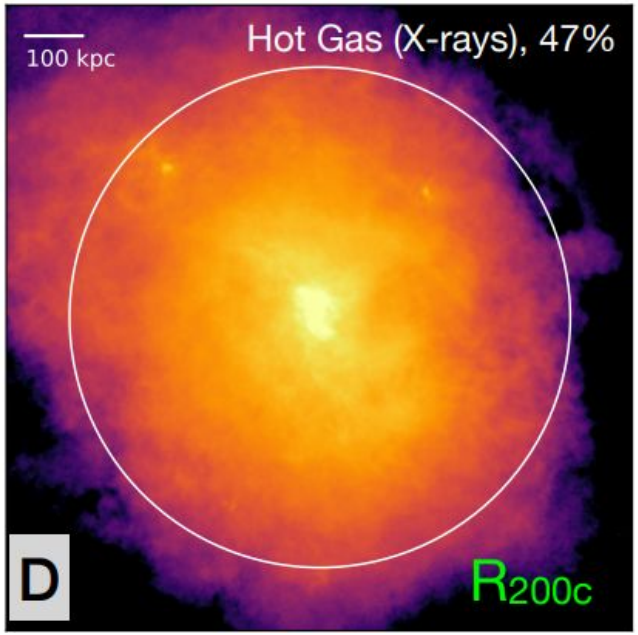




Kraft+, incl. AO 2024

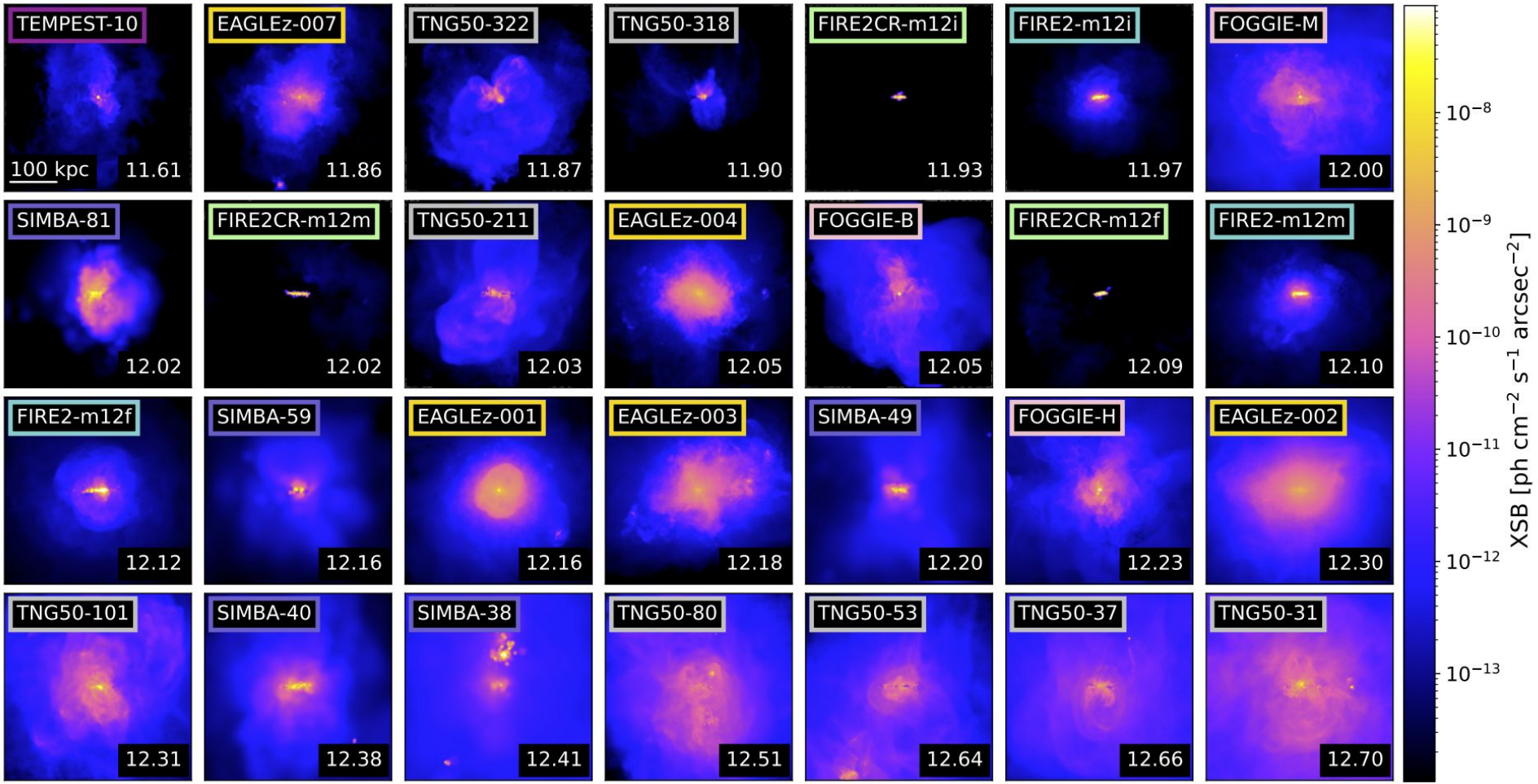
random sightline





what we probe now

what we should be probing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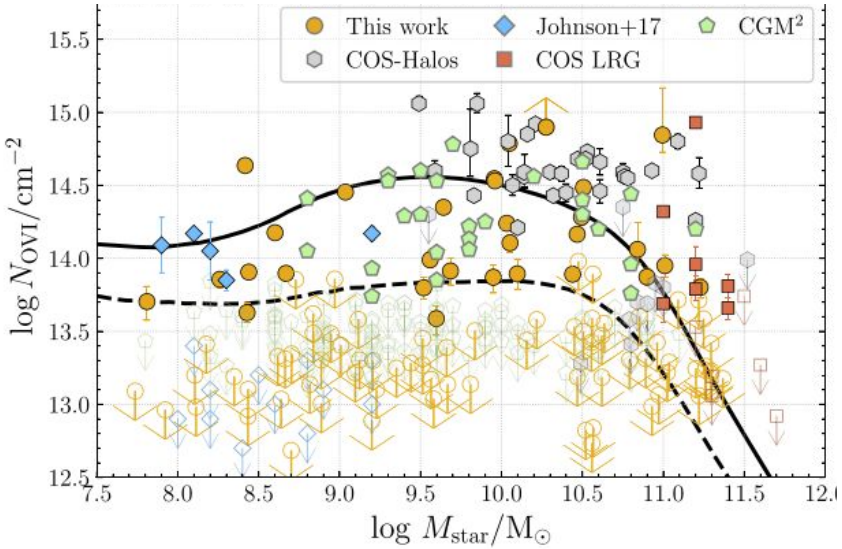
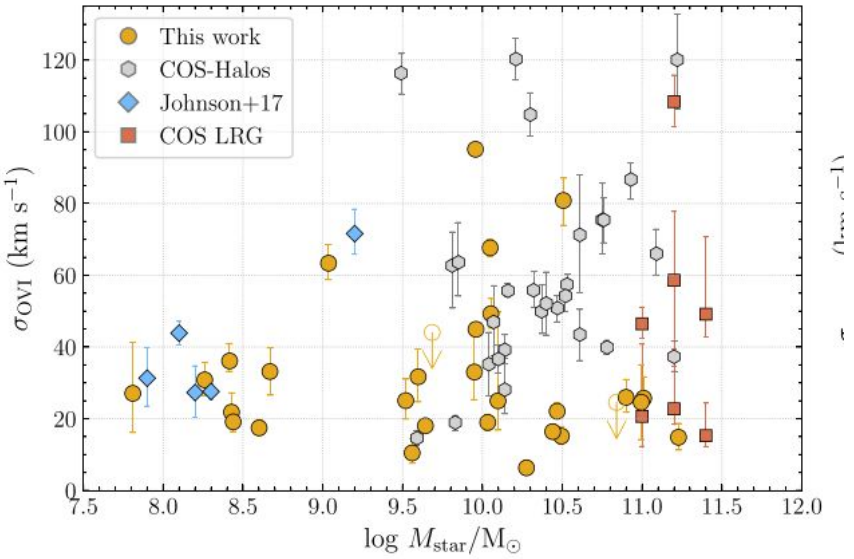
100 kpc
11.61
EAGLEz-007
11.86
TNG50-322
11.87
TNG50-318
11.90
FIRE2CR-m12i
11.93
FIRE2-m12i
11.97
FOGGIE-M
12.00
SIMBA-81
12.02
FIRE2CR-m12m
12.02
TNG50-211
12.03
EAGLEz-004
12.05
FOGGIE-B
12.05
FIRE2CR-m12f
12.09
FIRE2-m12m
12.10
FIRE2-m12f
12.12
SIMBA-59
12.16
EAGLEz-001
12.16
EAGLEz-003
12.18
SIMBA-49
12.20
FOGGIE-H
12.23
EAGLEz-002
12.30
TNG50-101
12.31
SIMBA-40
12.38
SIMBA-38
12.41
TNG50-80
12.51
TNG50-53
12.64
TNG50-37
12.66
TNG50-31
12.70
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
XSB [ph cm^{-2} s^{-1} arcsec^{-2}]

Silich+2025





Qu+2024

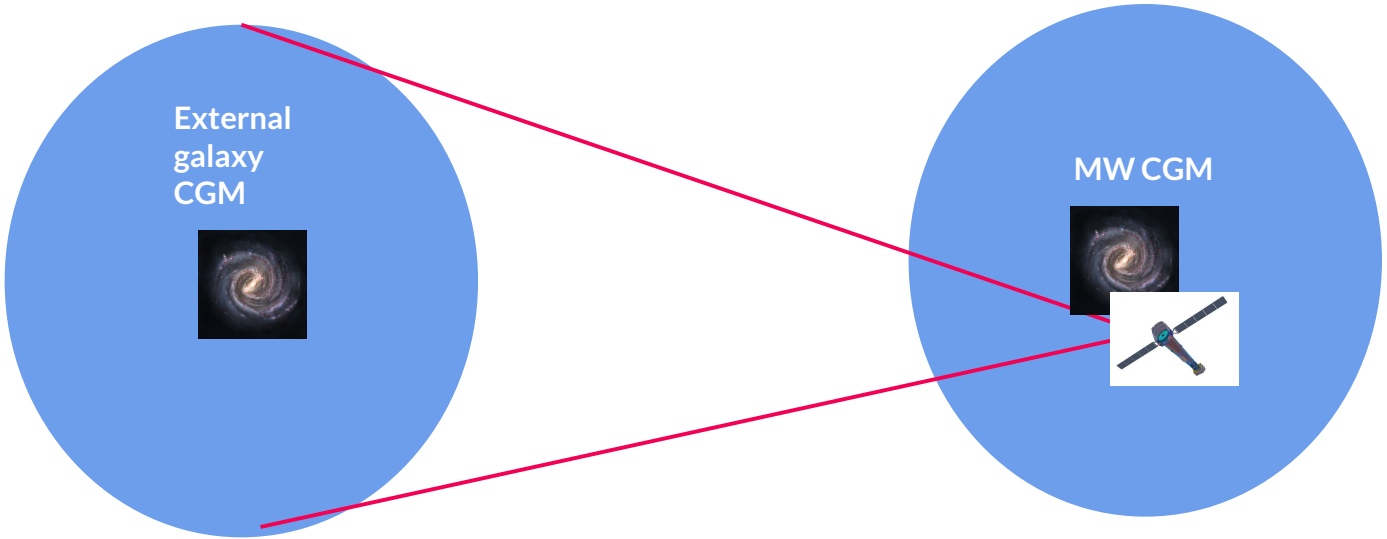
large scatter of CGM properties, even when controlling for galaxy properties

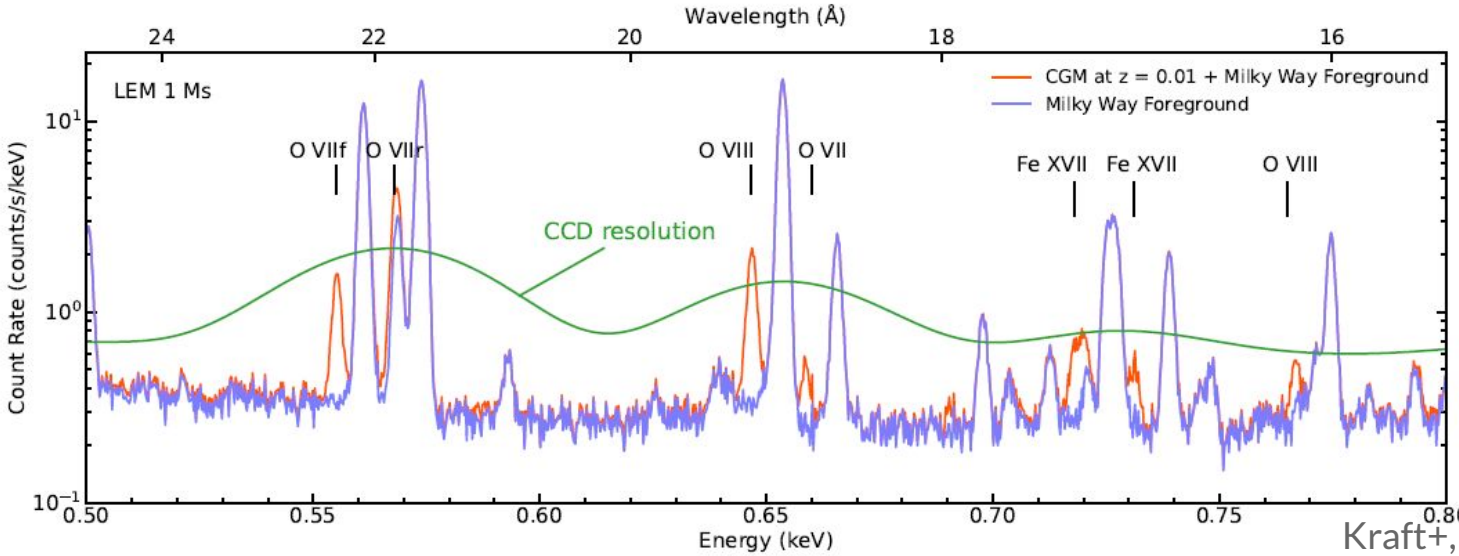
-> need large samples of CGM halos

To truly understand CGM, we need

1) X-ray observations of CGM emission
2) In large samples of halos

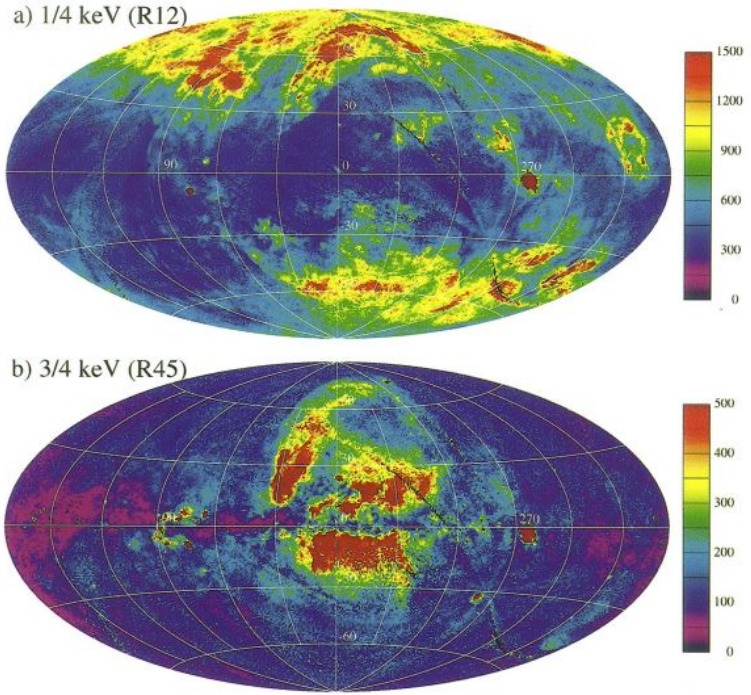
Astro2020 Decadal: observing CGM emission is key discovery area



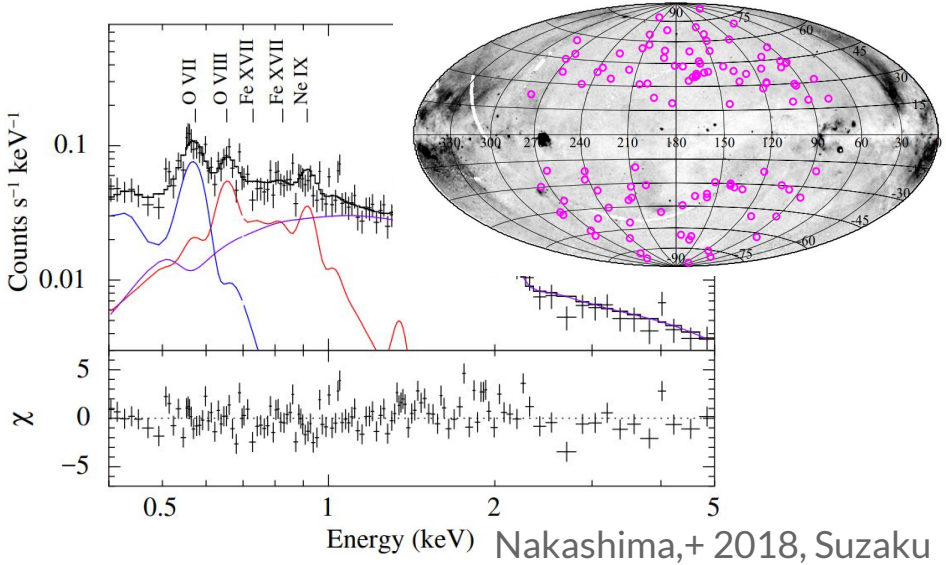


Kraft+, incl. AO 2024

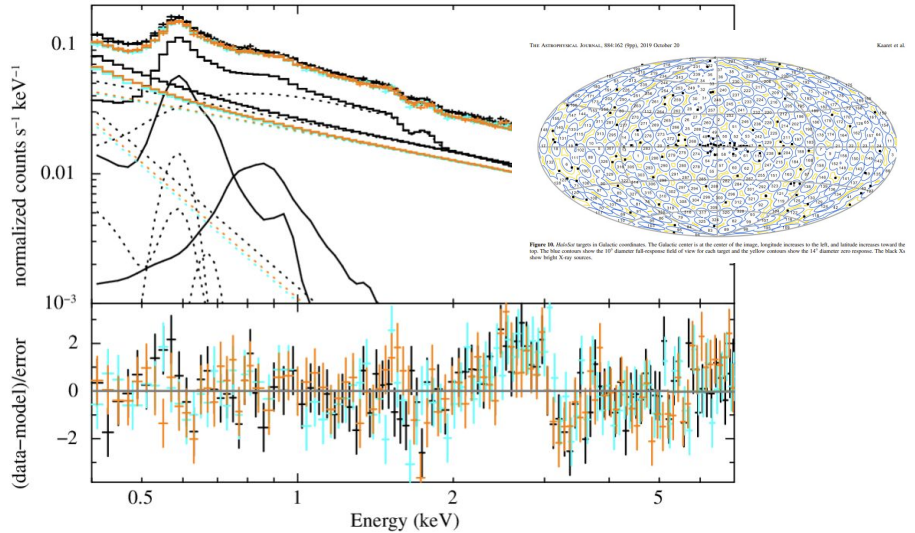
Milky Way hot halo: emission studies



Snowden+ 1997, ROSAT



Nakashima,+ 2018, Suzaku

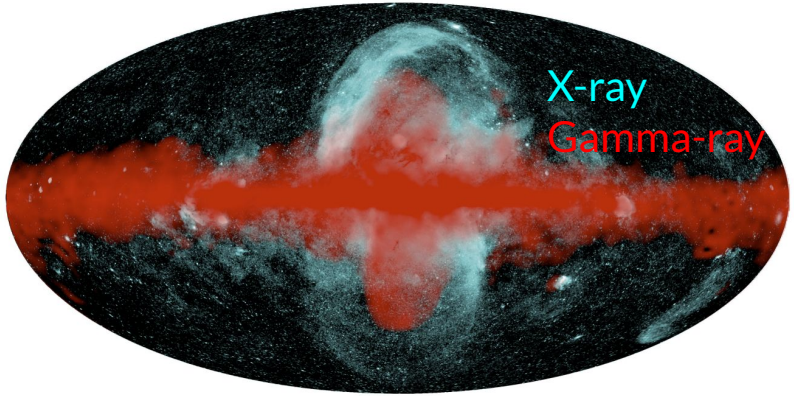


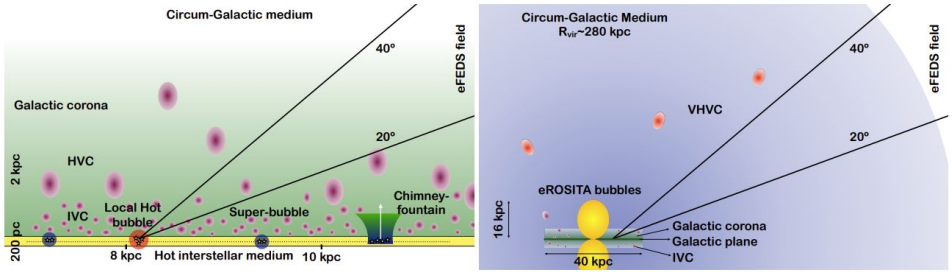
Kaaret+ 2019, Bluem+2022, HaloSAT

Milky Way hot halo: emission studies

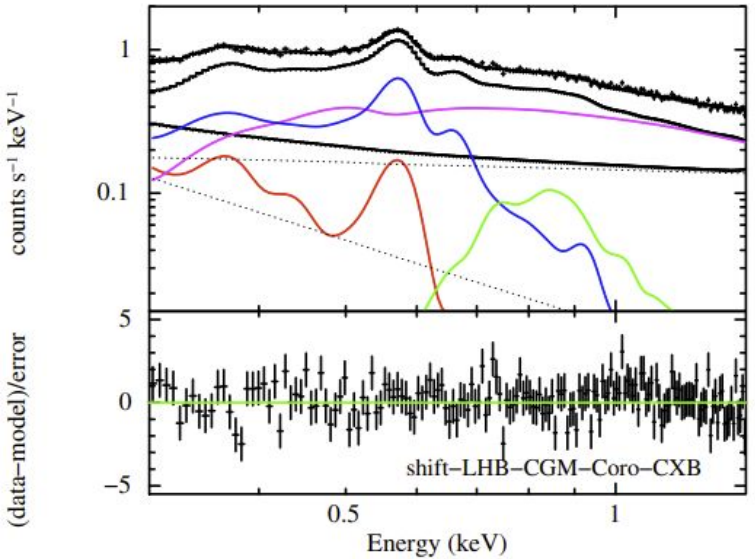
- consistent picture of a virial phase (6.2 mln Kelvin) and hotter regions, possibly caused by unresolved stars
- discovery of eROSITA bubbles

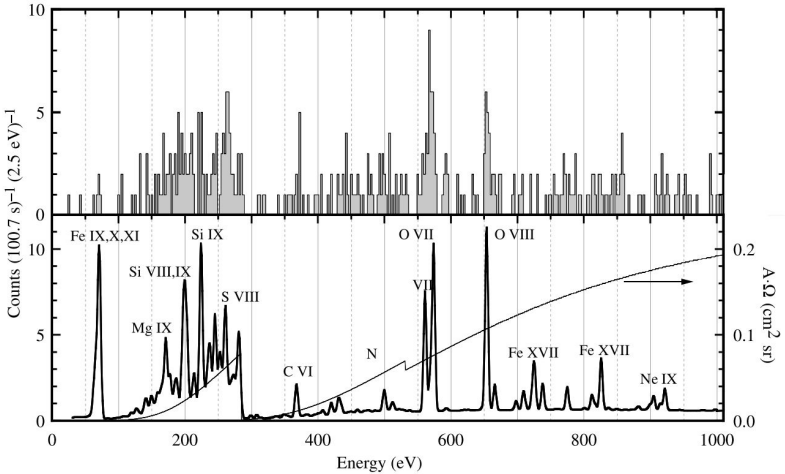
Predehl,+ 2020, Nature/ eROSITA





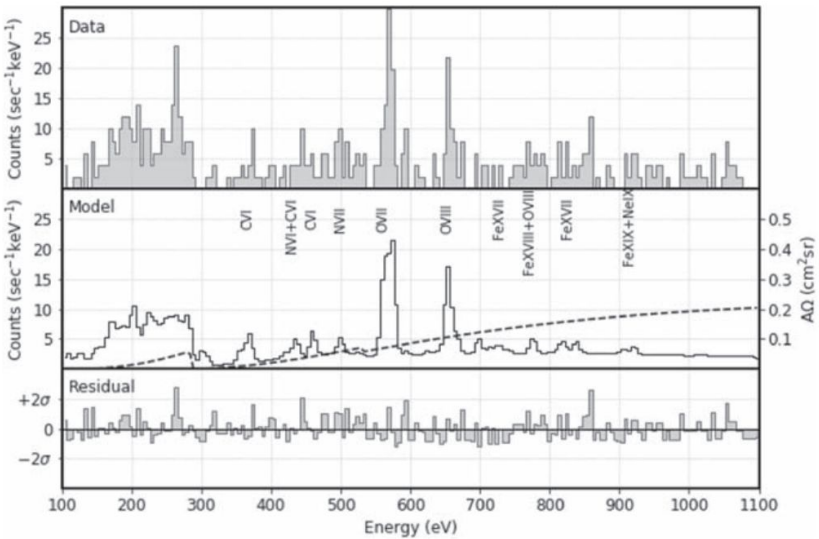
Ponti+ 2023 / eROSITA



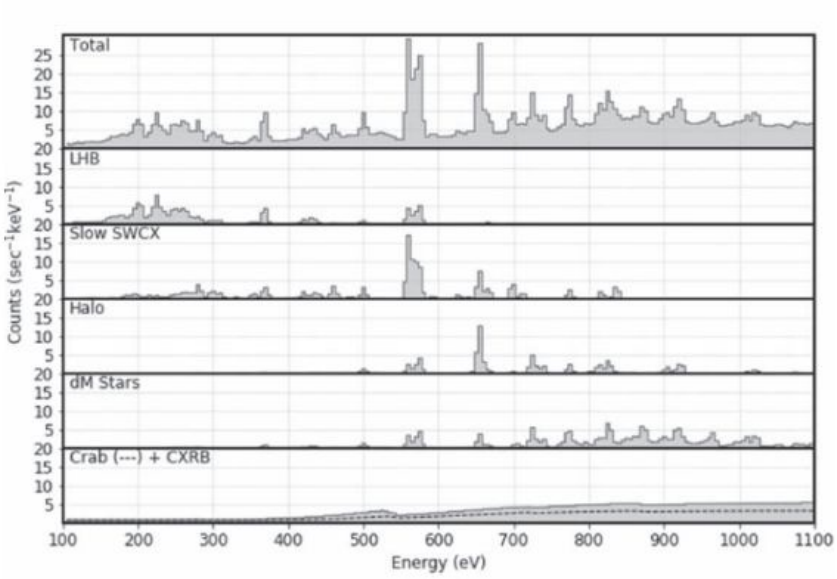


5-12 eV resolution, McCammon+ 2002

- sounding rocket experiments with an X-ray microcalorimeter
- first high resolution X-ray spectra of Milky Way emission

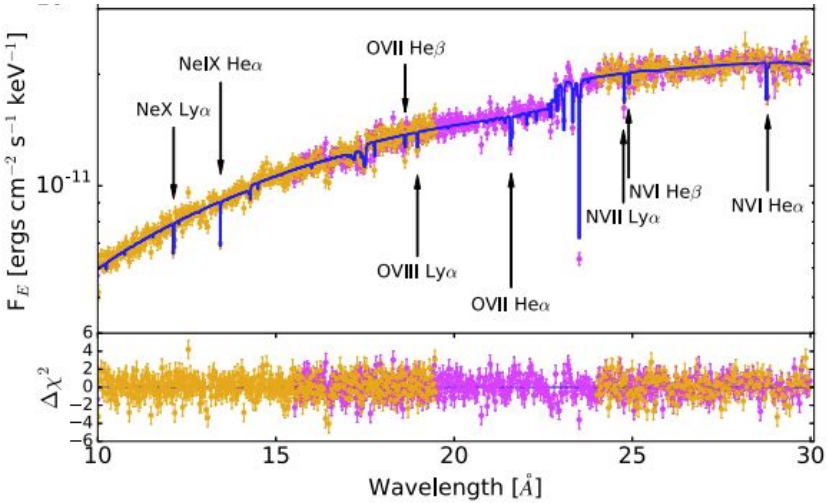


~6 eV resolution, Wolf+ 2019



Milky Way hot halo: absorption studies

- similar temperatures to emission measurements
- high resolution spectra: possible non-solar abundances
- low SNR can be an issue



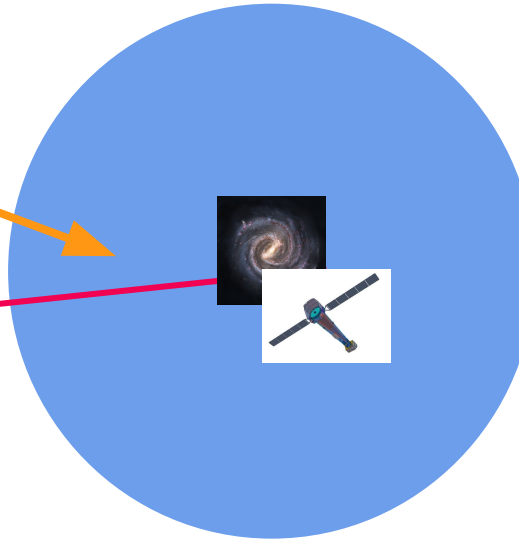
Das+2019, XMM RGS

extragalactic bright point source



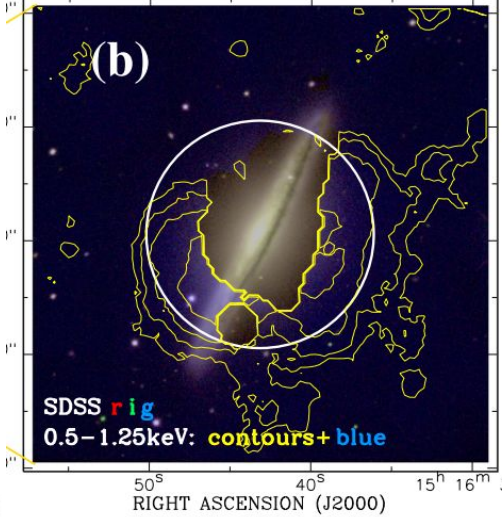
absorption happens here

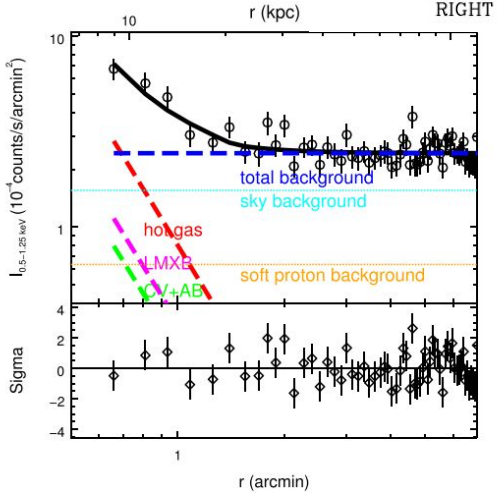
line of sight



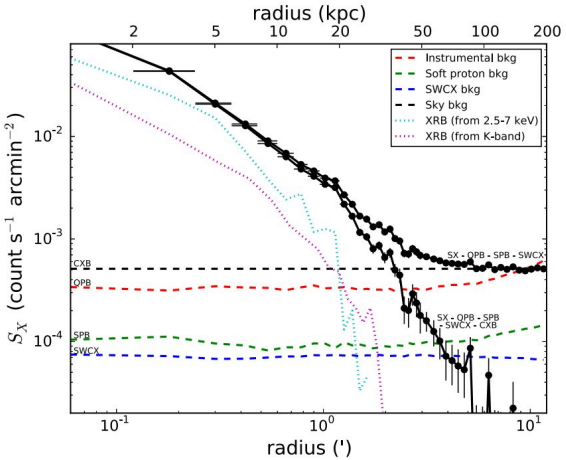
CGM of massive spirals *(larger than Milky Way)*

- excess soft X-ray emission detected with CCD imaging in few galaxies larger than Milky Way
- spatial scales up to ~20-50 kpc





Li+2016
NGC 5908



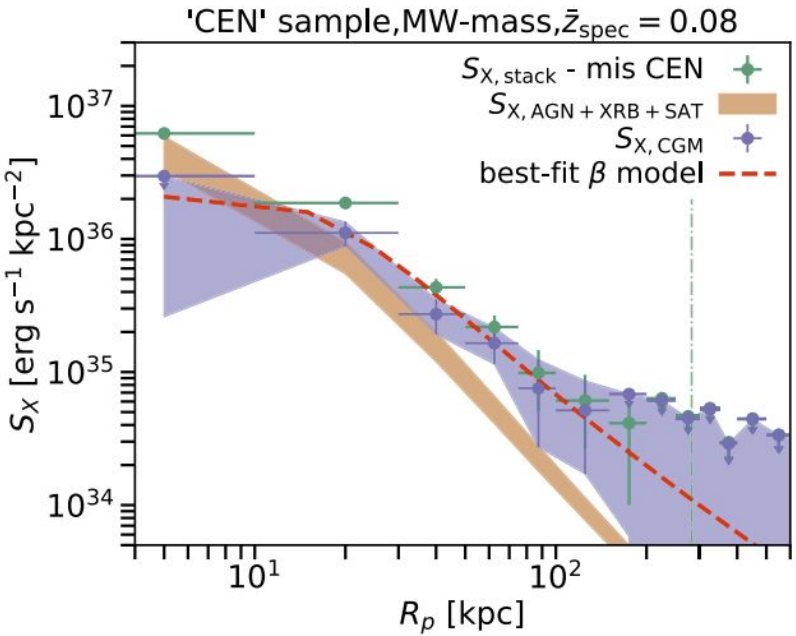
Anderson +2016, NGC 1961



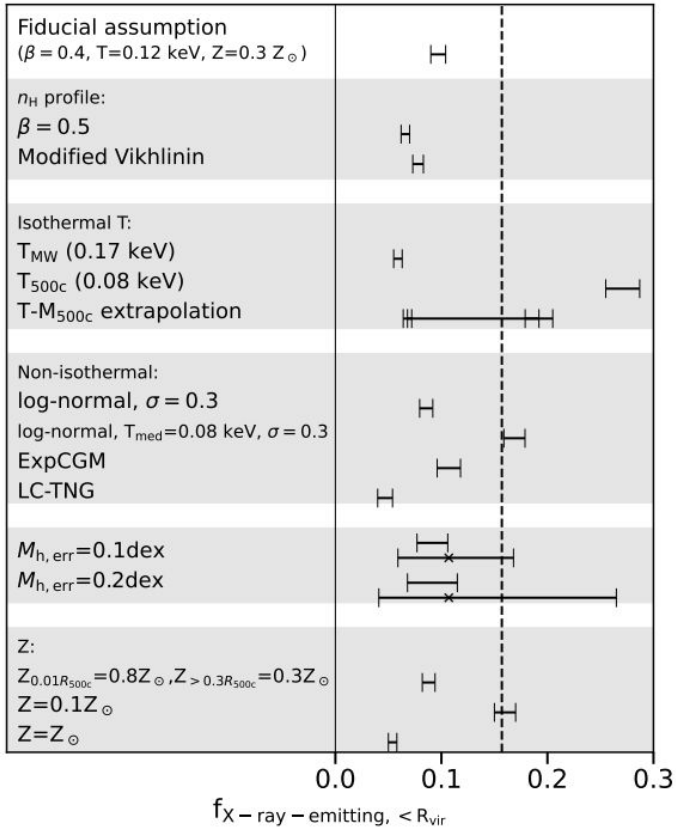
also: UGC 12591 Dai+2012, NGC 266 Bogdan+2013a, NGC 6753 Bogdan+2013b, NGC 5746 Laktionov+2025

CGM of MW-like galaxies

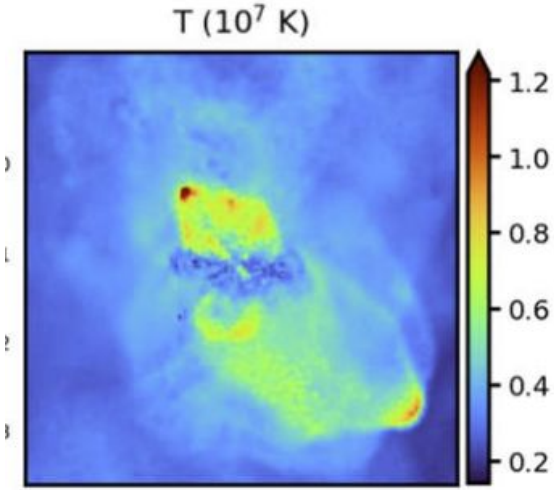
- excess surface brightness up to ~100 kpc
- no inference on properties

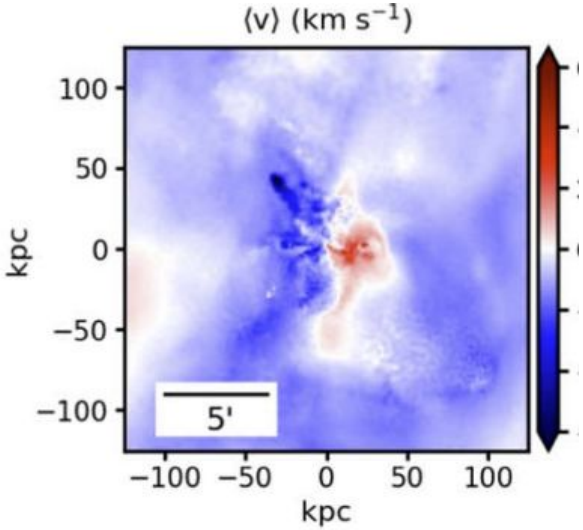


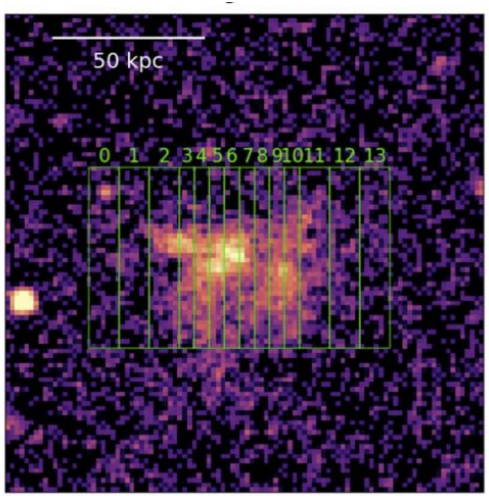
Zhang+ 2024 eROSITA stacks of millions of galaxies

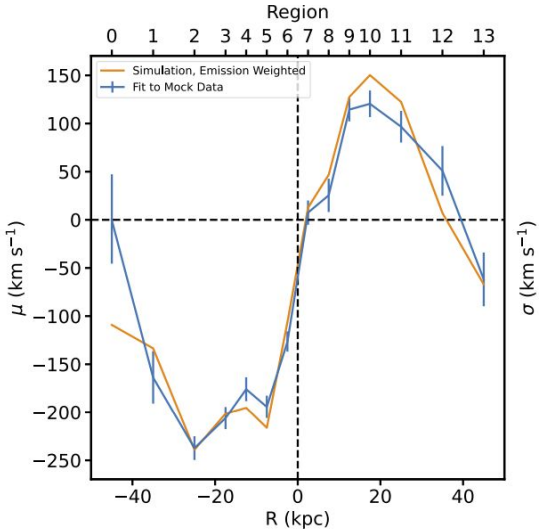


Zhang+ 2026



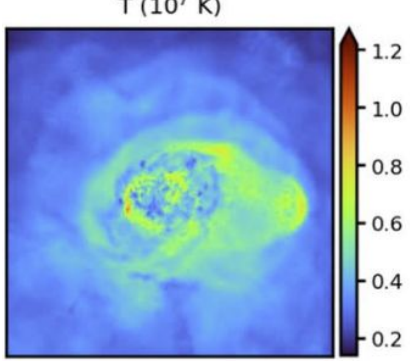


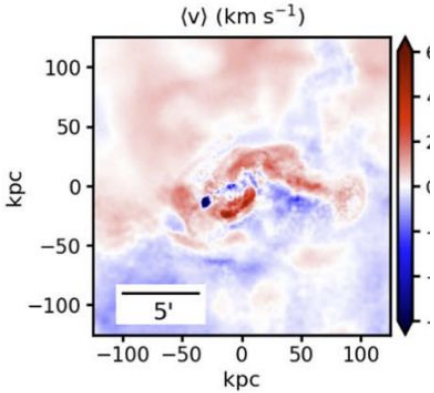


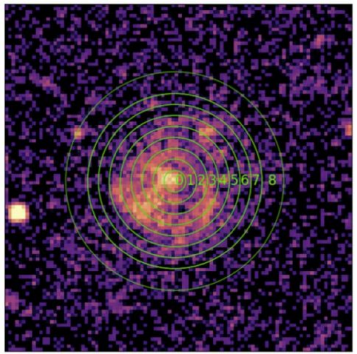


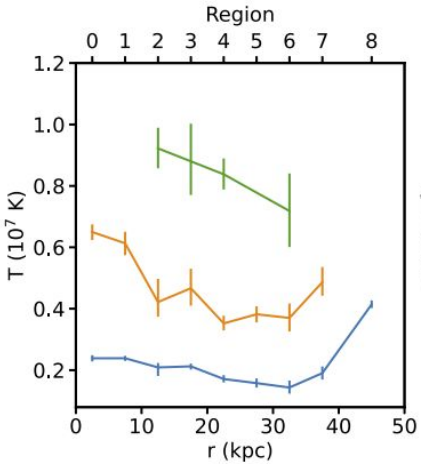
microcalorimeter X-ray spectra of CGM can clearly show the dynamical state of the gas

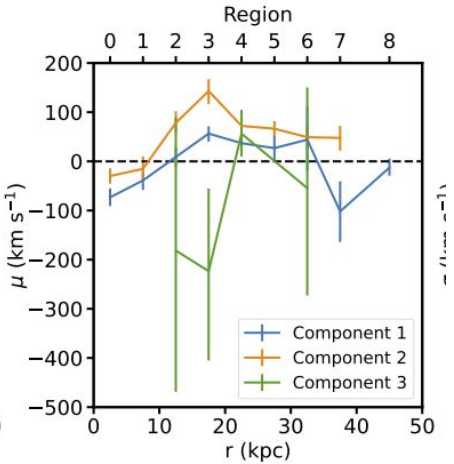
ZuHone+(incl. AO) 2024

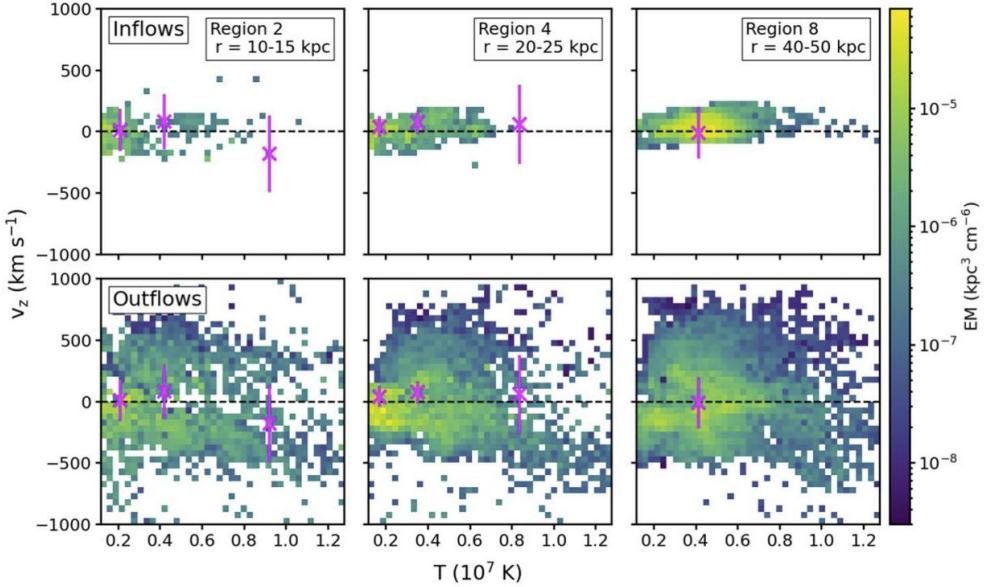




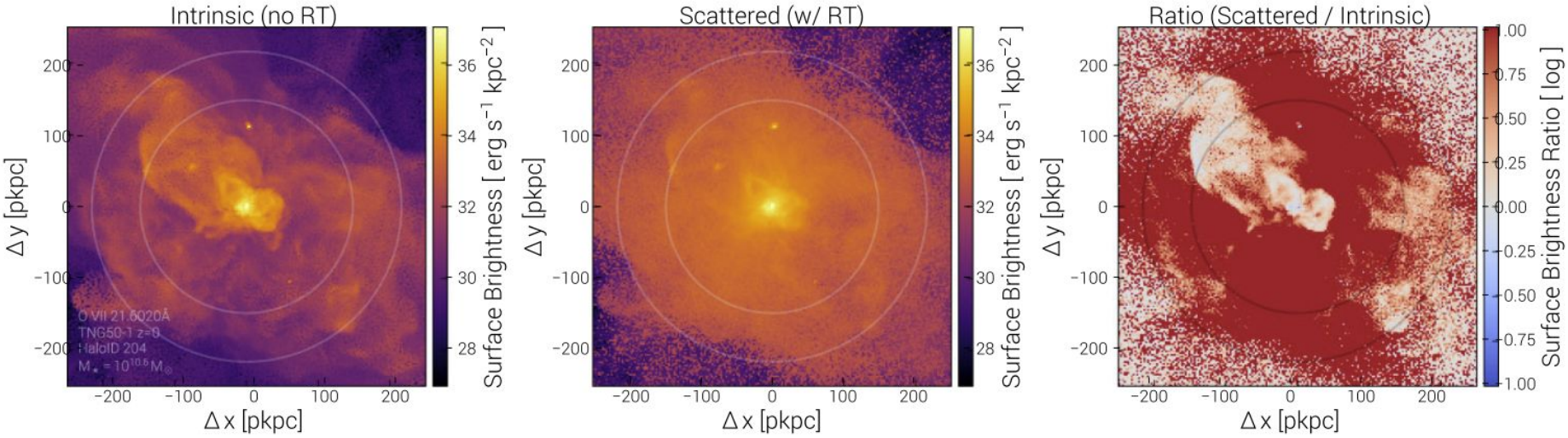


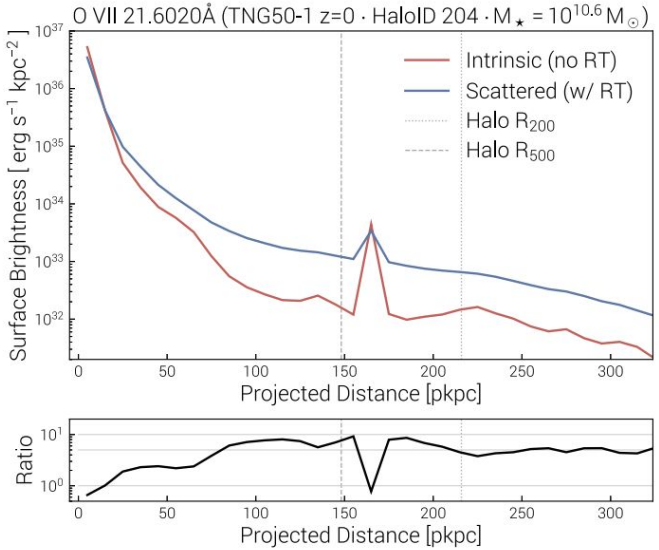






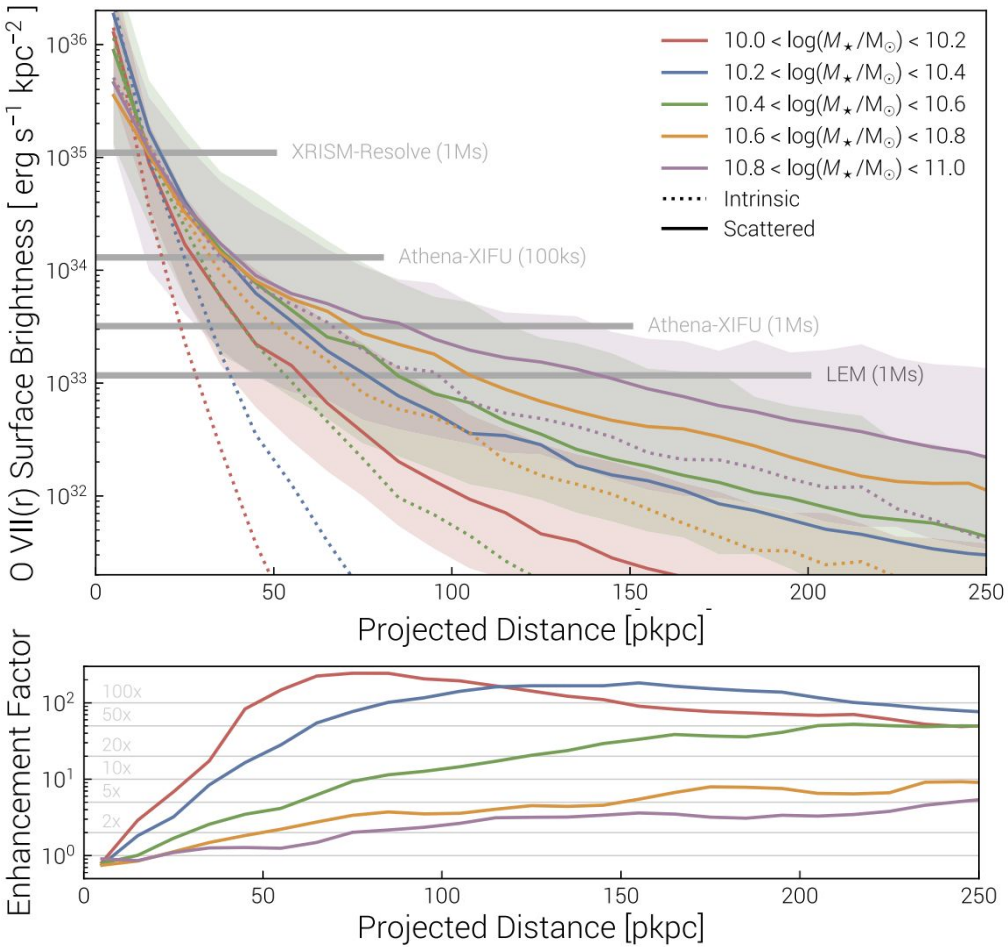
ZuHone+(incl. AO) 2024

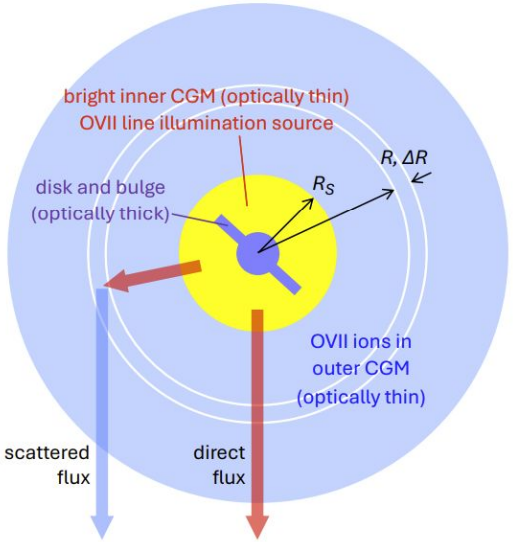




radiative transfer of bright OVII resonant line extends the radius of detection

Nelson+(incl. AO) 2023





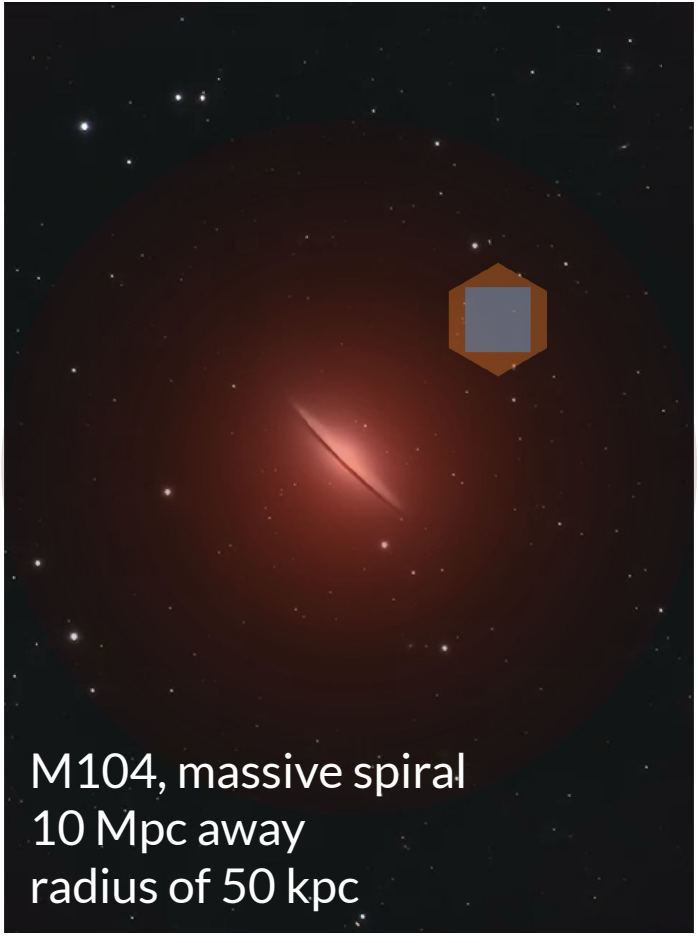
See also Truong+2026 for how to use this effect to estimate the total CGM mass

Nelson+(incl. AO) 2023

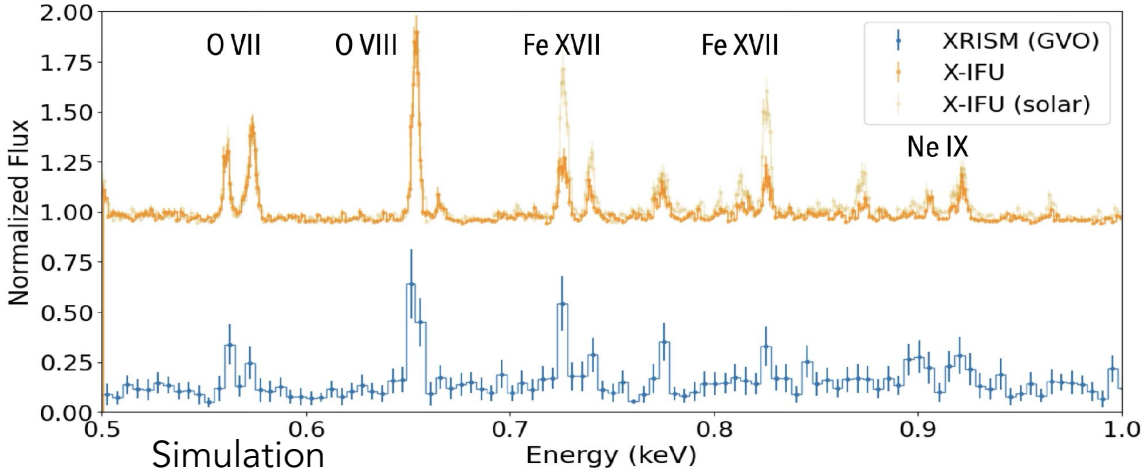
To truly understand CGM, we need

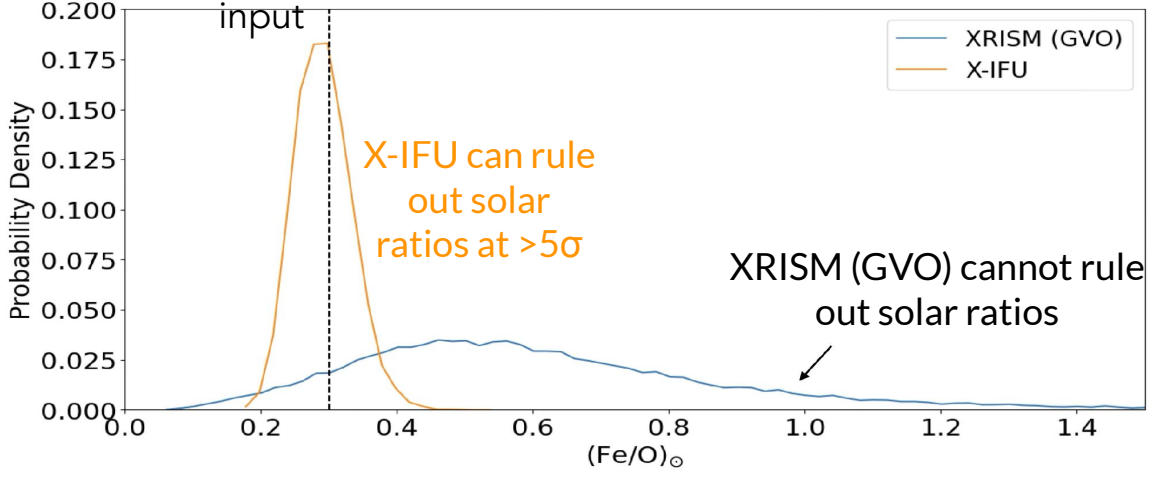
1) **Spatially-resolved high spectral resolution** X-ray observations of CGM emission
2) In large samples of halos

CGM makeup



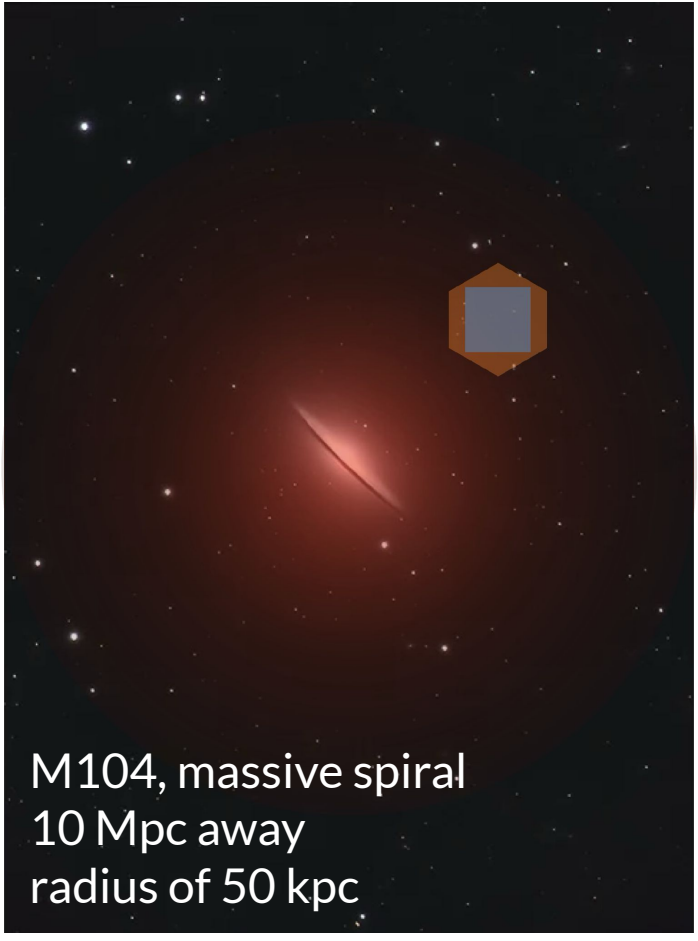
Simulated 300 ks observation of
CGM with subsolar Fe/O including all backgrounds



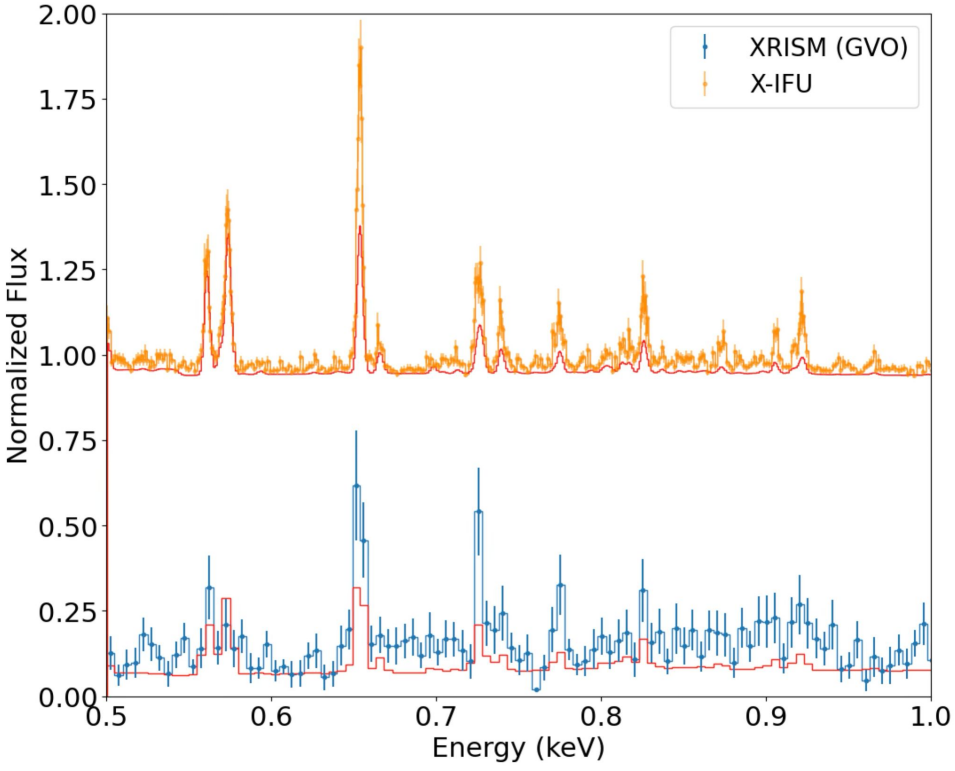


Simulations by E. Hodges-Kluck

CGM makeup

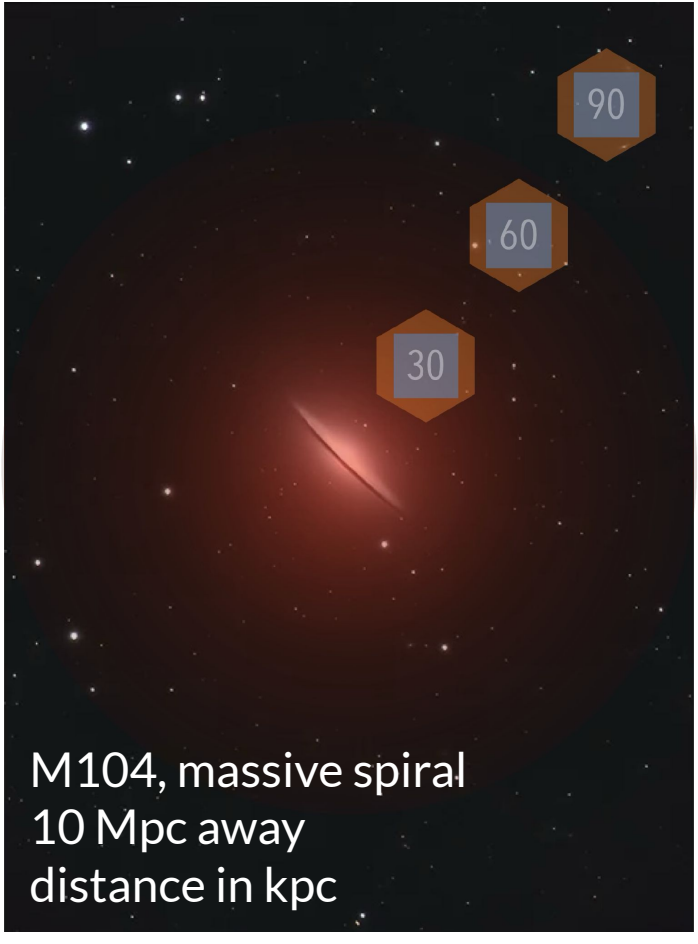


Simulated 300 ks observation of
CGM with subsolar Fe/O including all backgrounds

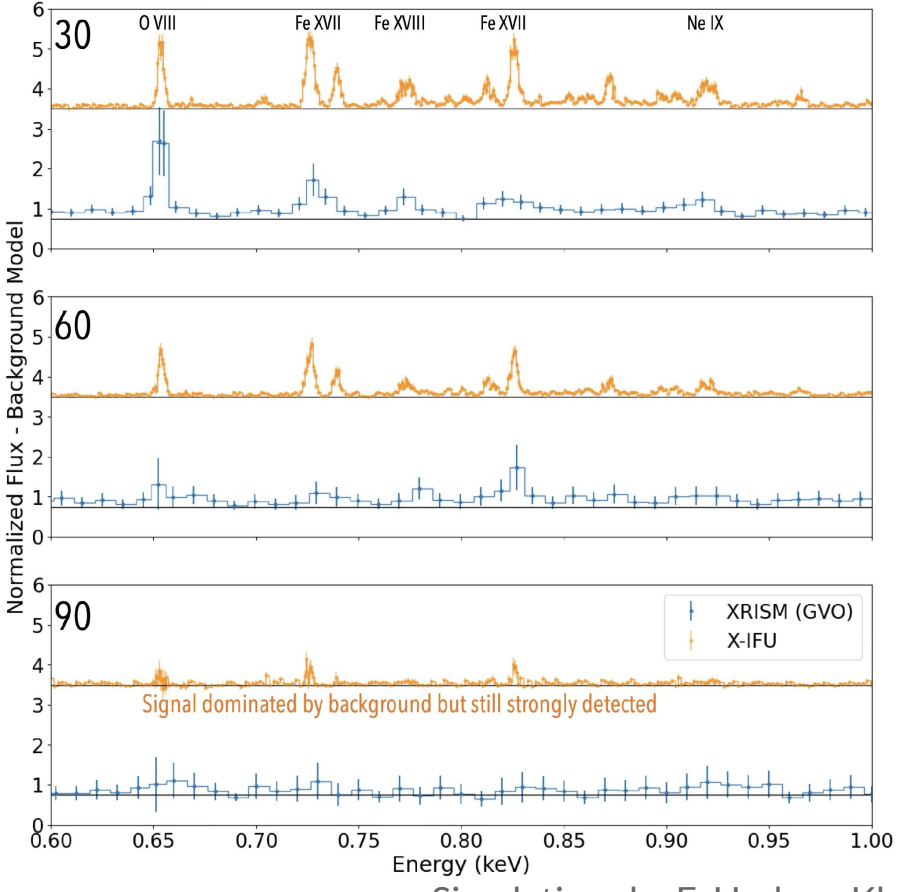


Simulations by E. Hodges-Kluck

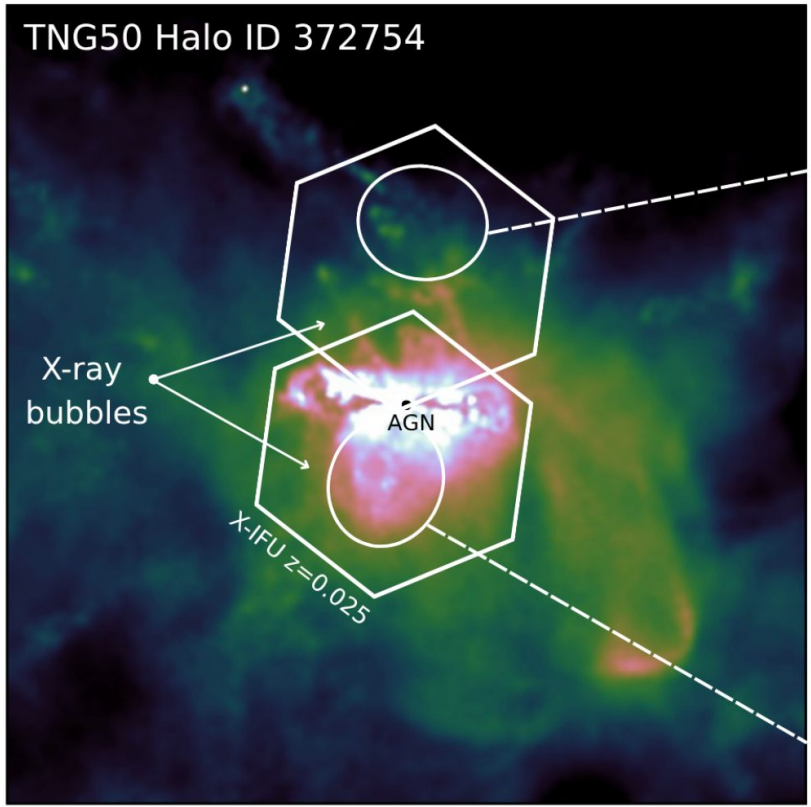
CGM spatial extent

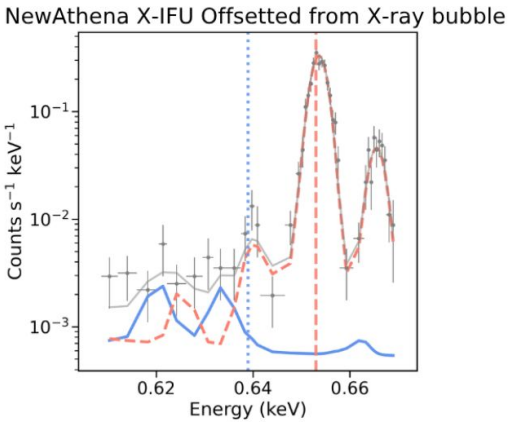


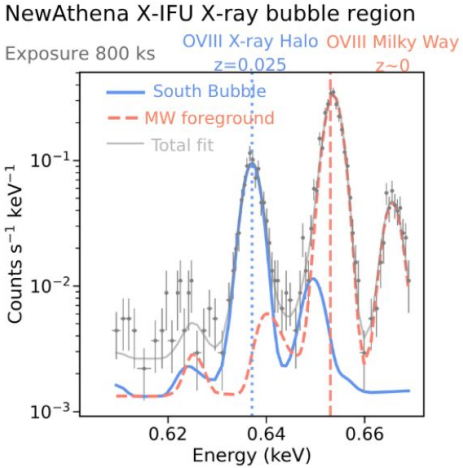
XRISM (GVO) limited to low radii

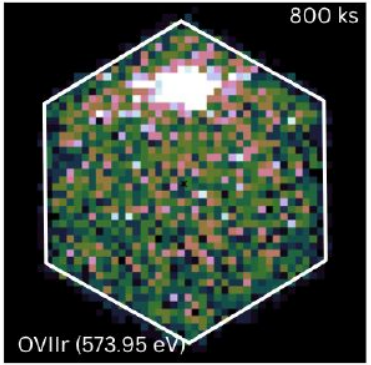


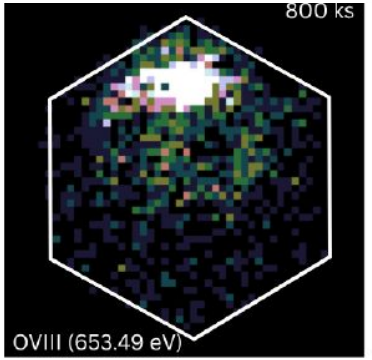
Simulations by E. Hodges-Kluck

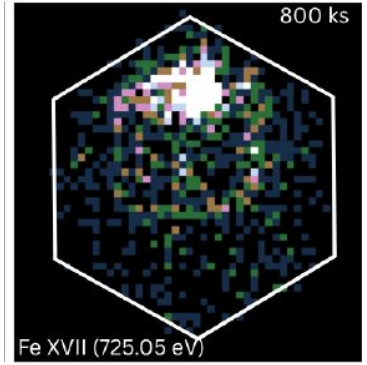




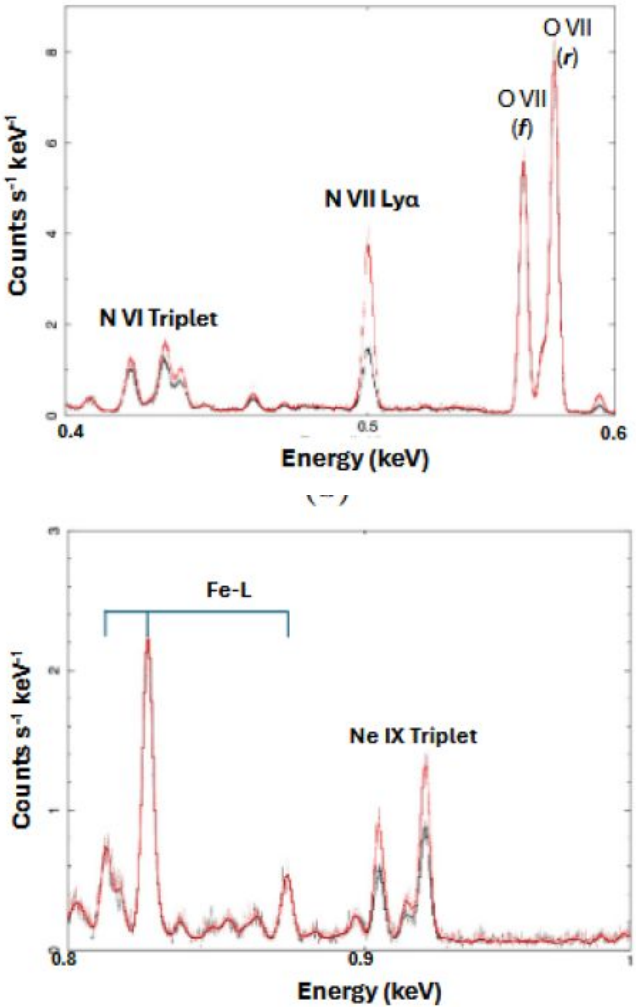




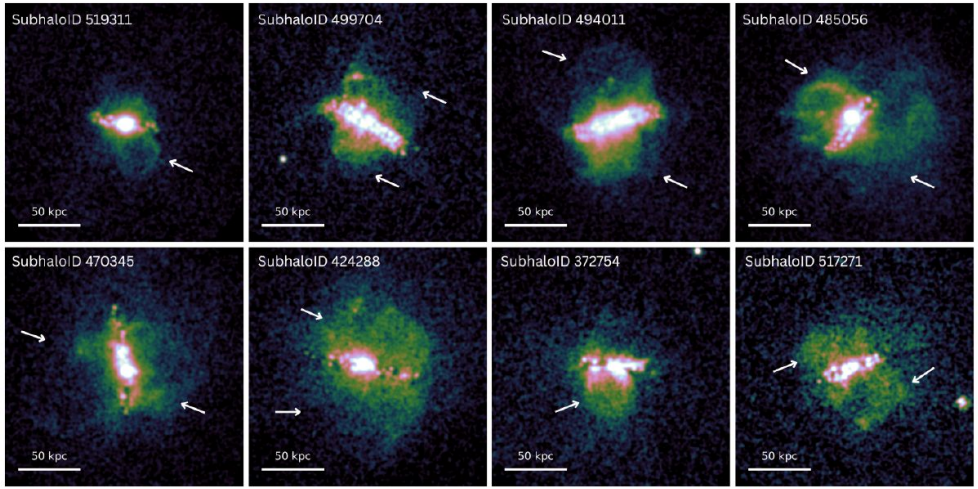




Gupta, Prunier, et al submitted to NewAthena Special Issue



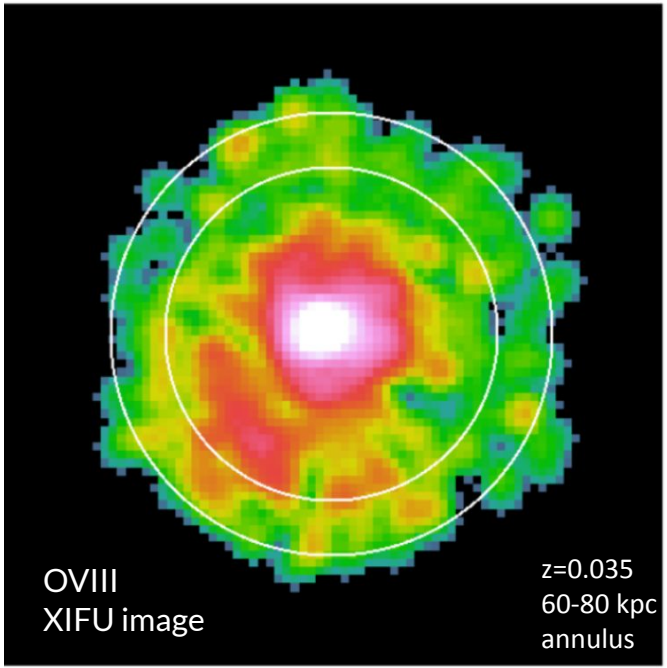
300 ks XIFU simulation
of Milky Way eROSITA Bubbles

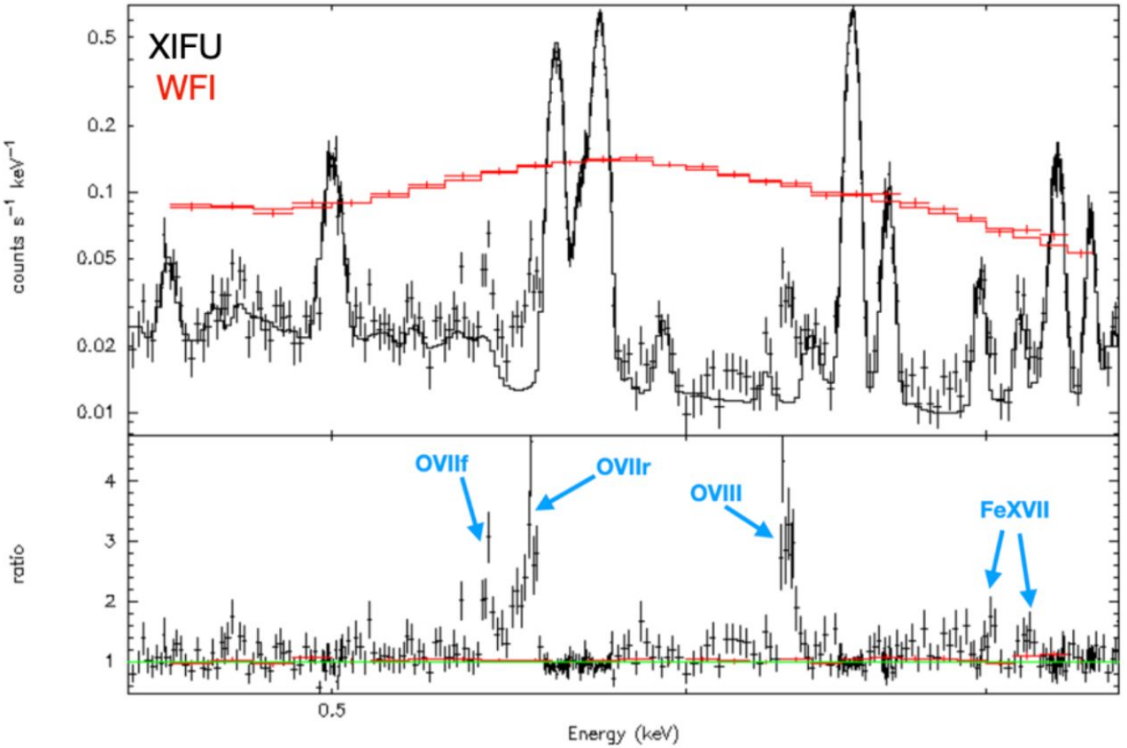


300 ks WFI simulation of eROSITA-like bubbles
in external galaxies at z=0.01

Gupta, Prunier, et al submitted to
NewAthena Special Issue

Towards unwabigous detection of CGM of Milky Way-like galaxy





Simulations by A. Simionescu

To truly understand CGM, we need

1) Spatially-resolved high spectral resolution X-ray observations of CGM emission

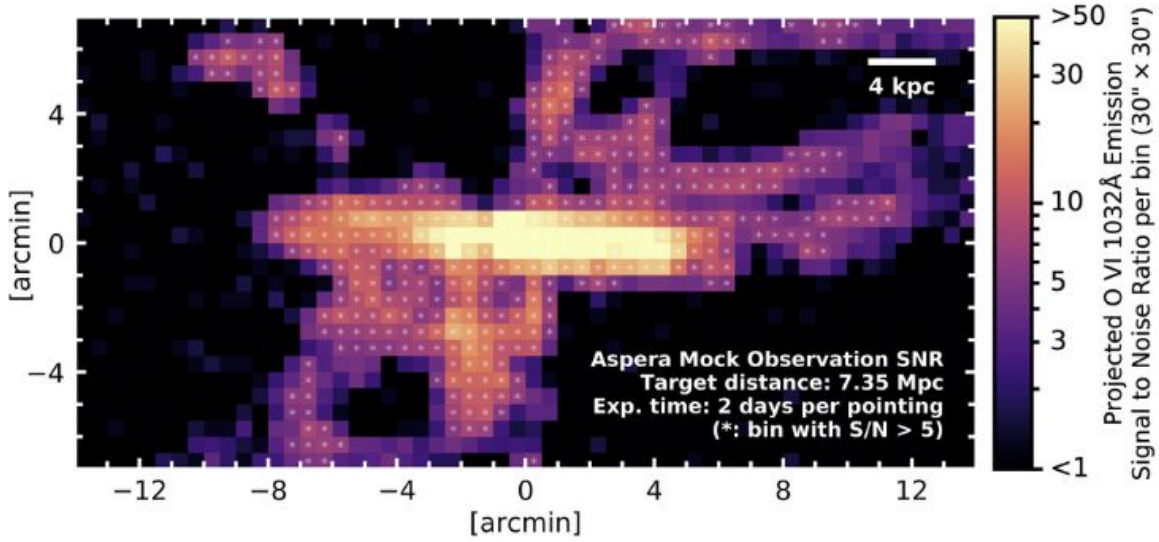
   -> XIFU great for our Galaxy, local massive spirals and really bright structures like eROSITA-like bubbles, ok for detections of extended CGM in some smaller halos

2) In large samples of halos

   -> large time investments necessary, hopefully next NASA flagship or other dedicated mission help

UV emission measurements on the horizon

Aspera - NASA Pioneer, launch in ~January narrow band UV imaging of OVI emission



Chung et al. 2021

UV emission measurements on the horizon

- Ardua - NASA ASTRA Initiative concept (very early stage), UV+X-ray, Vargas+(incl. AO) 2026
- Habitable Worlds Observatory - potential small FOV UV IFU, Burchett+2025
- and others …

Summary:

- *X-ray emission from CGM of Milky Way-like and larger galaxies remains key to understanding how galaxies evolve*
- *Low resolution measurements are informative, but are reaching their limits in the post-eROSITA era*
- *Imaging spectrometers like XIFU are the only way that we can make the crucial measurements*
- *XIFU will perform critical measurements for detection of CGM in Milky Way analogs, and characterization of inner CGM for nearby massive spirals*
- *However, due to the large time investments involved, more spatially resolved high spectral resolution missions are likely necessary*

More about NewAthena and CGM:

- *Gabriele Ponti's NewAthena CGM Webinar talk! (more WFI focused)*
- *NewAthena Special Issue paper:* "Galactic atmospheres with NewAthena: The circumgalactic medium and eROSITA-like bubbles around Milky Way-like galaxies" *by Gupta, A.; Prunier, M.; Truong, N.; Pillepich, A.; Zhang, Y.; Mathur, S.; Das S.; Simionescu, A.; Roy M.*