Gas around galaxies at z>2: linking emission & absorption with large surveys

Michele Fumagalli
ICC,CEA – Durham University
Universita' degli Studi di Milano-Bicocca

Durham University

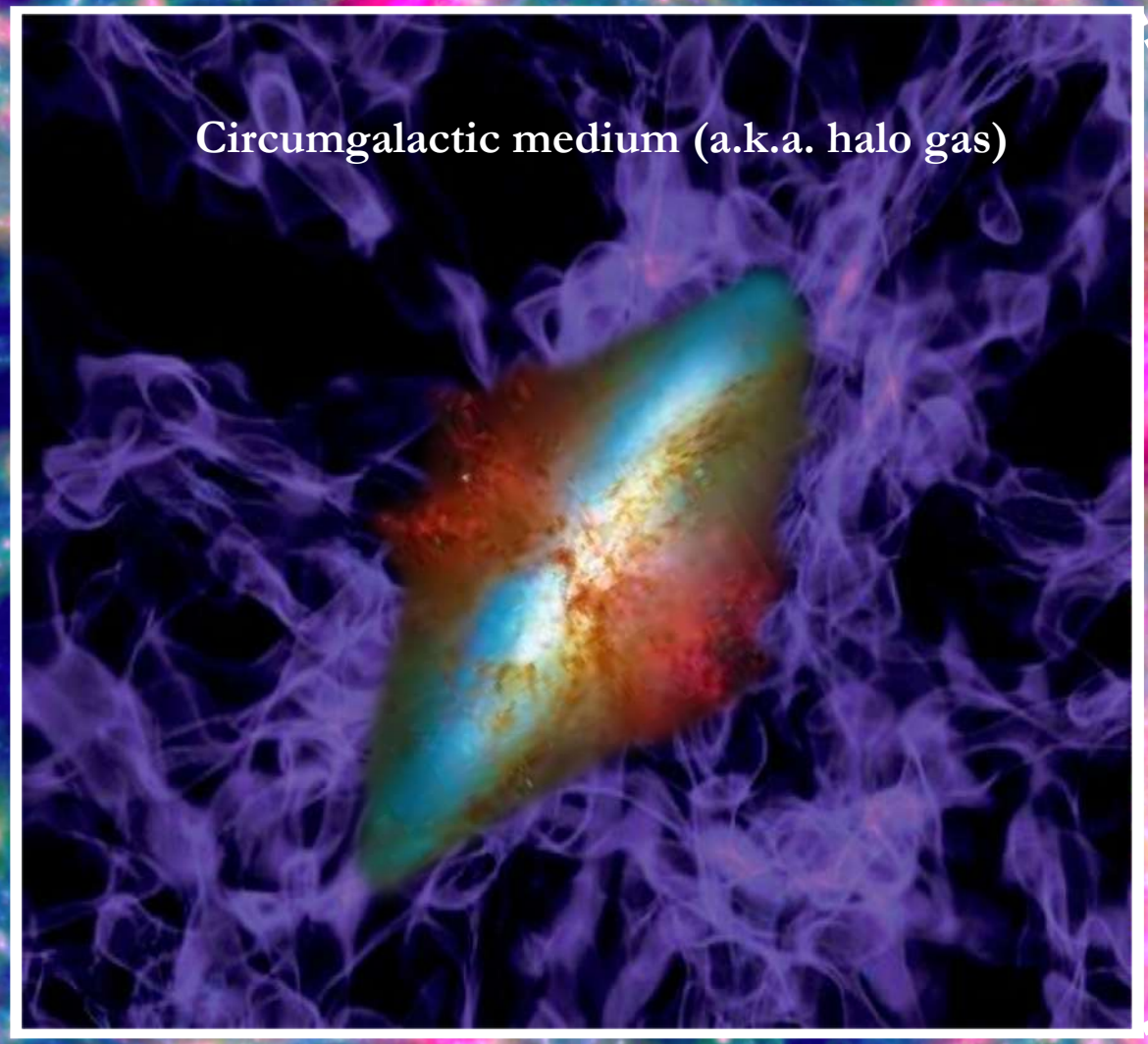
Durham Centre for Extragalactic Astronomy

ICC Institute for Computational Cosmology

Universita' degli Studi di Milano Bicocca

European Research Council
Established by the European Commission

Question 2: How are galaxies, gas flows, and the CGM related?

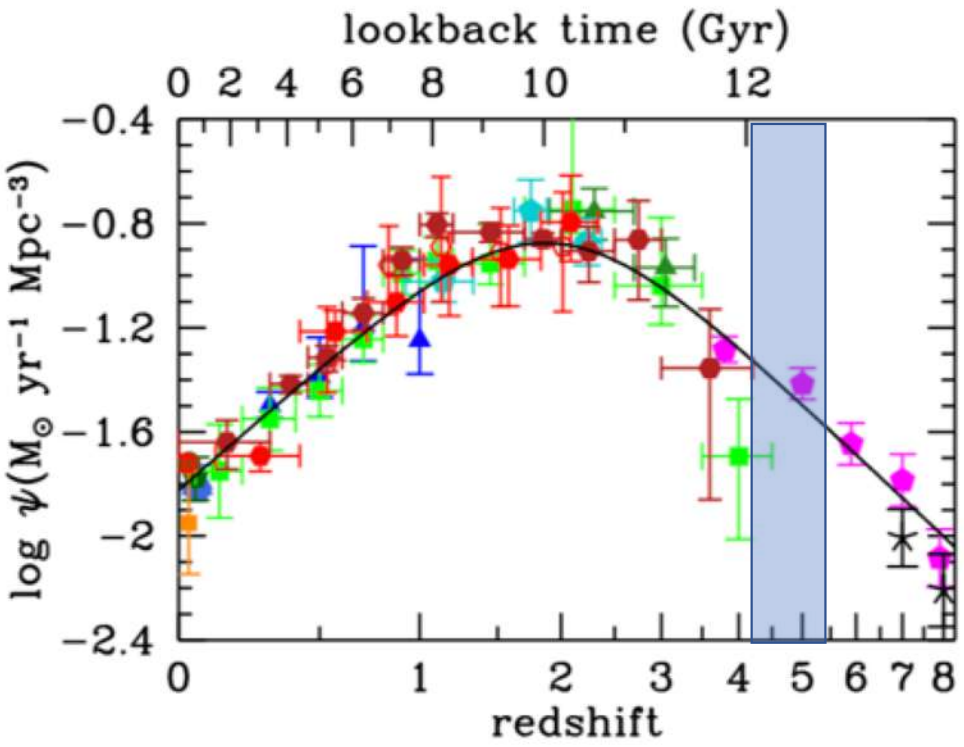


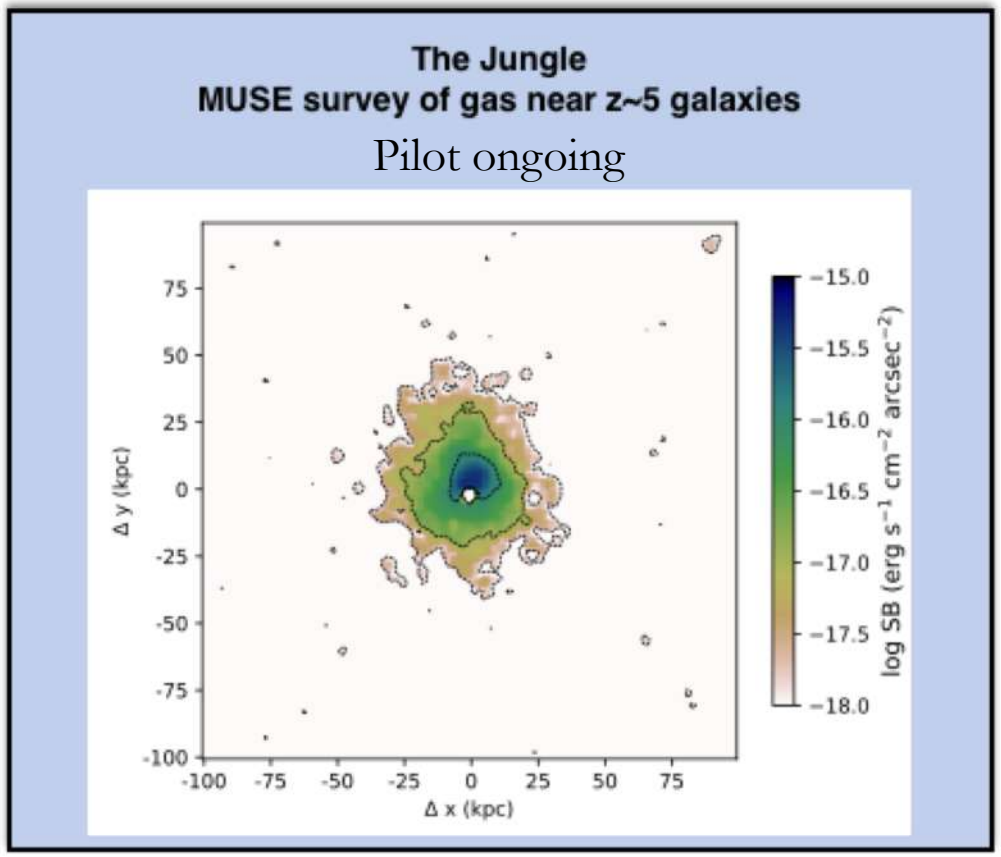
Intergalactic Medium

EAGLE simulation; Schaye et al. 2015

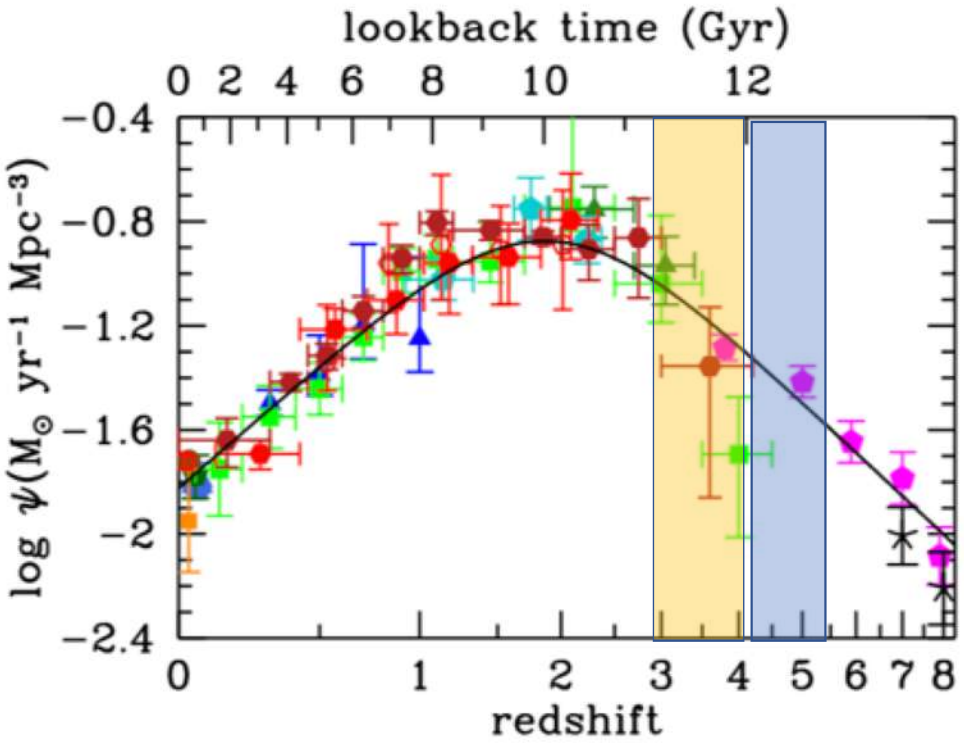
THE EAGLE PROJECT

The tools: large surveys at large telescopes





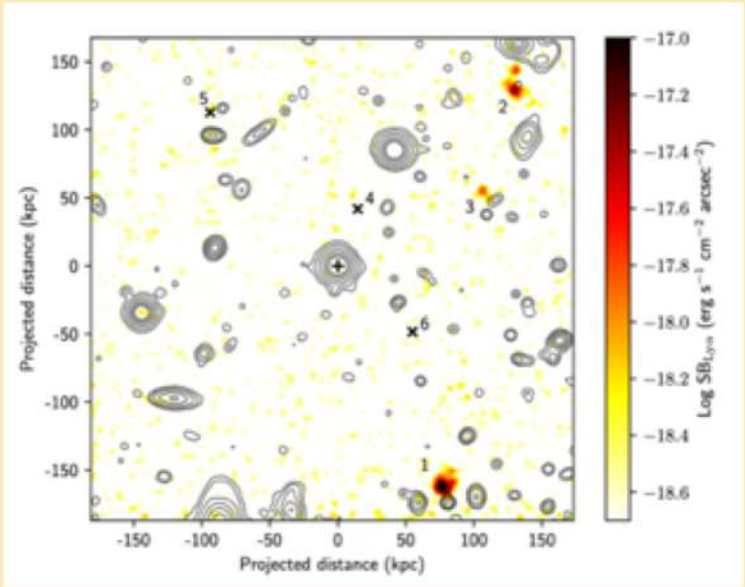
The tools: large surveys at large telescopes



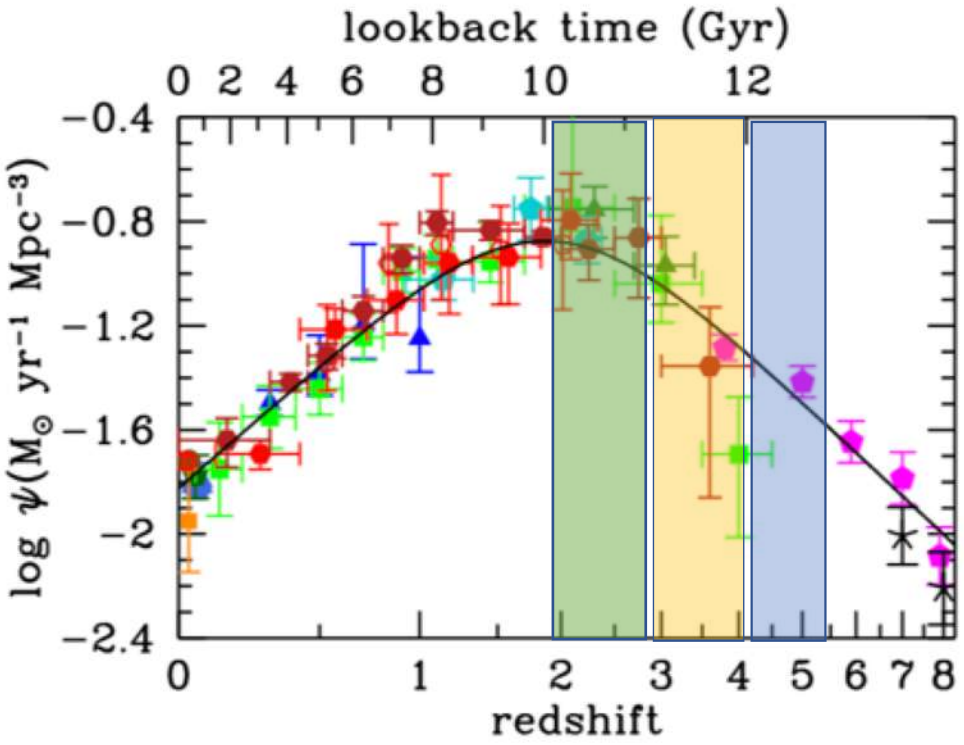
The Jungle
MUSE survey of gas near z~5 galaxies

MAGG
MUSE Analysis of Gas around Galaxies

106 h MUSE Large Programme



The tools: large surveys at large telescopes



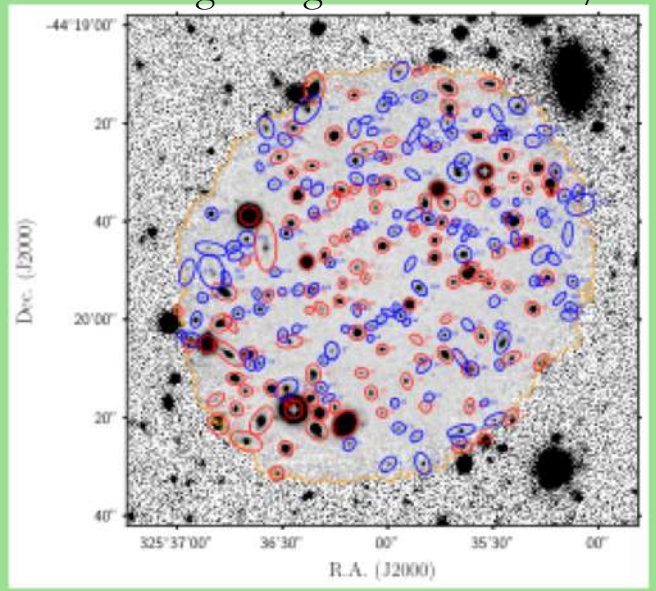
See also QSAGE, 96 orbits with HST to target z~1.5-2 quasars (Bielby et al. 2019)

The Jungle
MUSE survey of gas near z~5 galaxies

MAGG
MUSE Analysis of Gas around Galaxies

MUDF
The MUSE Ultra Deep Field

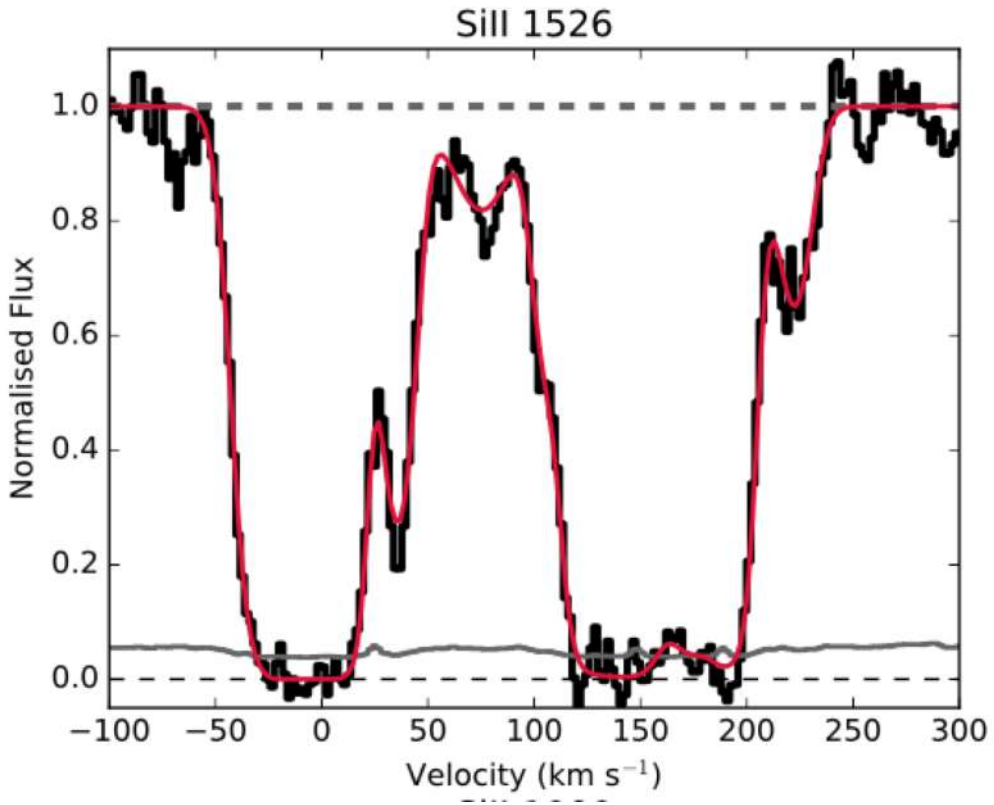
250 hour Large Programme on MUSE +
90 orbits Large Programme on HST/WFC3



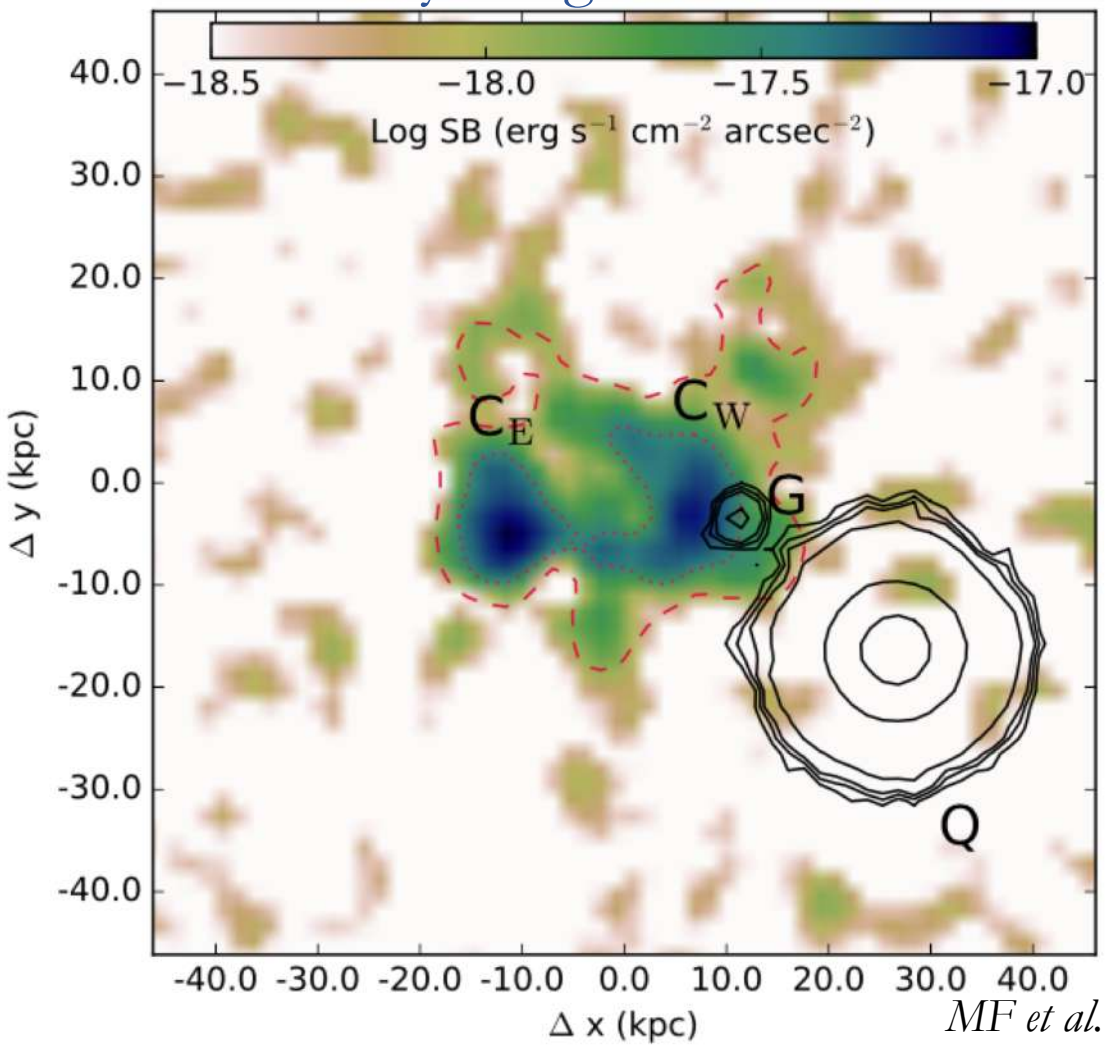
Part I. Inflows and outflows at z~3: the MAGG survey

Searching directly in emission for galaxies associated with LLSs: an example of a **very metal rich system.** Clustering is becoming a relevant feature of this type of studies.

Metal rich system (Z/Zsun) = -1.1 at z ~ 3.25



Galaxy merger with outflows

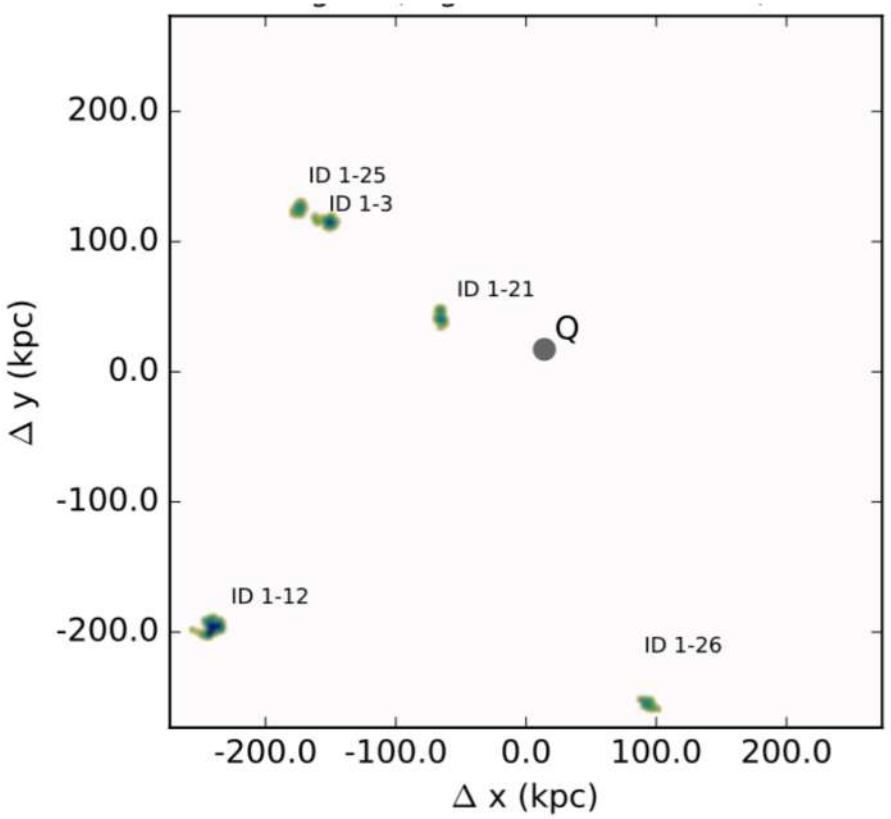


MF et al. 2017b

Part I - Inflows and outflows at z~3: the MAGG survey

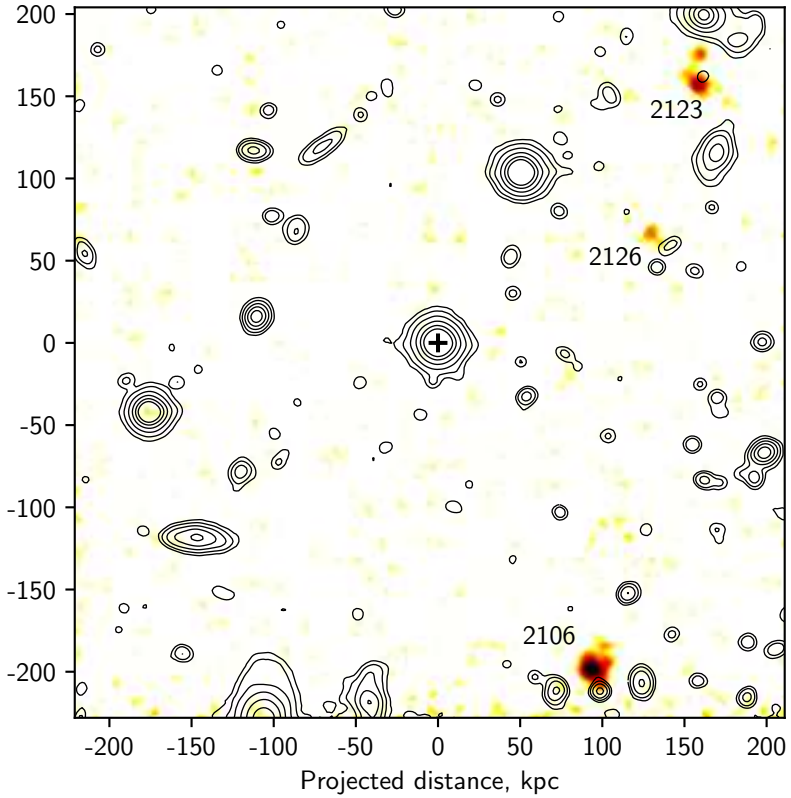
Searching directly in emission for galaxies associated with LLSs: examples of **very metal poor systems.**
Mixing must be inefficient at these redshifts.

Pristine LLS
Log(Z/Zsun) < -3.8



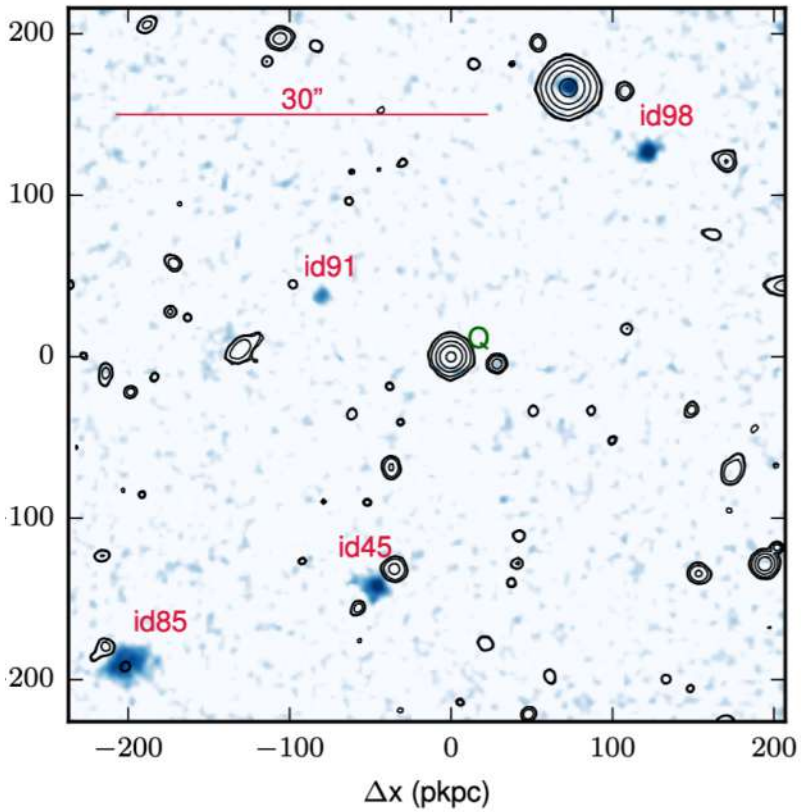
MF et al. 2011; MF et al. 2016b

Candidate PopIII
Log(Z/Zsun) = -3.4



Lofthouse, MF et al. 2019

Metal Poor DLA
Log(Z/Zsun) = -2.3

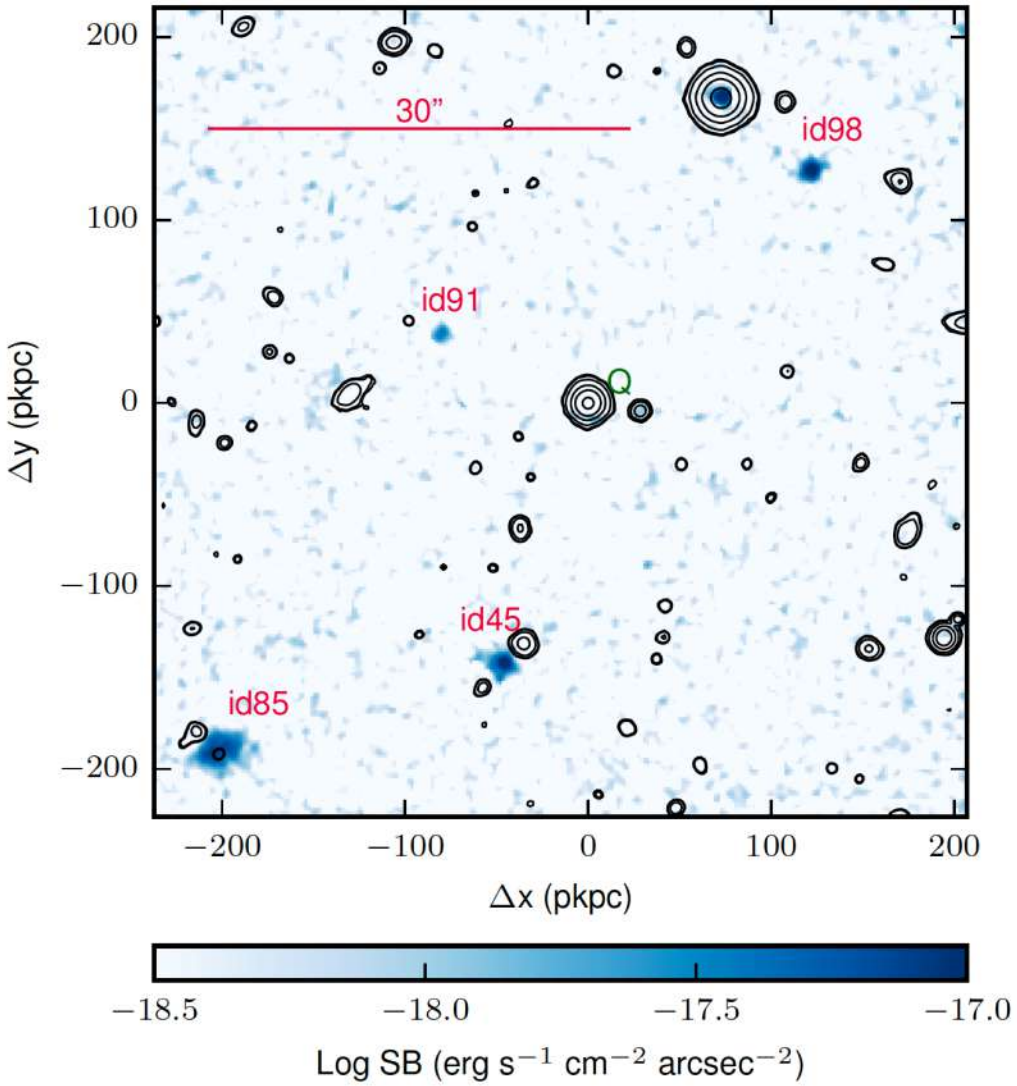


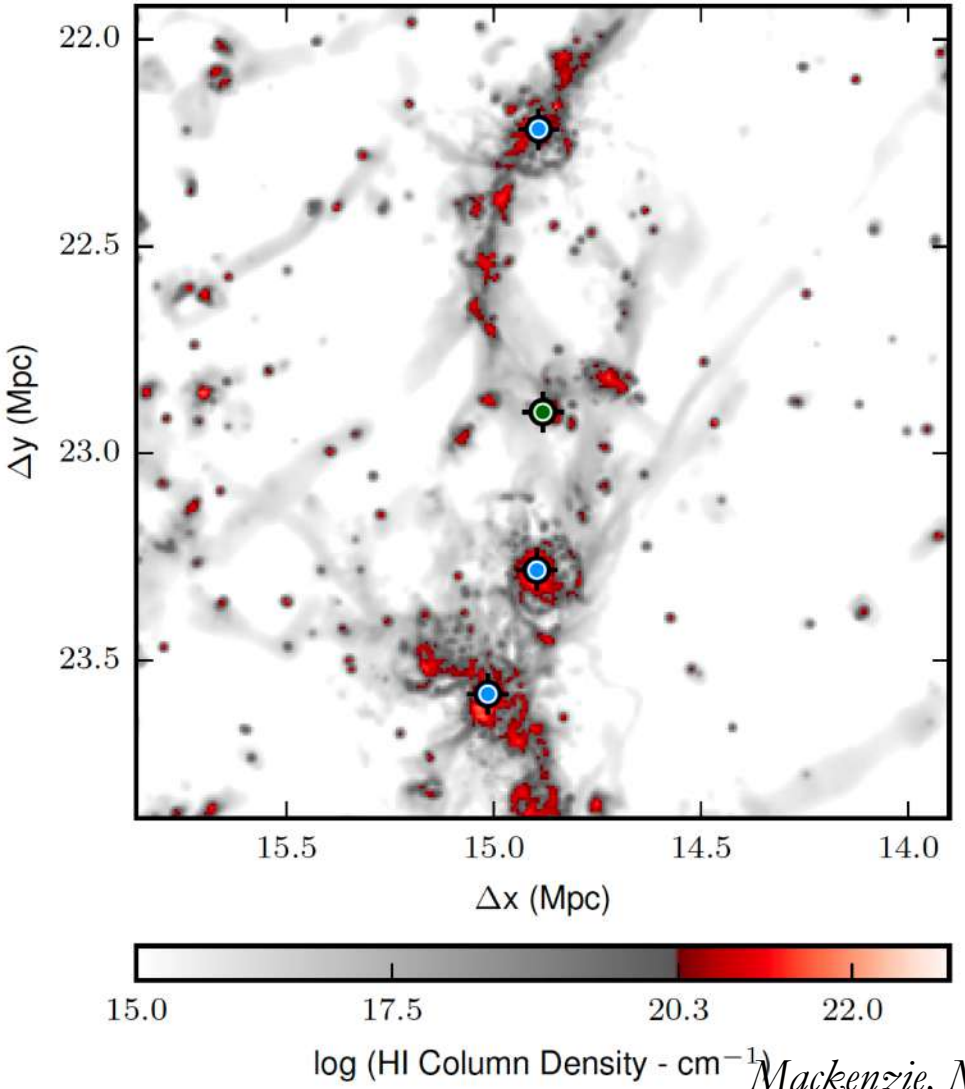
Mackenzie, MF et al. 2019

Ubiquitous detection of multiple galaxies (possibly aligned in filaments) in the environment of metal-poor gas

Part I - Inflows and outflows at z~3: the MAGG survey

With "samples", we can start learning about the **parent halos of strong absorbers** (e.g. DLAs)

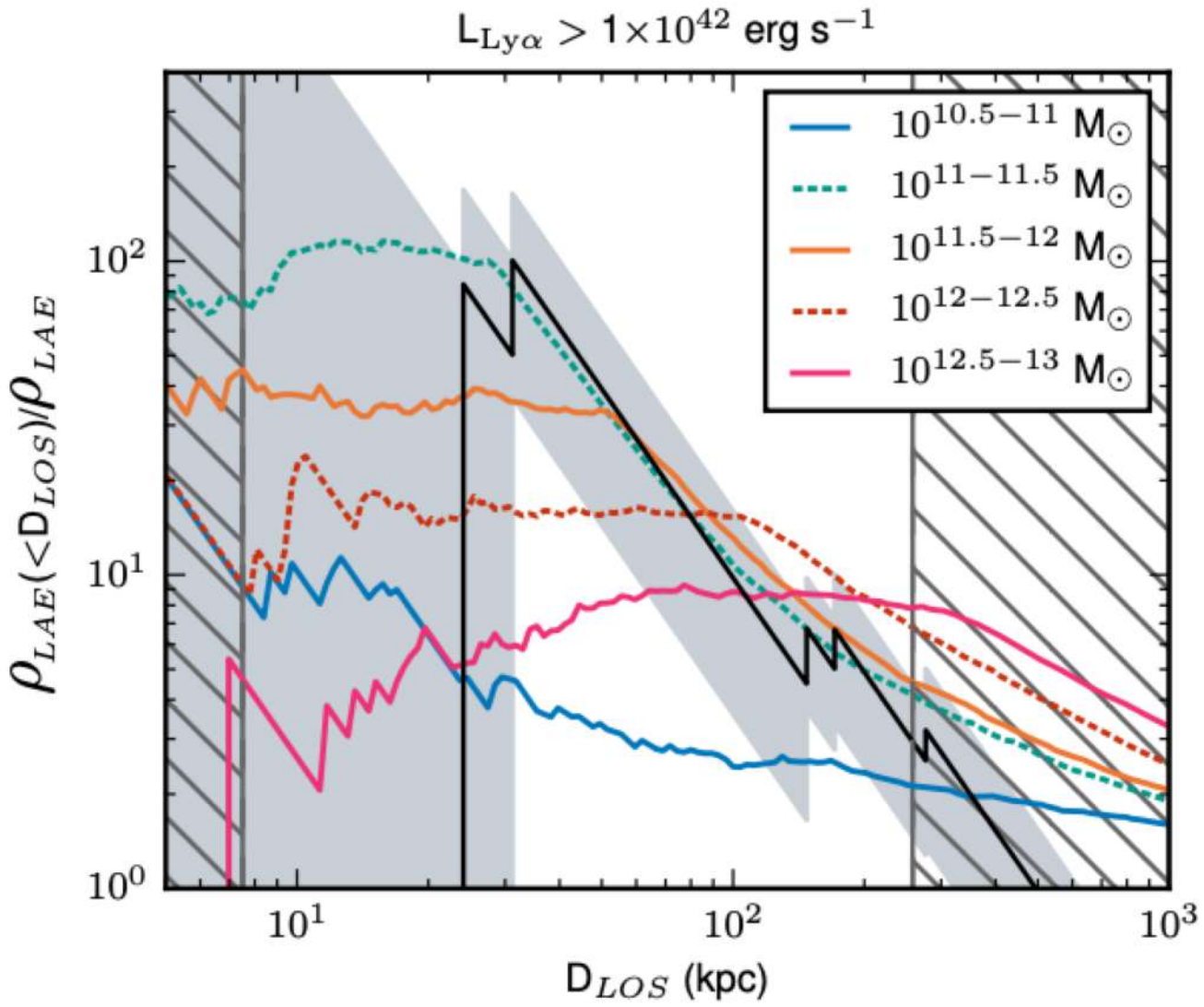




Mackenzie, MF et al. 2019

Part I - Inflows and outflows at z~3: the MAGG survey

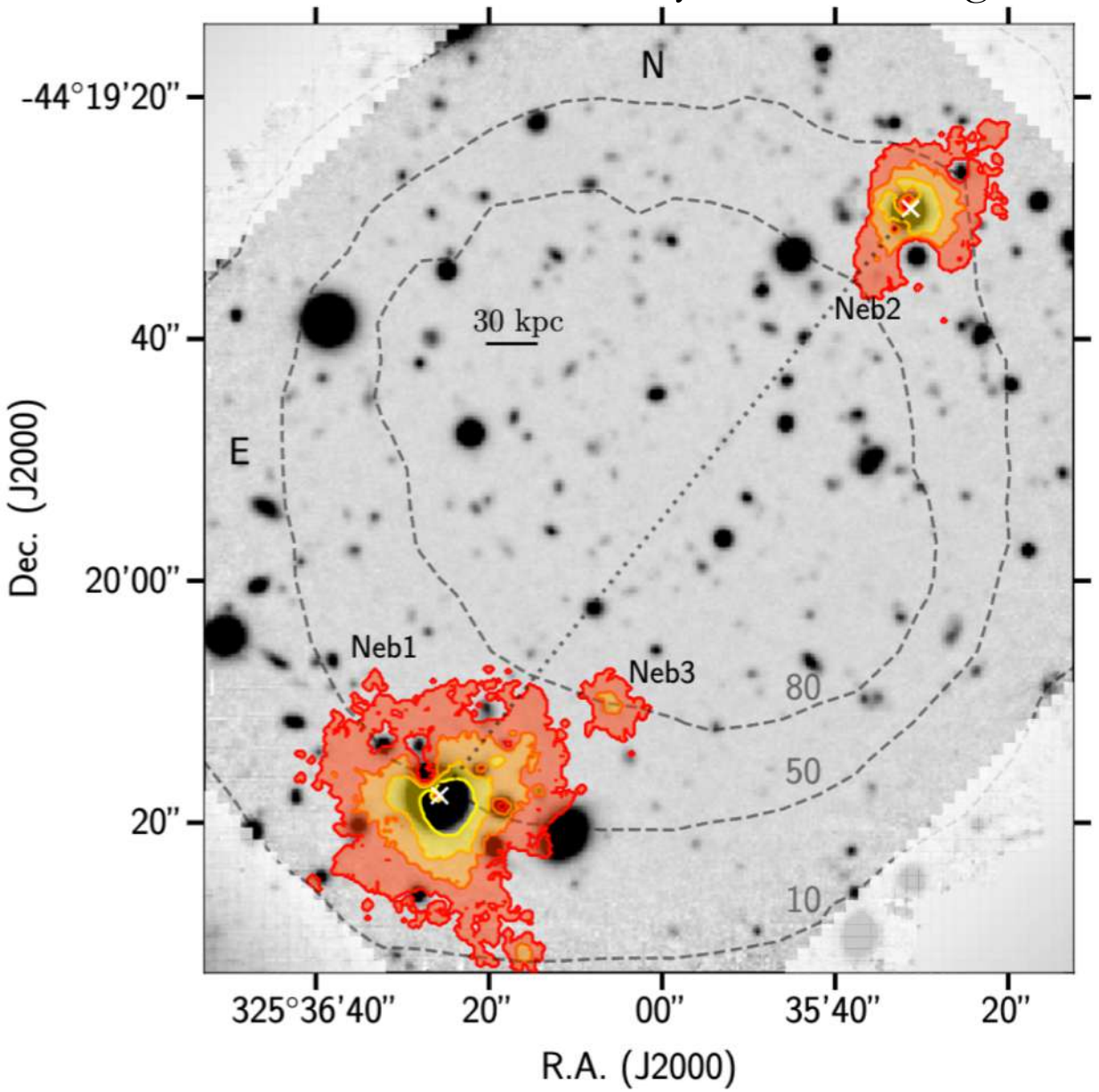
With "samples", we can start learning about the **parent halos of strong absorbers** (e.g. DLAs)

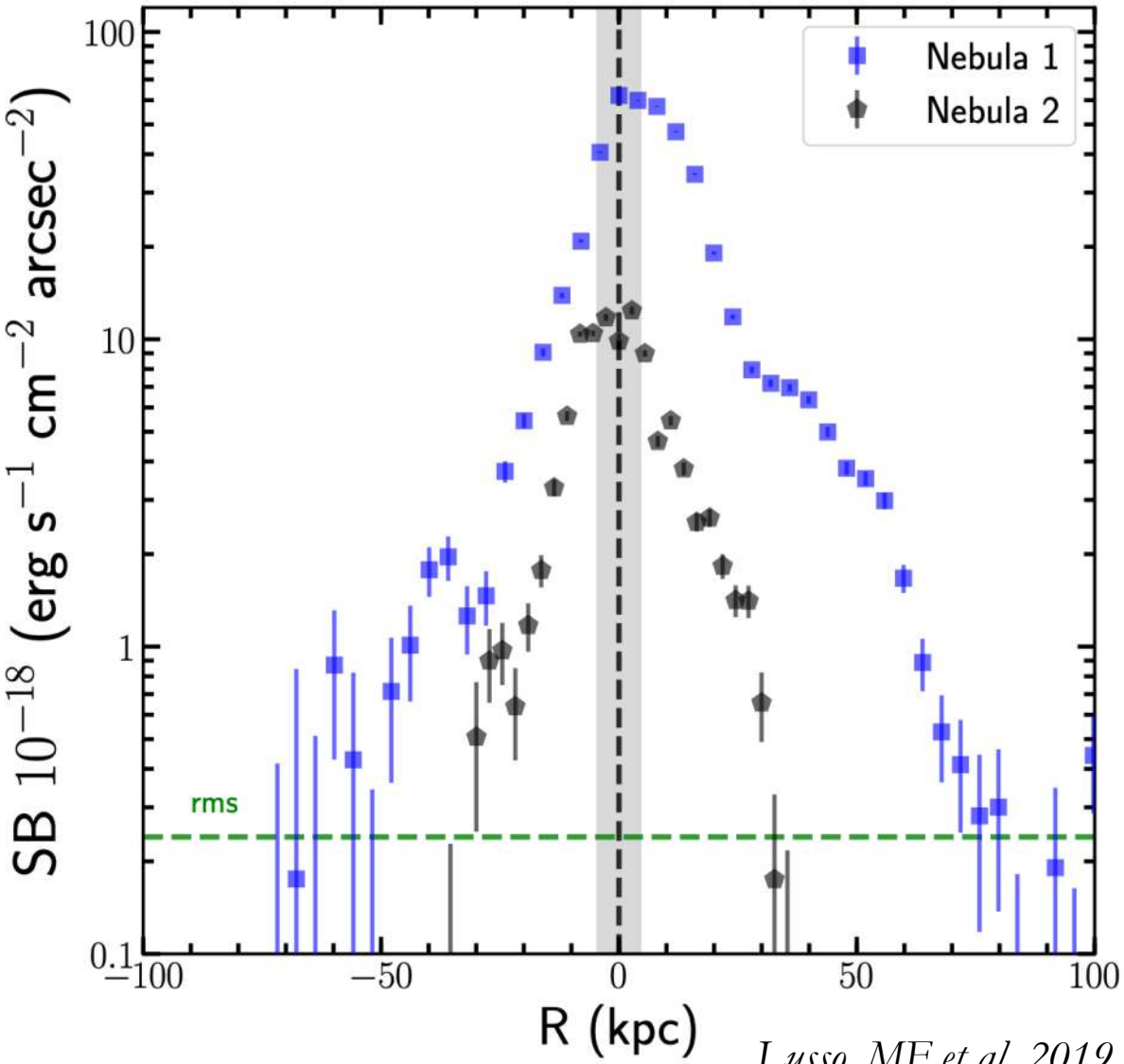


Mackenzie, MF et al. 2019

Part II – Probing the CGM in emission at z~3: the MUDF survey

We can extend this study to low-mass galaxies and we can start probing the CGM in emission

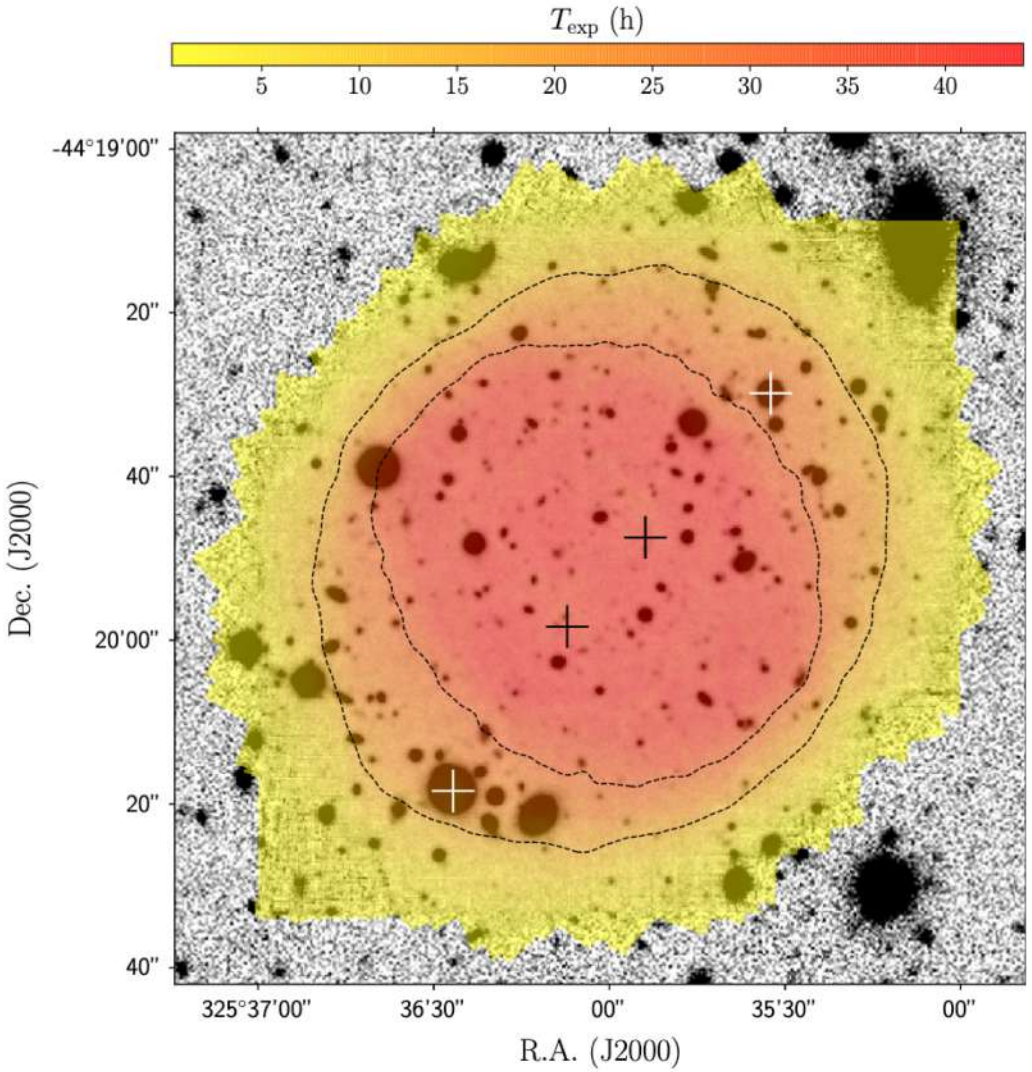


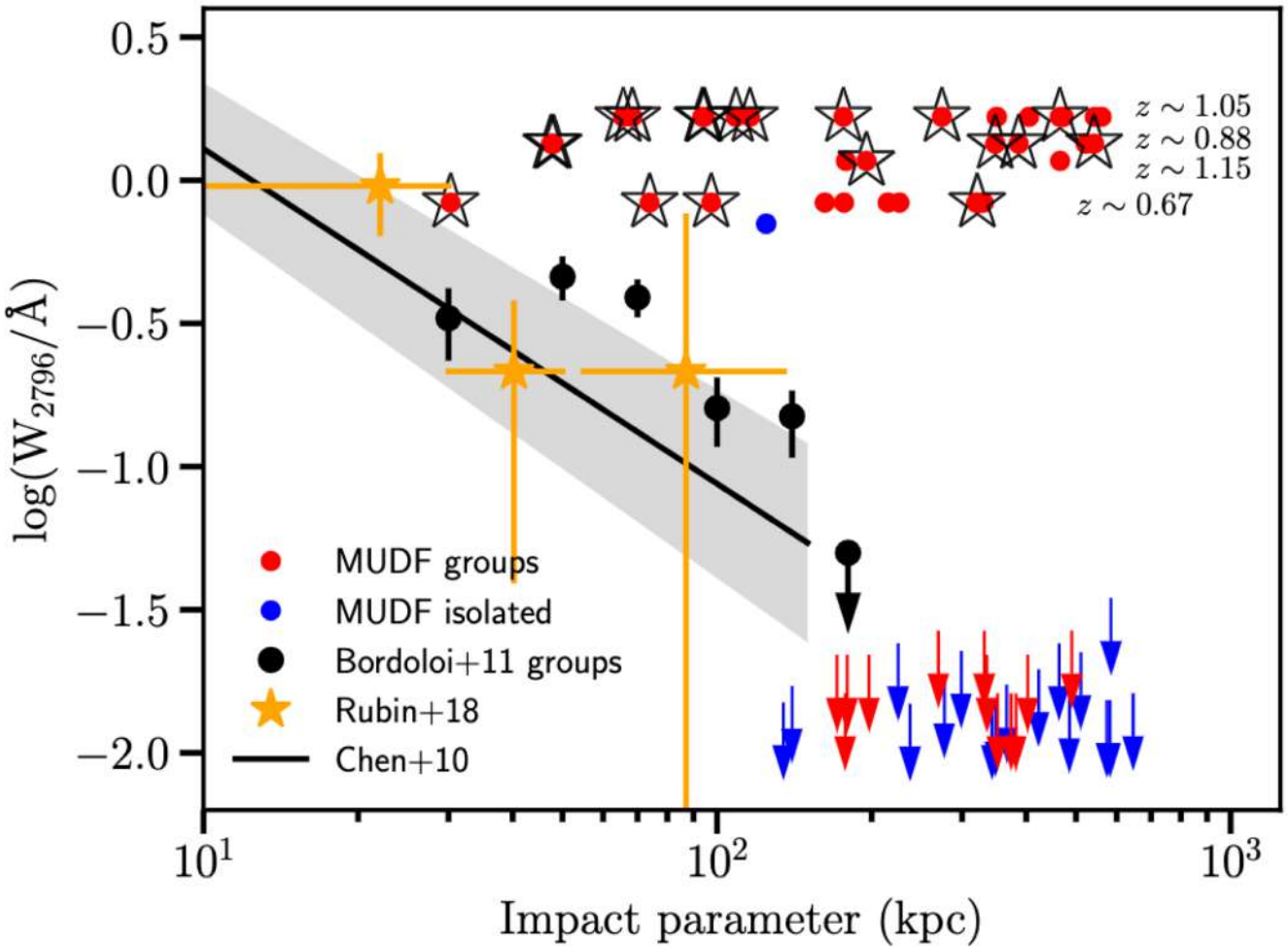


Lusso, MF et al. 2019

Part II – Probing the CGM in groups at z~1: the MUDF survey

Environmental processes boost the cross section of MgII in individual galaxies at z~0.5-1.0

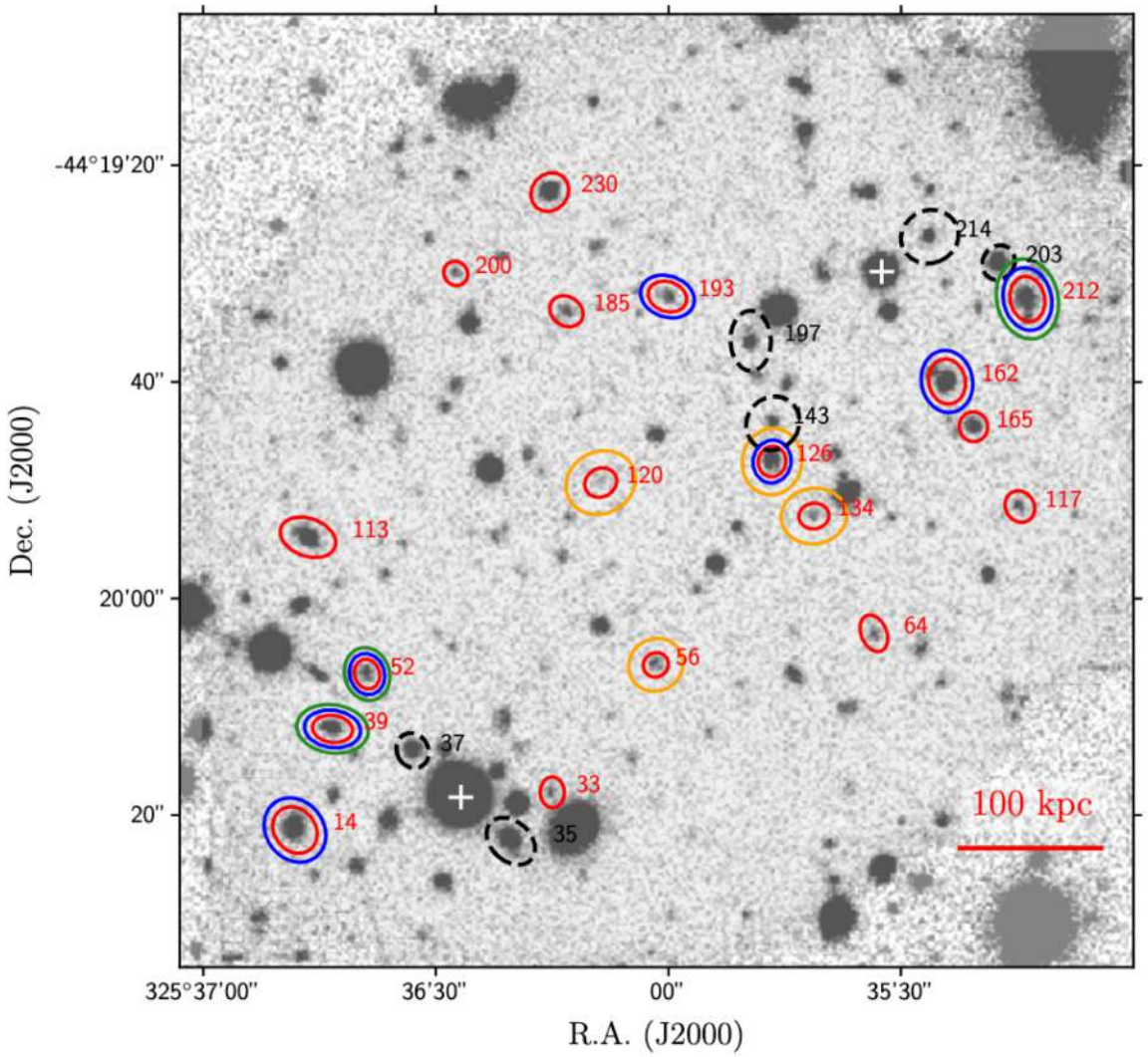


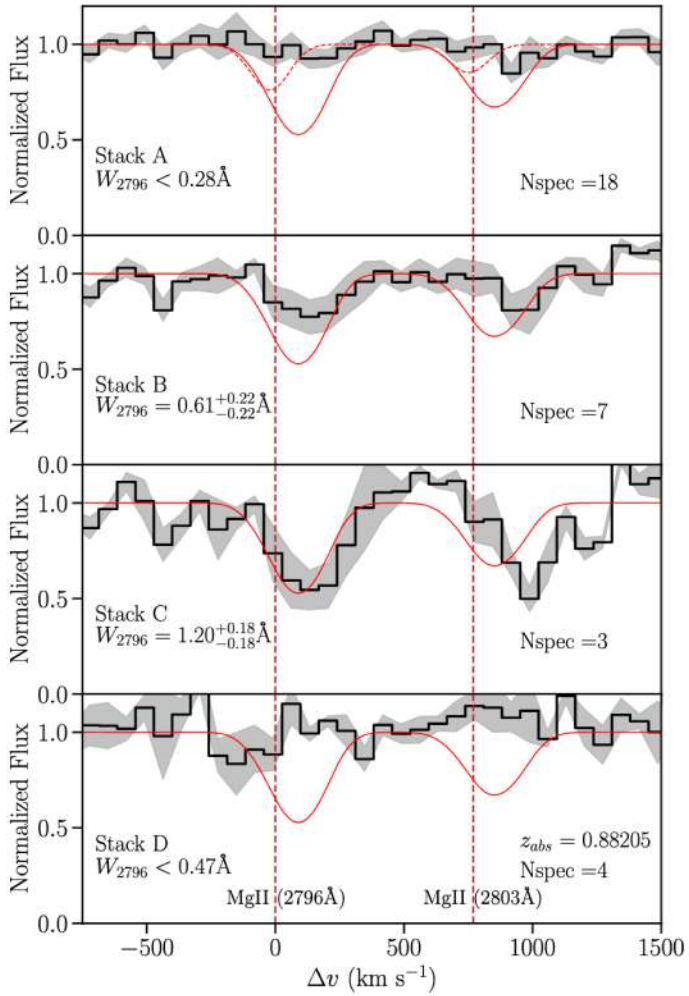


Fossati, MF et al. 2019

Part II – Probing the CGM in groups at z~1: the MUDF survey

Environmental processes boost the cross section of MgII in individual galaxies at z~0.5-1.0

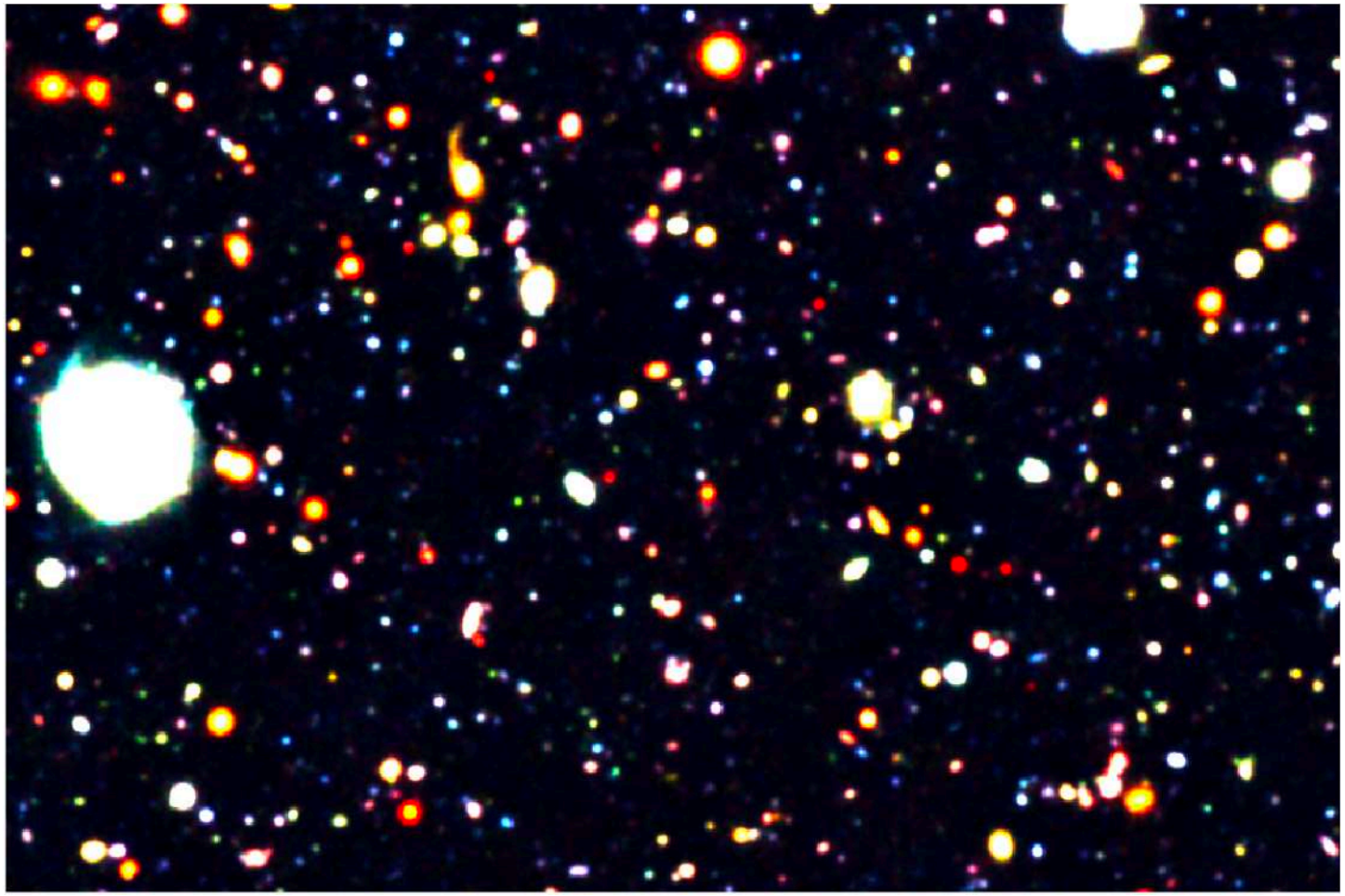




Fossati, MF et al. 2019

Bonus – Imaging filamentary structures in a z~3 protocluster

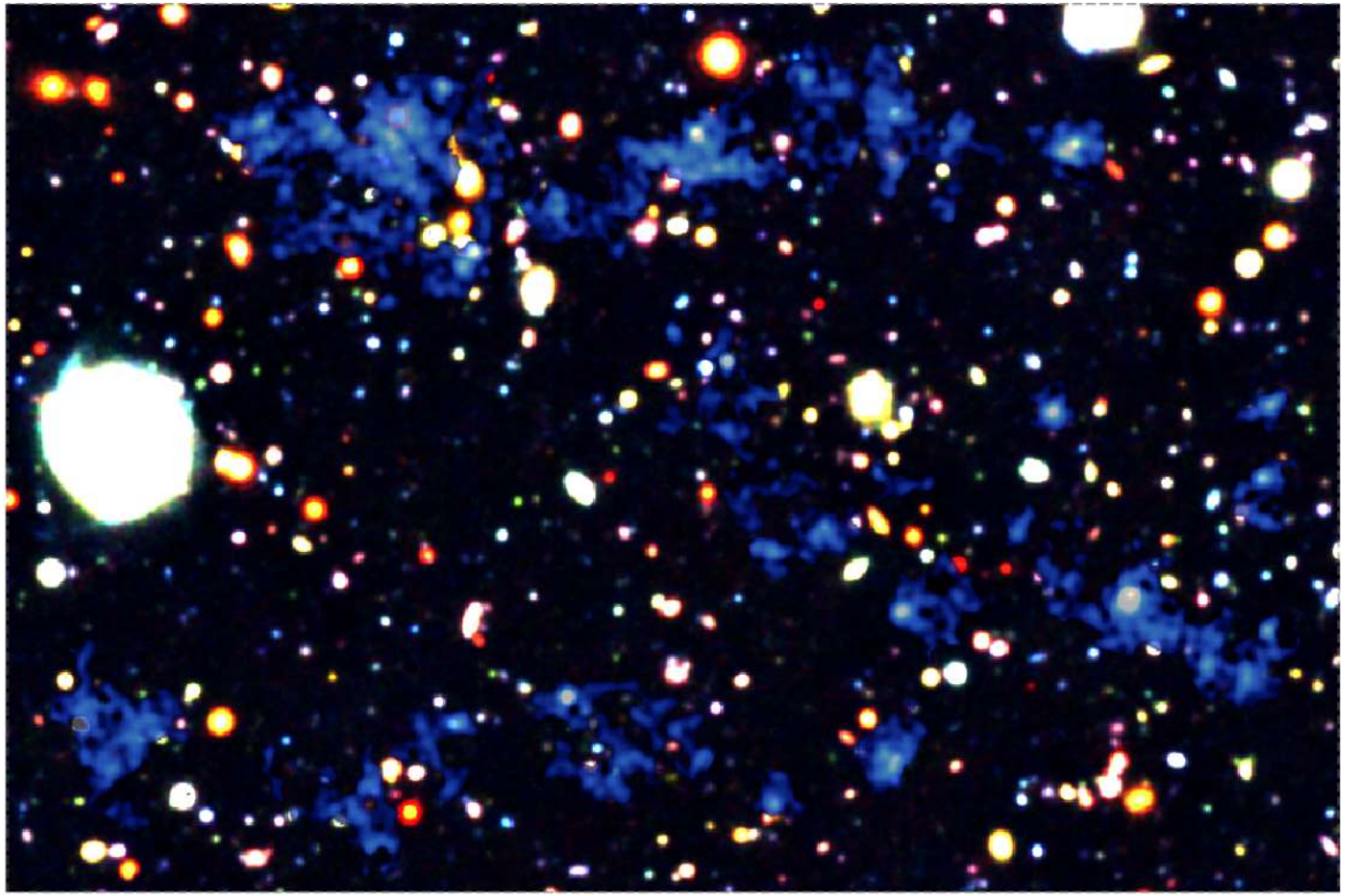
MUSE images filaments on Mpc scales in SSA22



Umehata, MF et al. 2019, Science

Bonus – Imaging filamentary structures in z~3 protocluster

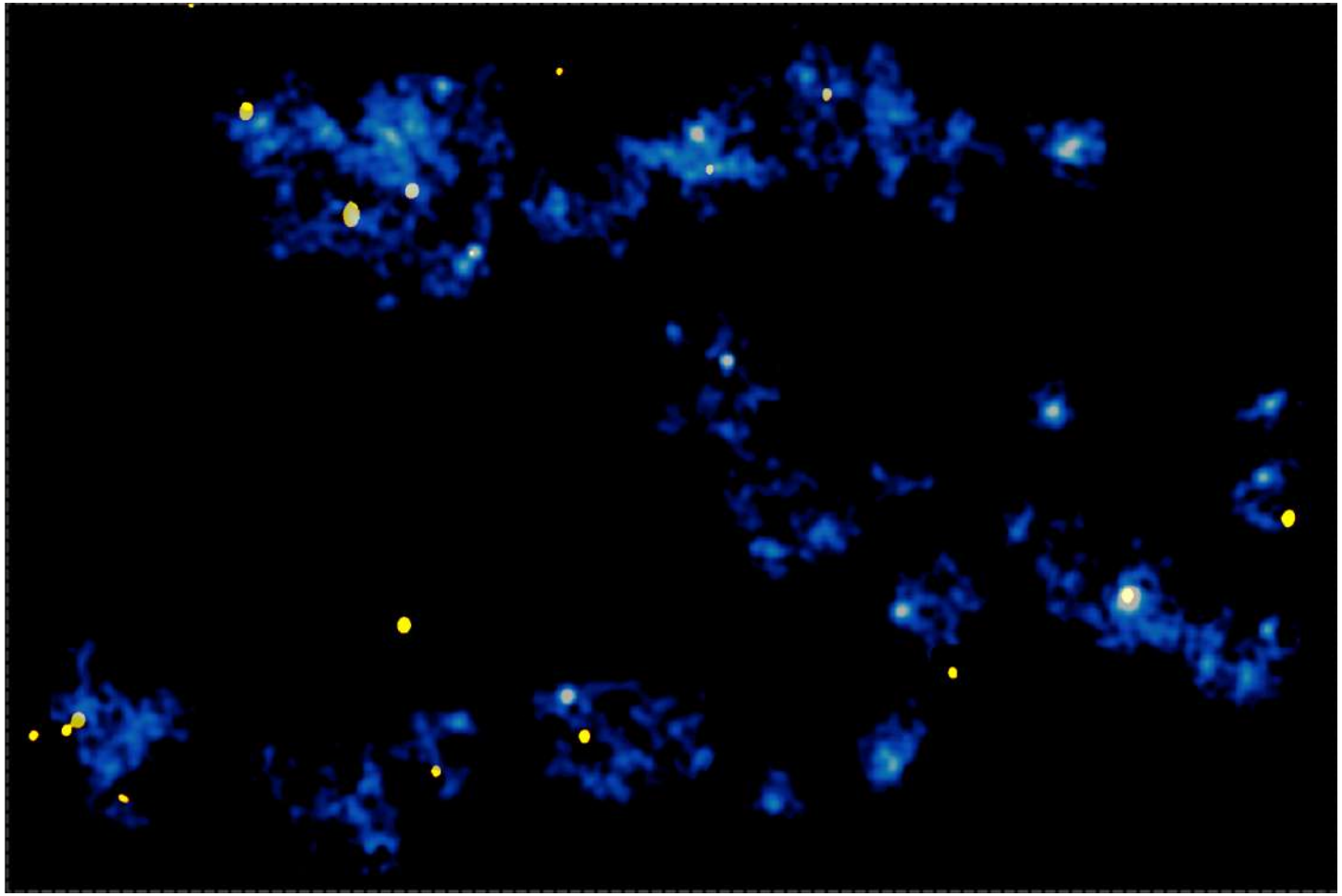
MUSE images filaments on Mpc scales in SSA22



Umehata, MF et al. 2019

Bonus – Imaging filamentary structures in z~3 protocluster

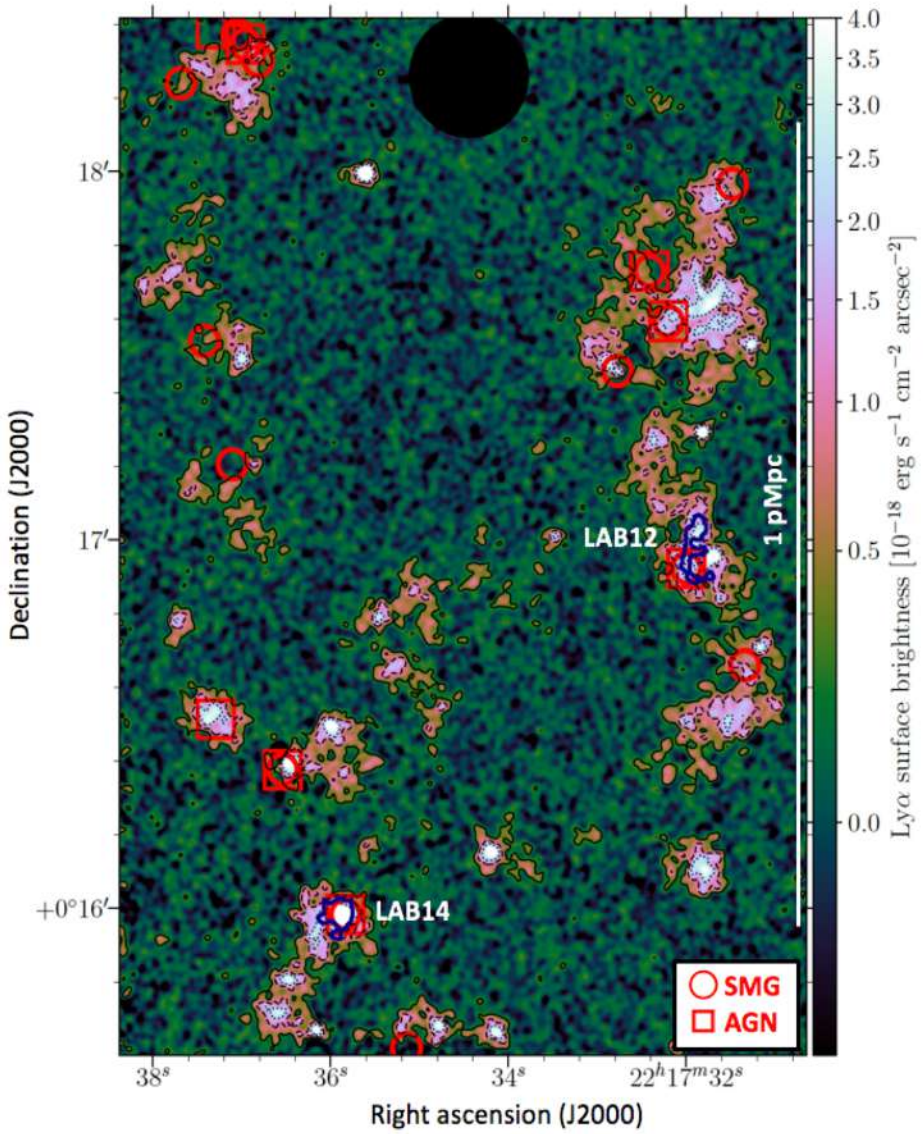
We find clear correlation between filaments and sub-mm/Xray sources

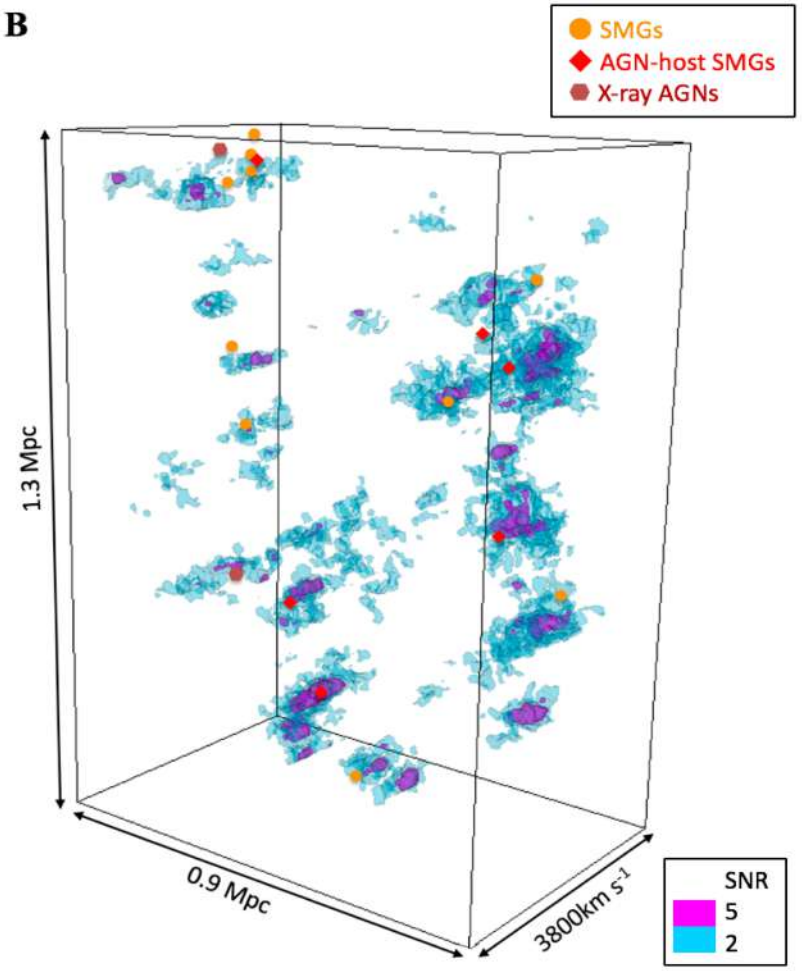


Umehata, MF et al. 2019

Bonus – Imaging filamentary structures in z~3 protocluster

We find clear correlation between filaments and submm/Xray sources

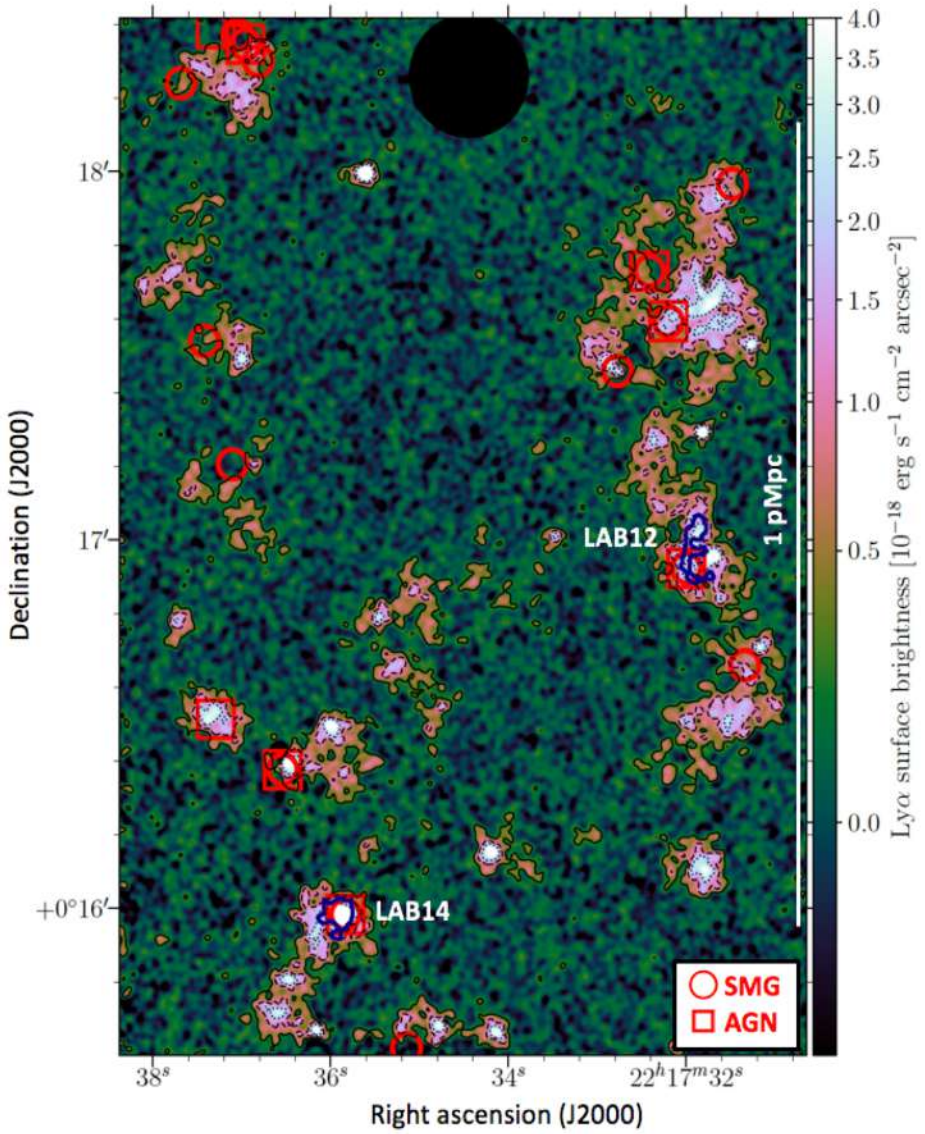


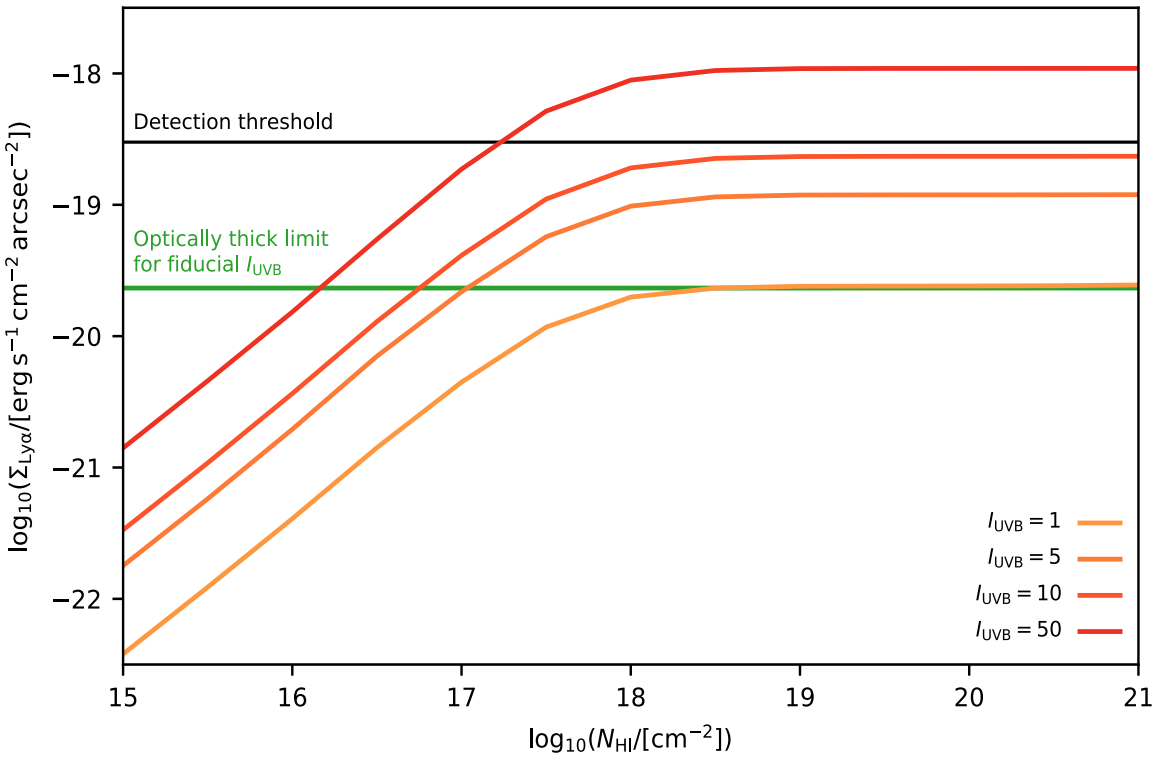


Umehata, MF et al. 2019

Bonus – Imaging filamentary structures in z~3 protocluster

Neat example of enhanced local radiation field





Umehata, MF et al. 2019

Combining CGM in absorption and emission with large surveys at large telescopes

We are learning about:

- Clustering of galaxies with LLSs/DLAs
-
- How metals spread around galaxies

- How CGM/galaxy correlation evolves with redshift and environment

- The spatial distribution of denser CGM both in emission and absorption

- How filaments connect and feed galaxies in proto-clusters