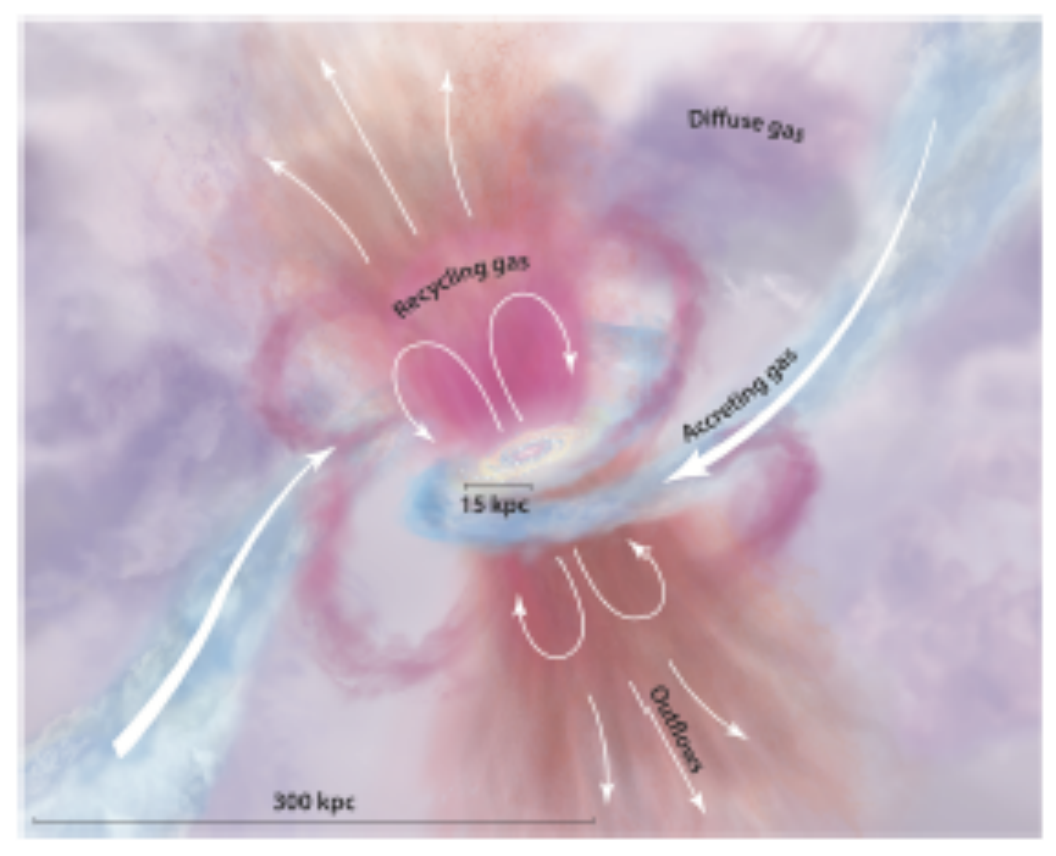
XMM-Newton Studies of the Hot Circumgalactic Medium of the Milky Way

Smita Mathur
The Ohio State University

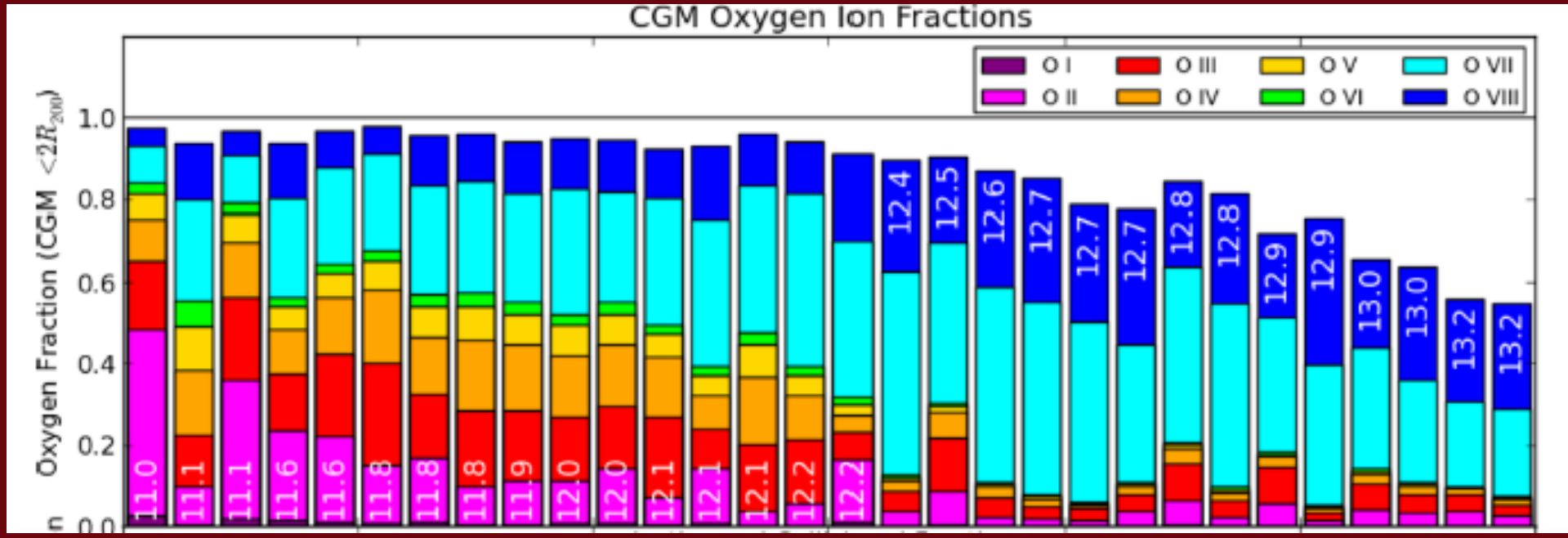
With: S, Das, A. Gupta,
F. Nicastro,Y. Krongold

The Circumgalactic Medium



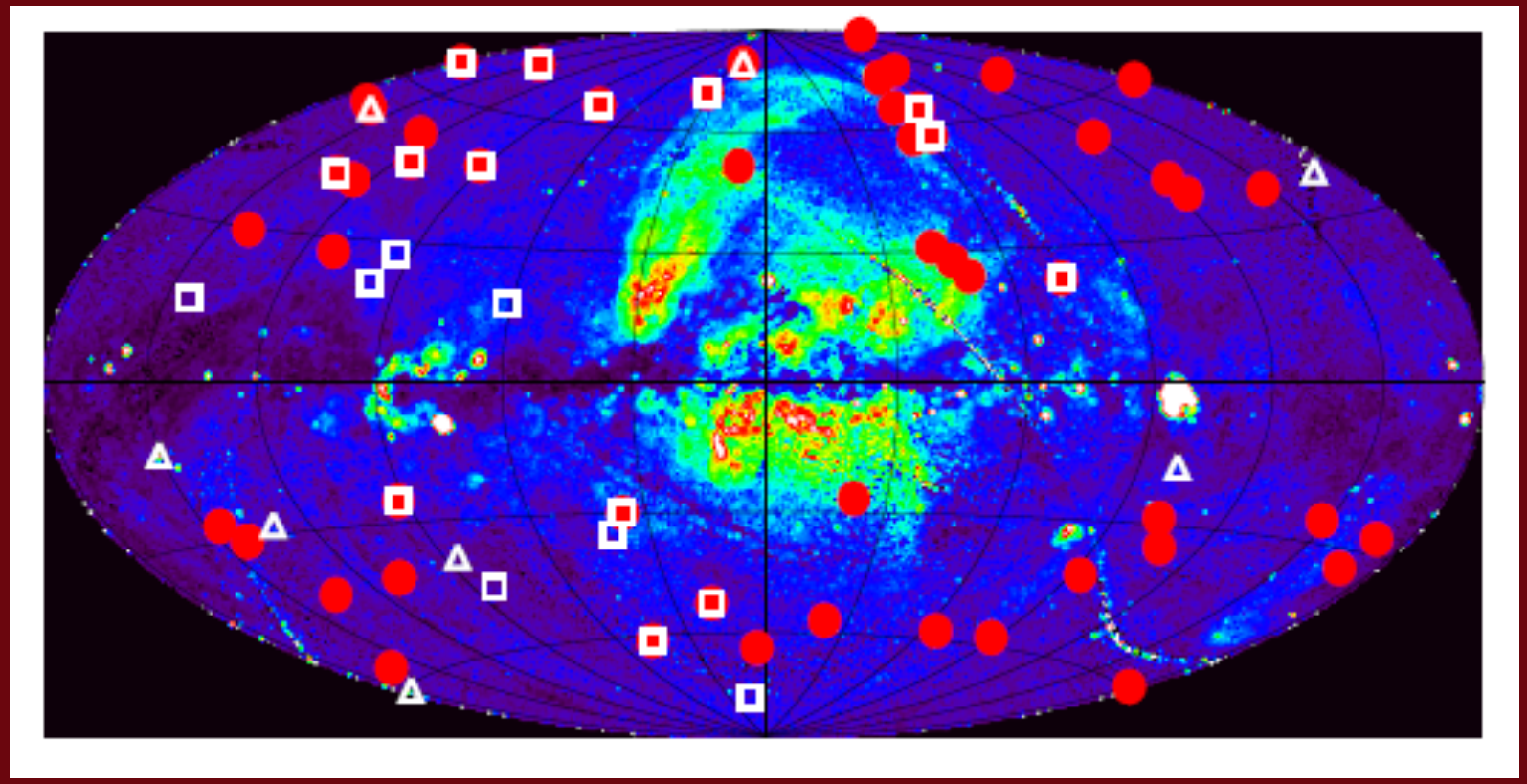
Tumlinson, Peeples & Werk 2017

The CGM is hot…traced by OVII, OVIII



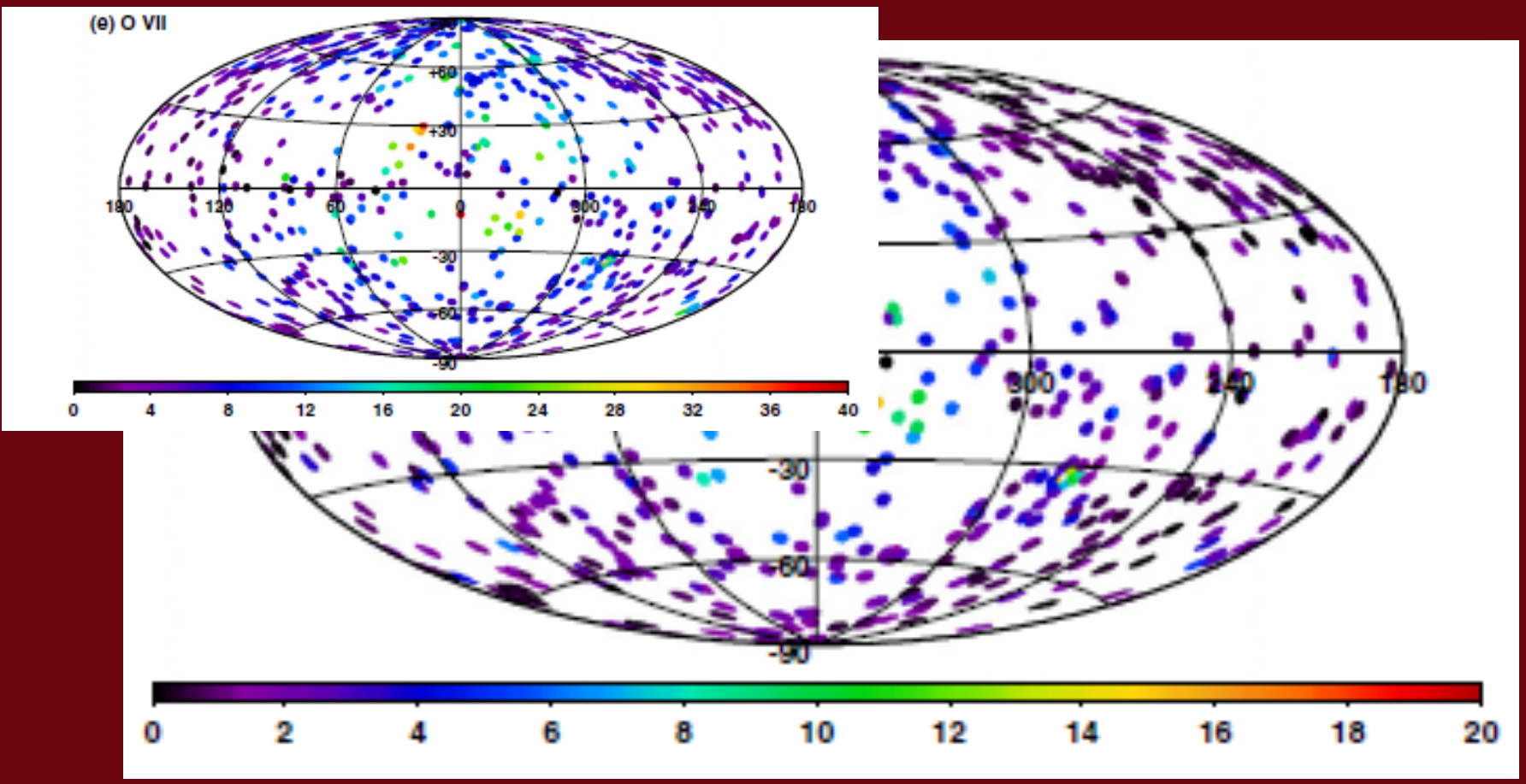
Oppenheimer+2016

ROSAT all sky survey map of the diffuse background at ¾ keV



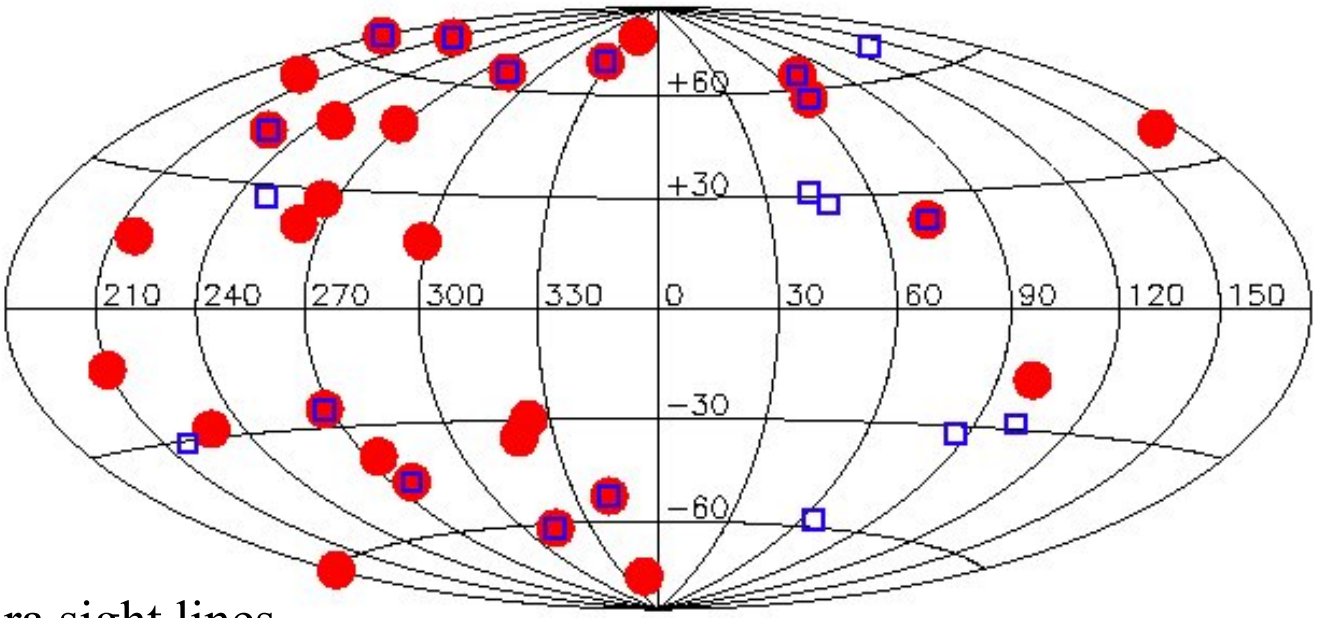
Snowden+1995

XMM Observations of Soft X-ray Galactic Halo Emission



Henley & Shelton 2012

Our Chandra Survey of OVII and OVIII



Chandra sight lines

Previous OVII detection

Mass Probed by OVII and OVIII X-ray Absorbing/Emitting Gas Phase

$$M_{total} > 1.7 \times 10^{9} (fc/0.72) (8.51 \times 10^{-4}/(A_O/A_H))^3 (0.5/f_{OVII})^5 (Z_\Theta/Z)^3 M_\Theta$$

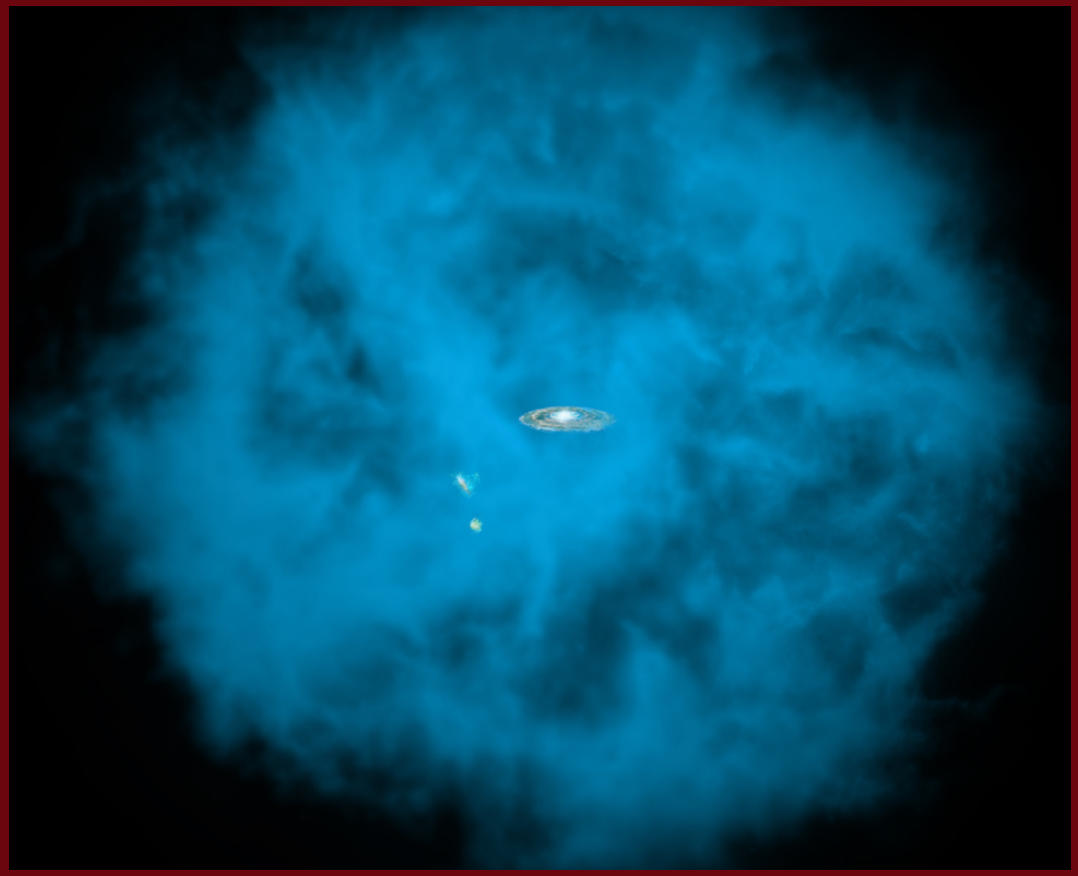
For $Z = 0.3Z_\Theta$

$L > 138$ kpc

$M_{total} > 6.1 \times 10^{10} M_\Theta$

Gupta, Mathur + 2012, 2014,2016

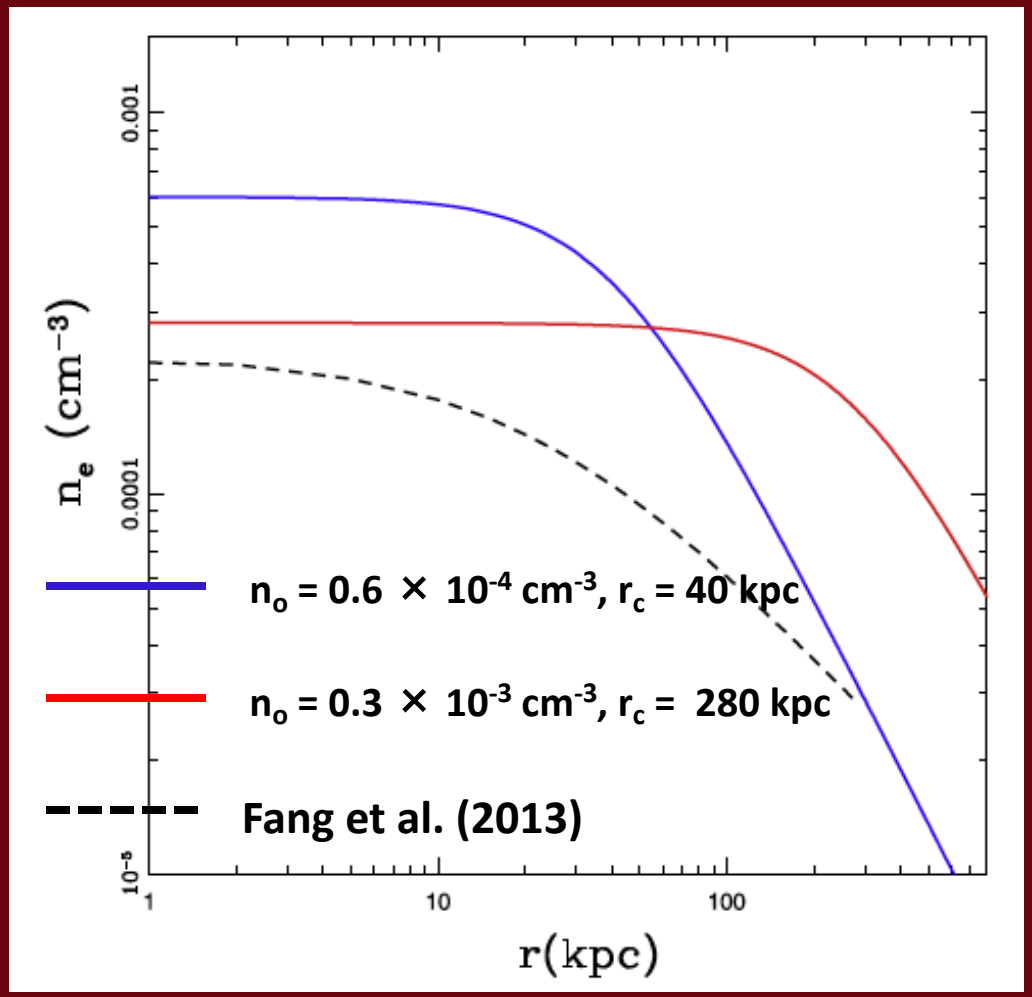
Massive, Extended, Hot Galactic halo



Courtesy: Chandra presss office

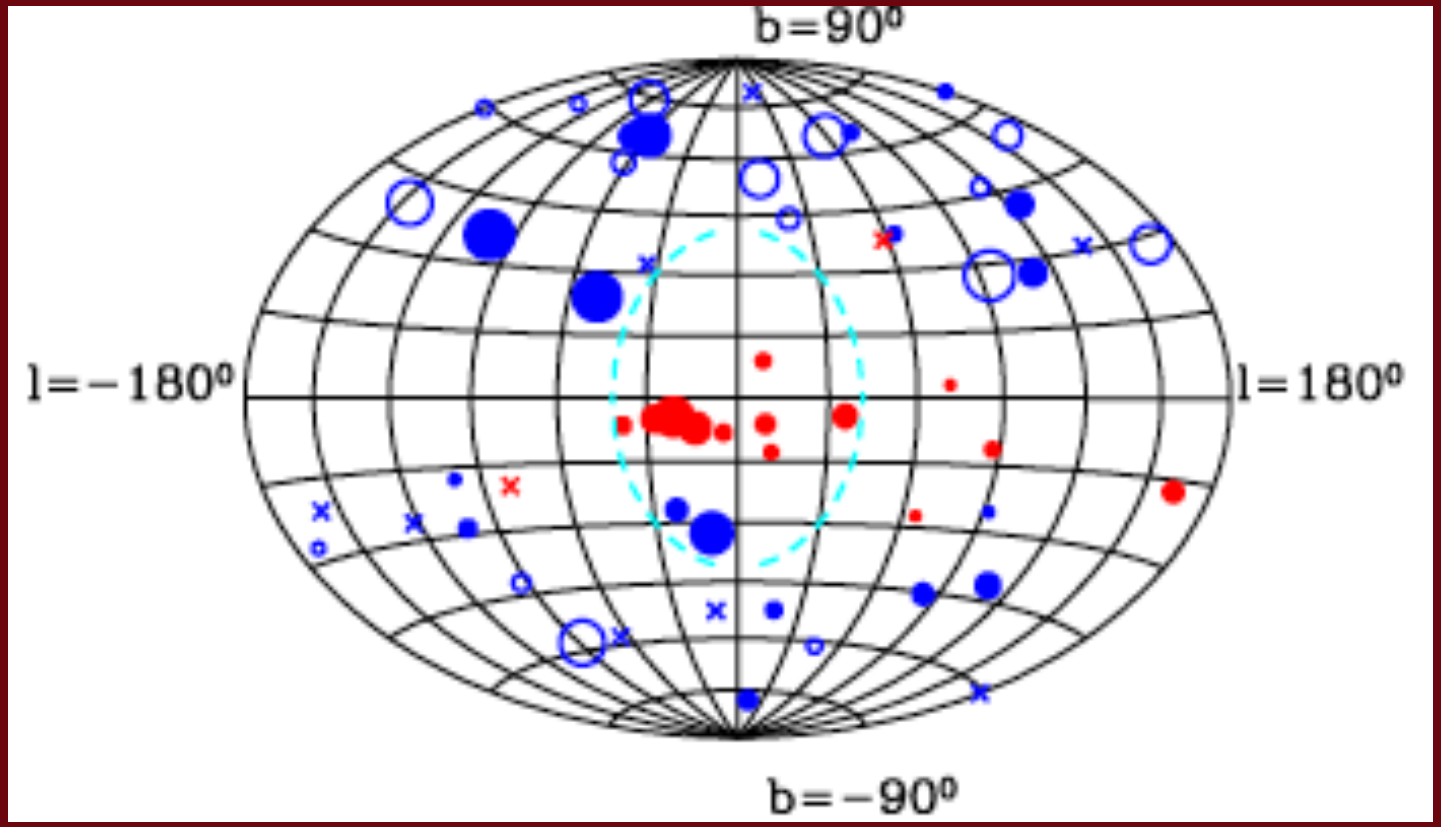
Moving beyond finding missing baryons to characterizing the CGM to understand accretion and feedback in galaxy formation and evolution.

β- Model



Maller & Bulock profile: hot gas in hydrostatic equilibrium in NFW dark matter halo potential

Galactic and extragalactic sightlines

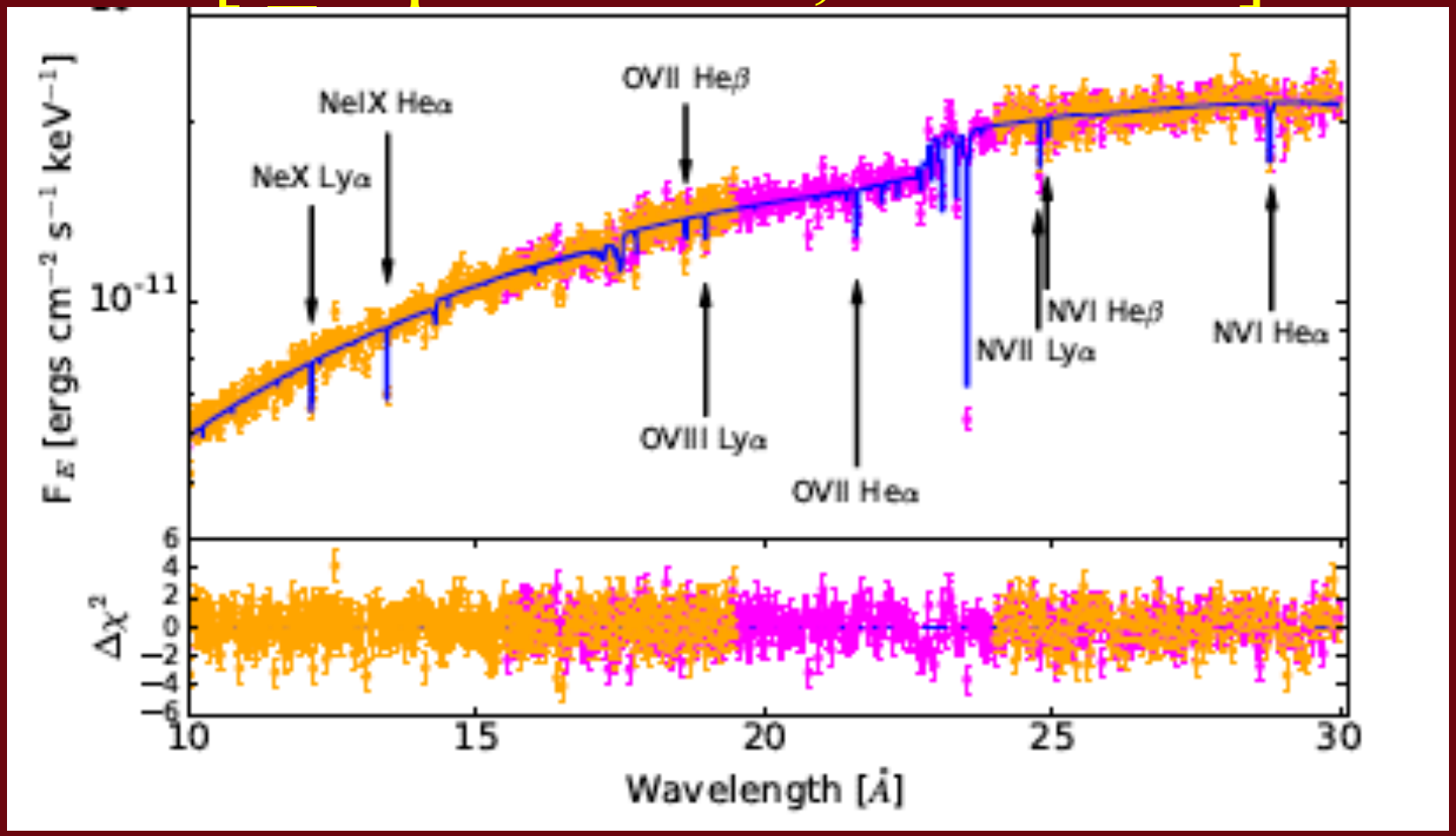


Nicastro et al. 2016

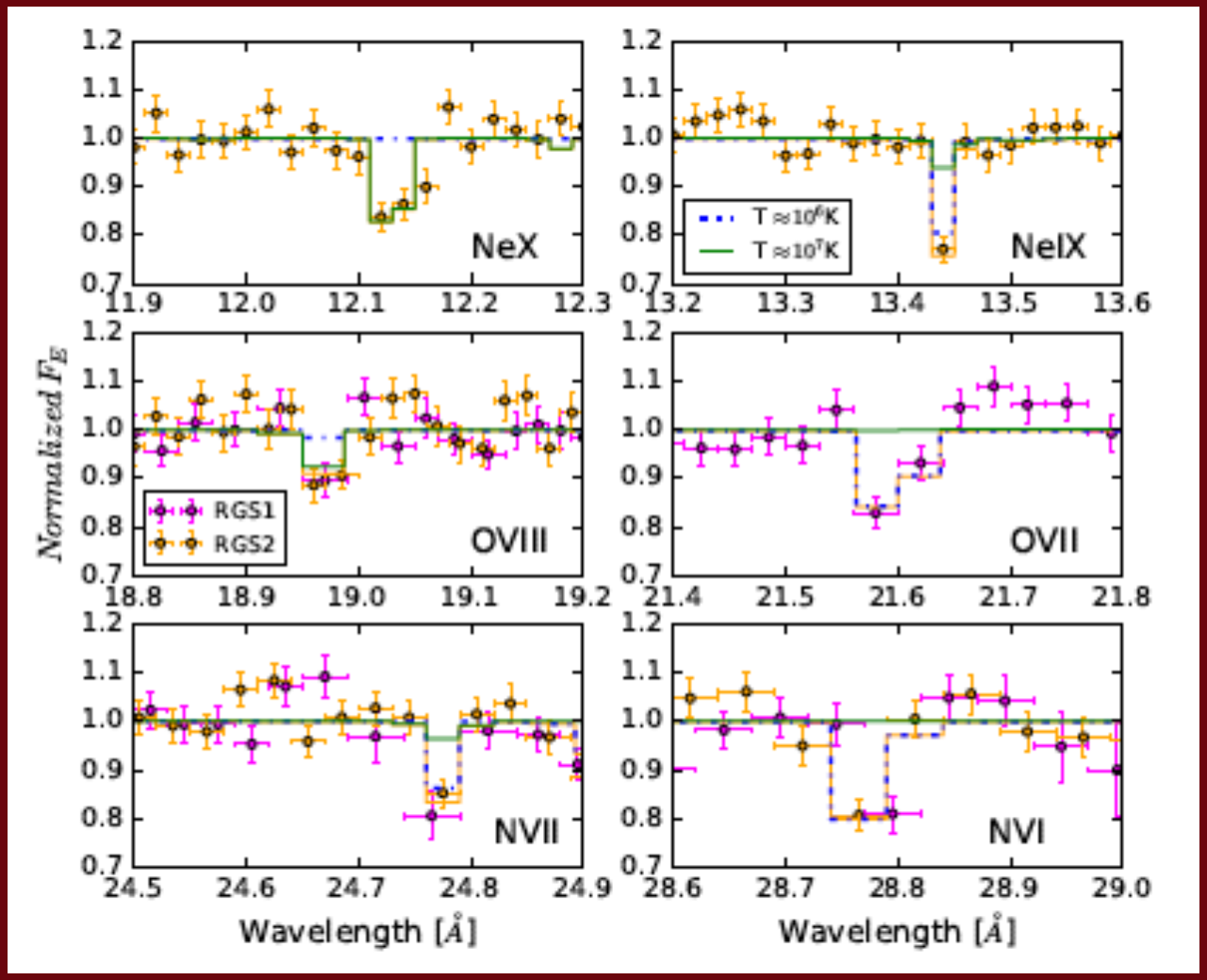
Fermi bubbles

- Both the Galactic plane and the halo are filled with million degree hot gas
- There is a hole in the middle. A bubble of radius 6kpc centered on the Galactic center.
- Relic of the AGN activity few million yrs ago
- The mass reservoir in the hot halo is huge.

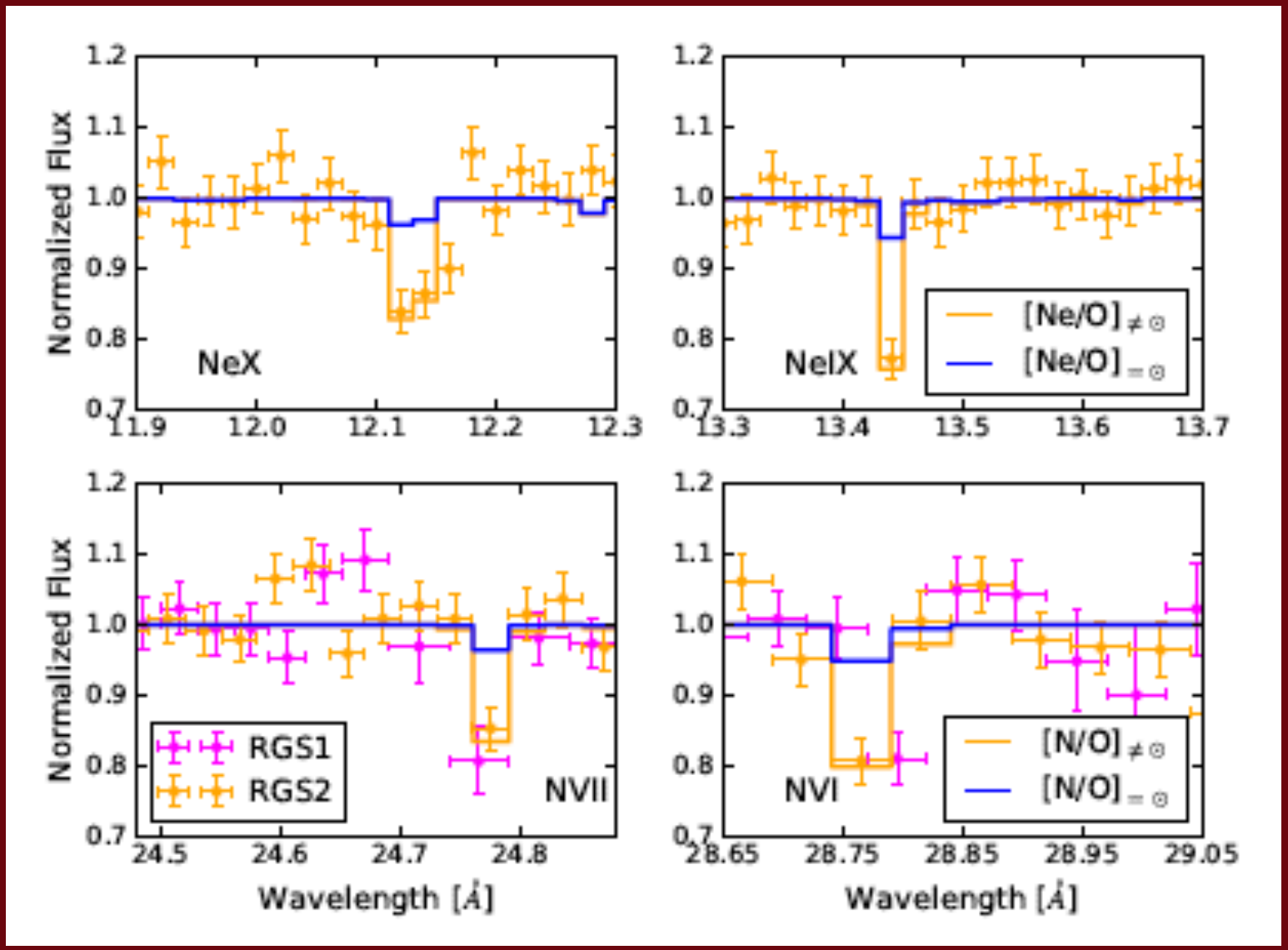
XMM-Newton spectrum toward 1ES1553 [t_exp=1.85 Ms, SNRE 43]



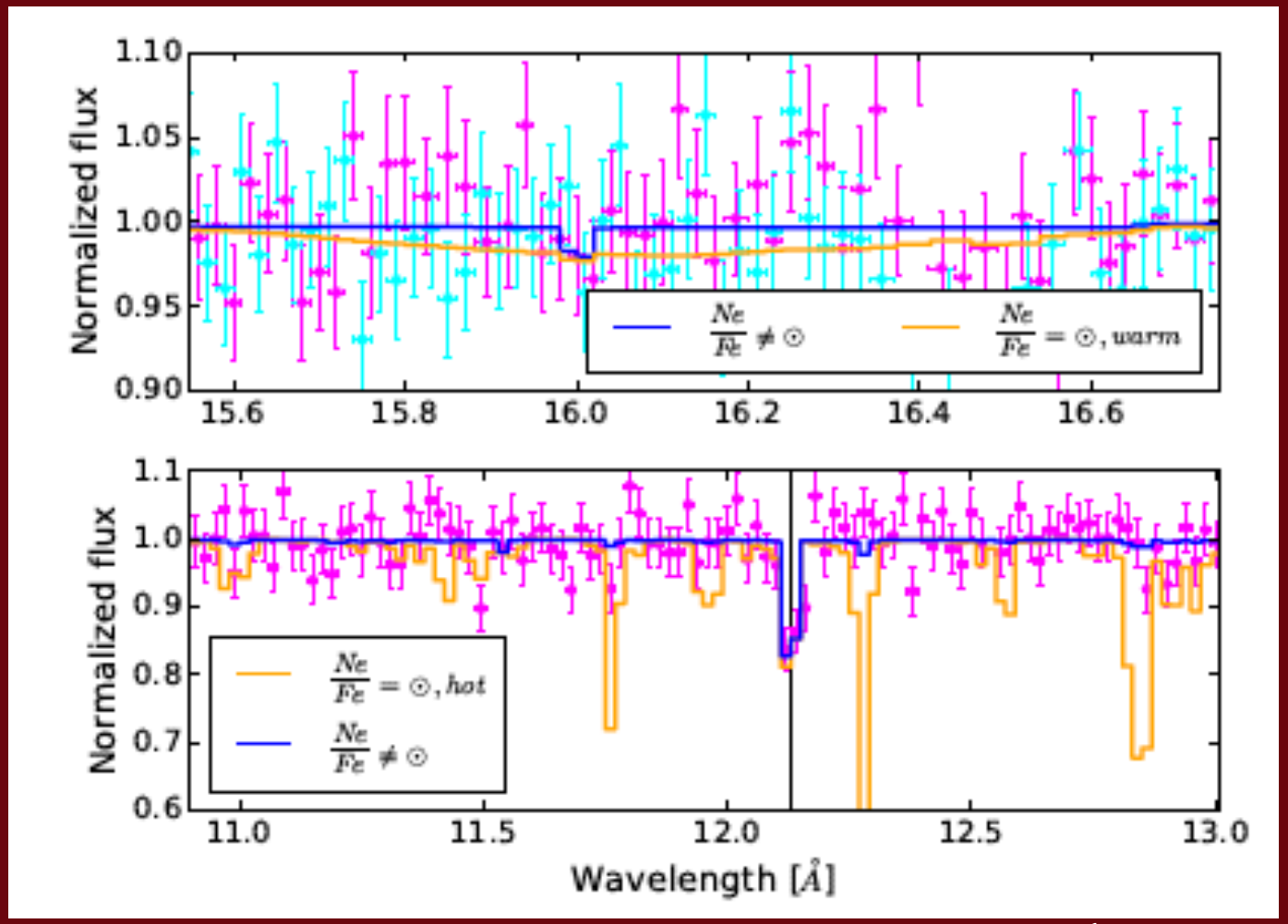
Result 1: Discovery of a hot (T= 10^7K) component



Result 2: Non-solar mixture



Result 3: α-enhancement



Das, Mathur + 2019

Implications

- α-enhancement: core-collapse SNe enrichment
- Supersolar N/O: contribution from AGB stars
- But solar N/Ne: subsolar Oxygen

Possible scenarios for non-solar abundance ratios

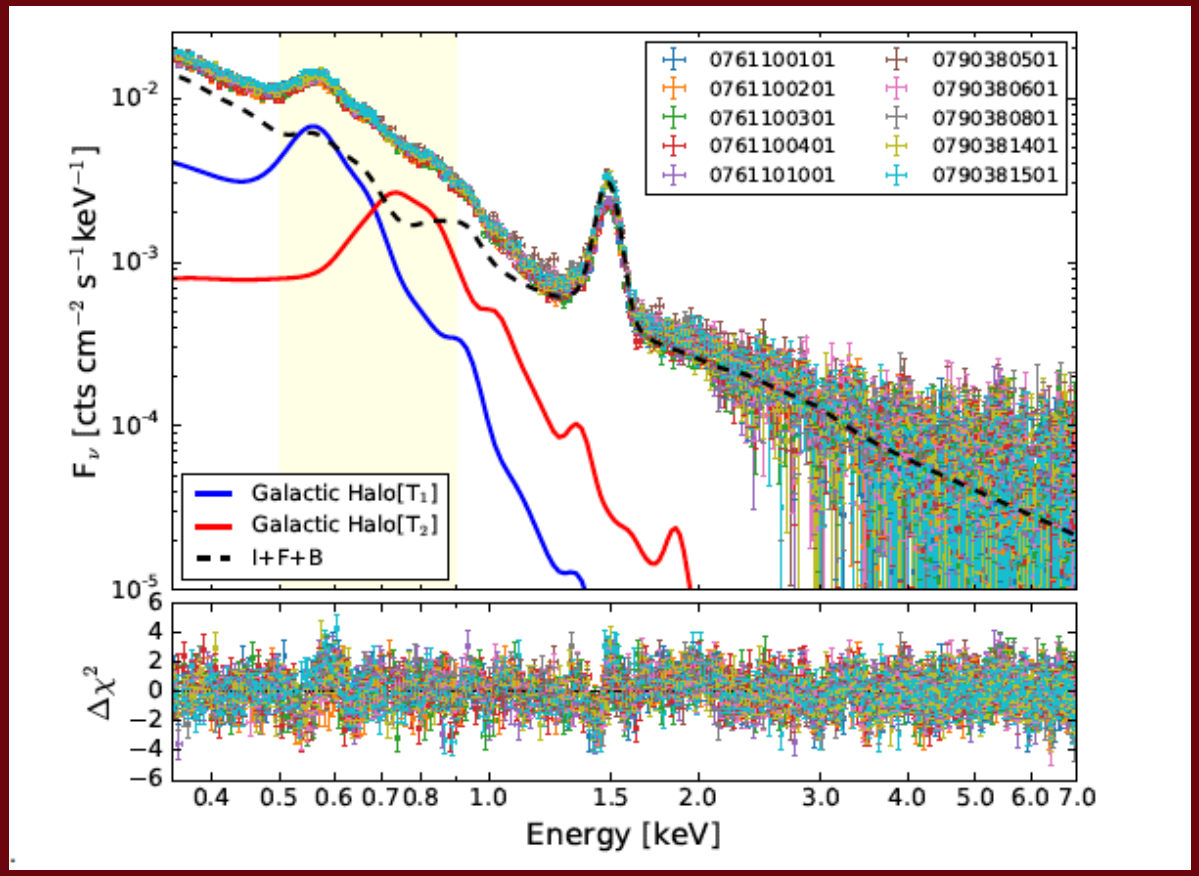
- Inhomogenous mixing (Ford+13,14; Huang+19)
- Efficient cooling of Oxygen (Bertone+13)
- Eventual depletion of Oxygen onto ISM/CGM dust (Tielens+94, Todoni+01, Peeples+14)

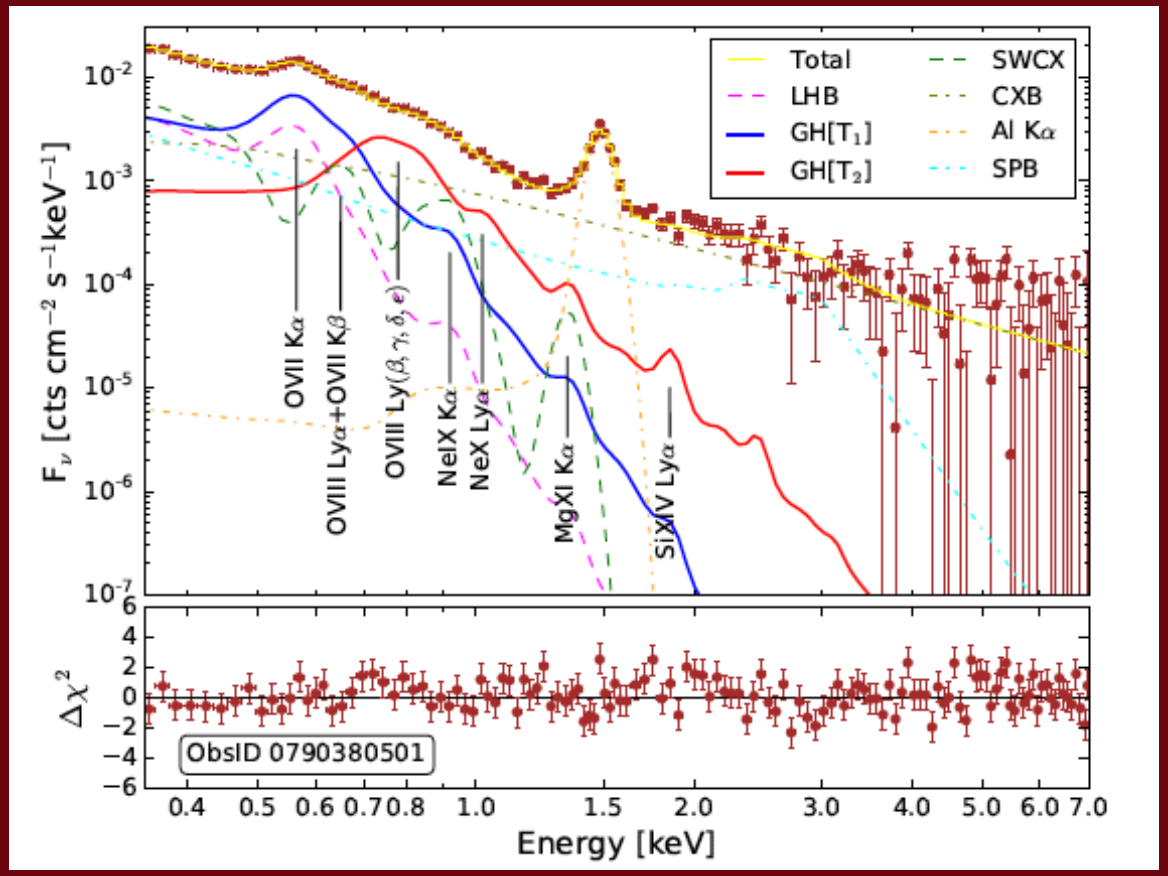
Possible scenario for very hot gas

- ~~SNR along the sightline?~~
- ~~Local Hot Bubble?~~
- ~~Fermi Bubble? North Polar Spur?~~

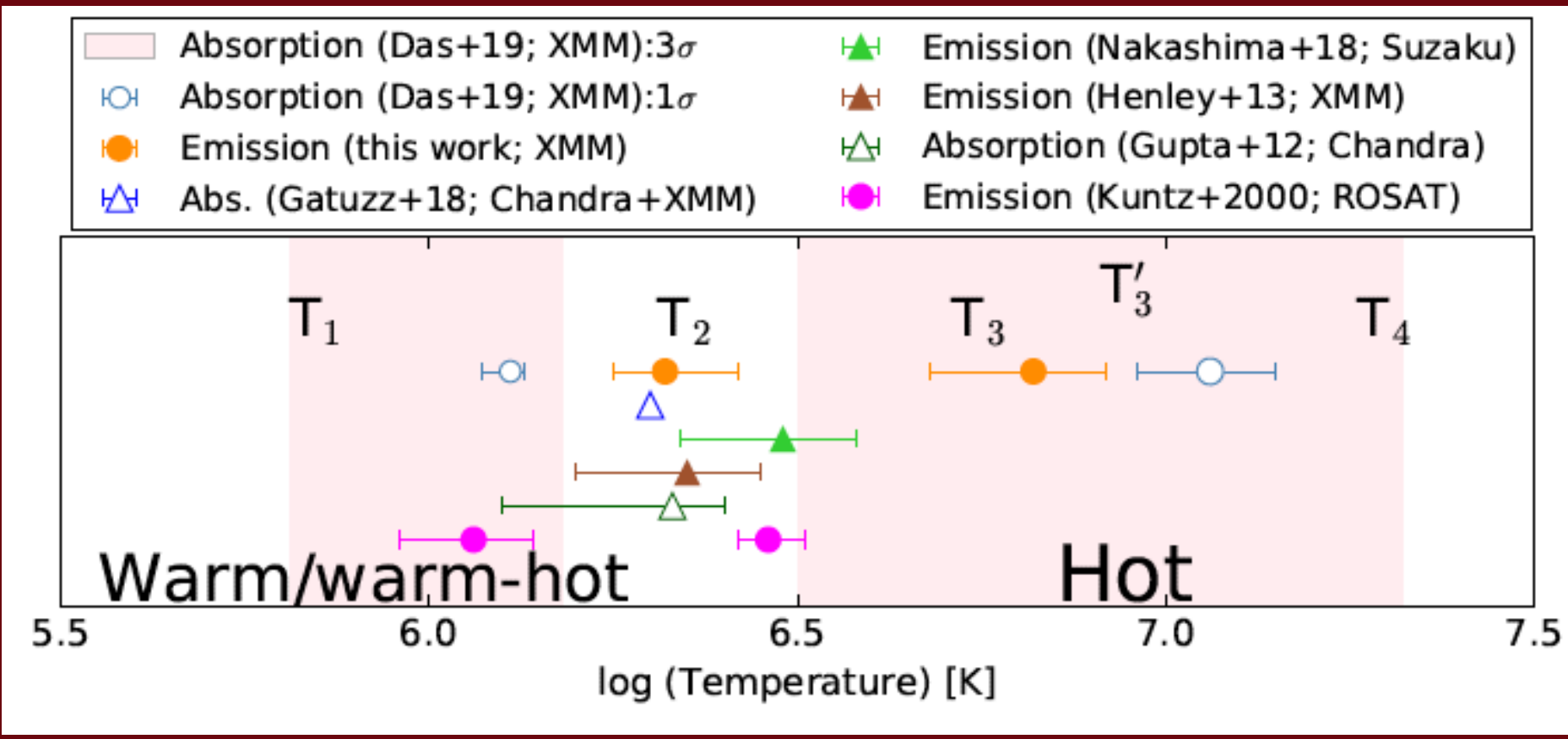
- The gas is likely from an extended region like the CGM. Multi-state stellar feedback (Tang+09)

Milky Way CGM emission around the same sightline


0761100101
0761100201
0761100301
0761100401
0761101001
0790380501
0790380601
0790380801
0790381401
0790381501
Galactic Halo[T1]
Galactic Halo[T2]
I+F+B
F_ν [cts cm^{-2} s^{-1}keV^{-1}]
$\Delta\chi^2$
Energy [keV]


Total
LHB
GH[T1]
GH[T2]
SWCX
CXB
Al Kα
SPB
OVII Kα
OVIII Lyα+OVII Kβ
OVIII Ly(β,γ,δ,ε)
NeIX Kα
NeX Lyα
MgXI Kα
SiXIV Lyα
F_ν [cts cm^-2 s^-1 keV^-1]
Δχ^2
ObsID 0790380501
Energy [keV]

Multi-temperature hot CGM



Das, Mathur+2019b

These observations provide new insights on the chemical enrichment and thermal history of the circumgalactic medium.

Future directions

- Ubiquity of: -multi-temperature structure
  -non-solar abundance ratios
- Most comprehensive phenomenological picture of the MW CGM
- Accurate determination of baryonic mass and metal content

- What are the fundamental galaxy properties that govern the CGM properties?

  -halo mass, SFR, sSFR

- External galaxies: -emission

  -absorption

- Theoretical models

…. *Stay tuned*!

Thank You XMM Team!