Physical Properties of the Circum-Galactic Medium

Celine Peroux
(Marseille / ESO Garching)

quasar

accretion

winds

Circum-
Galactic
Medium

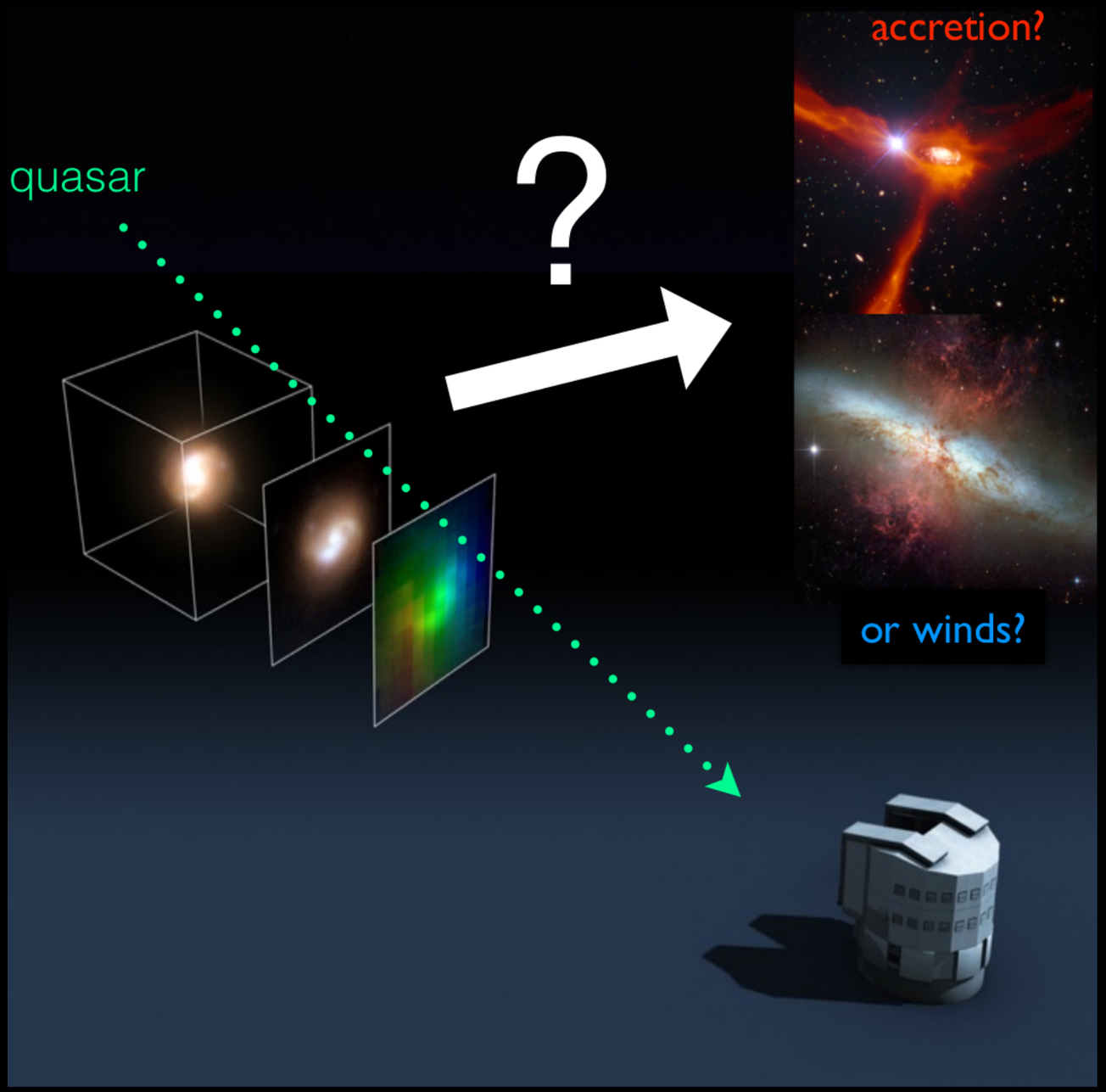
Questions to Address

1- Is the CGM multi-phase?

2- On which scales are metals mixed in the CGM?

3- Can we detect CGM emission at z<1?

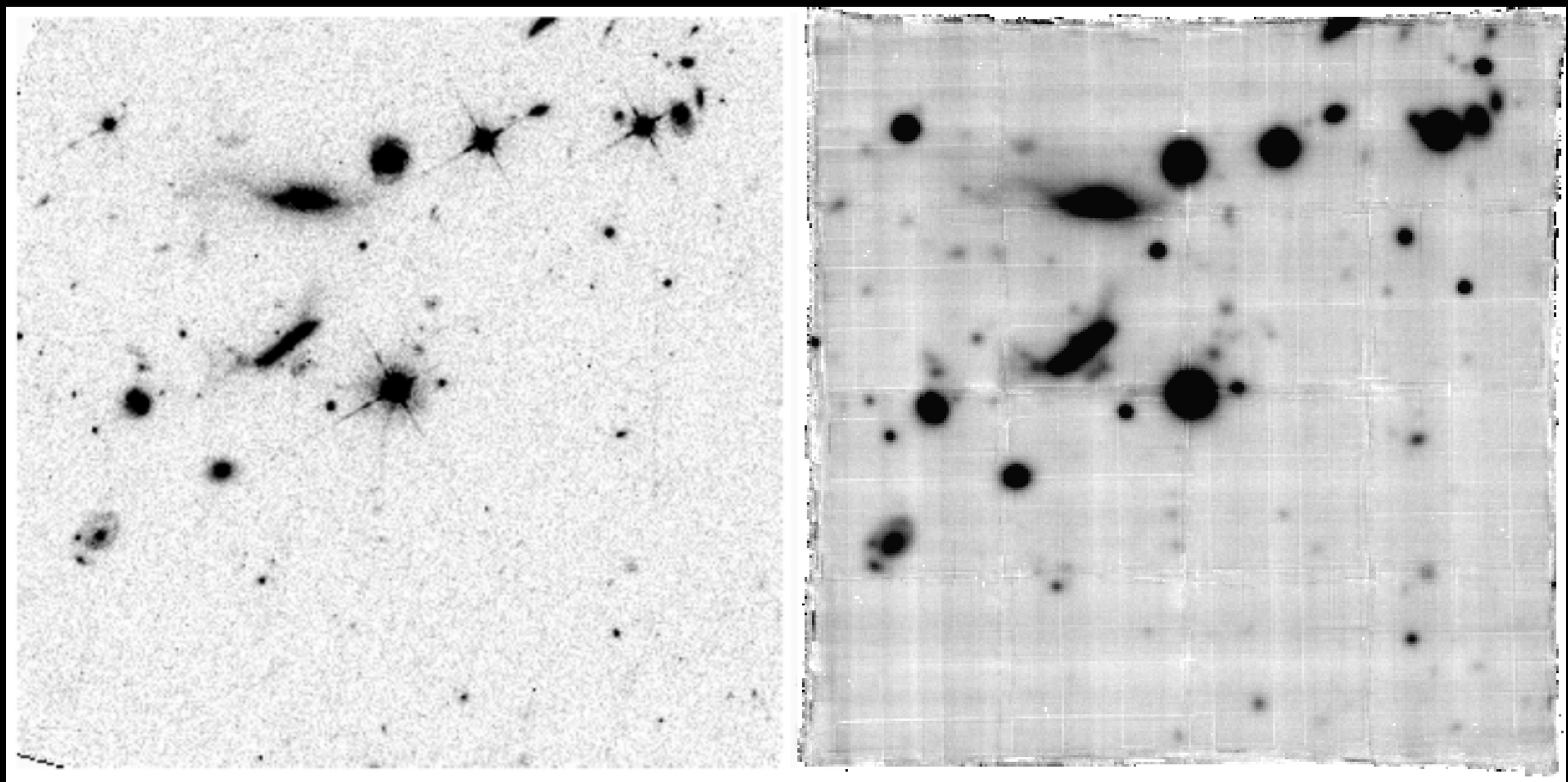
3D spectroscopy:
a powerful tool to connect gas & stars



Multi-Phase CGM

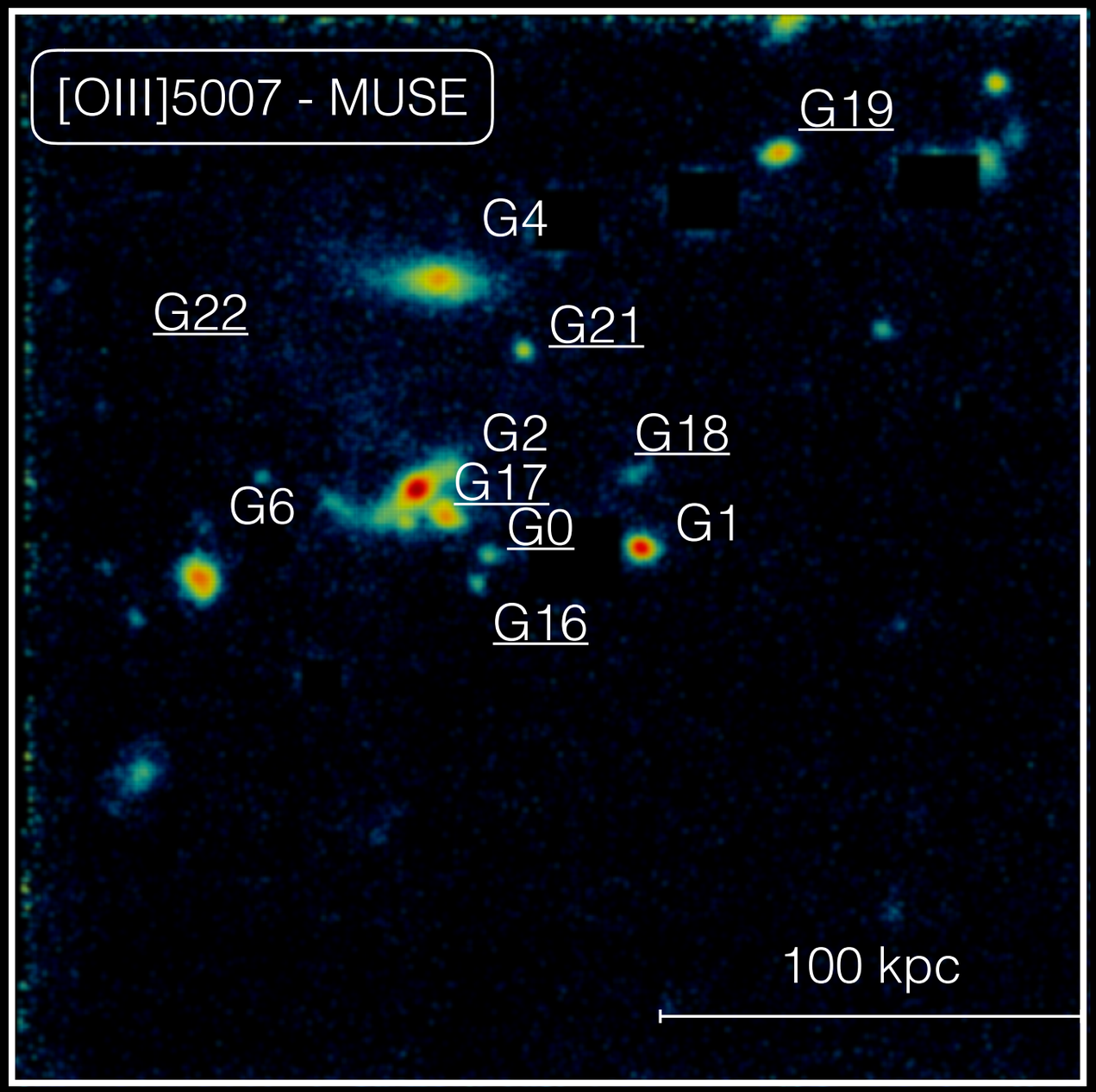
HST

MUSE

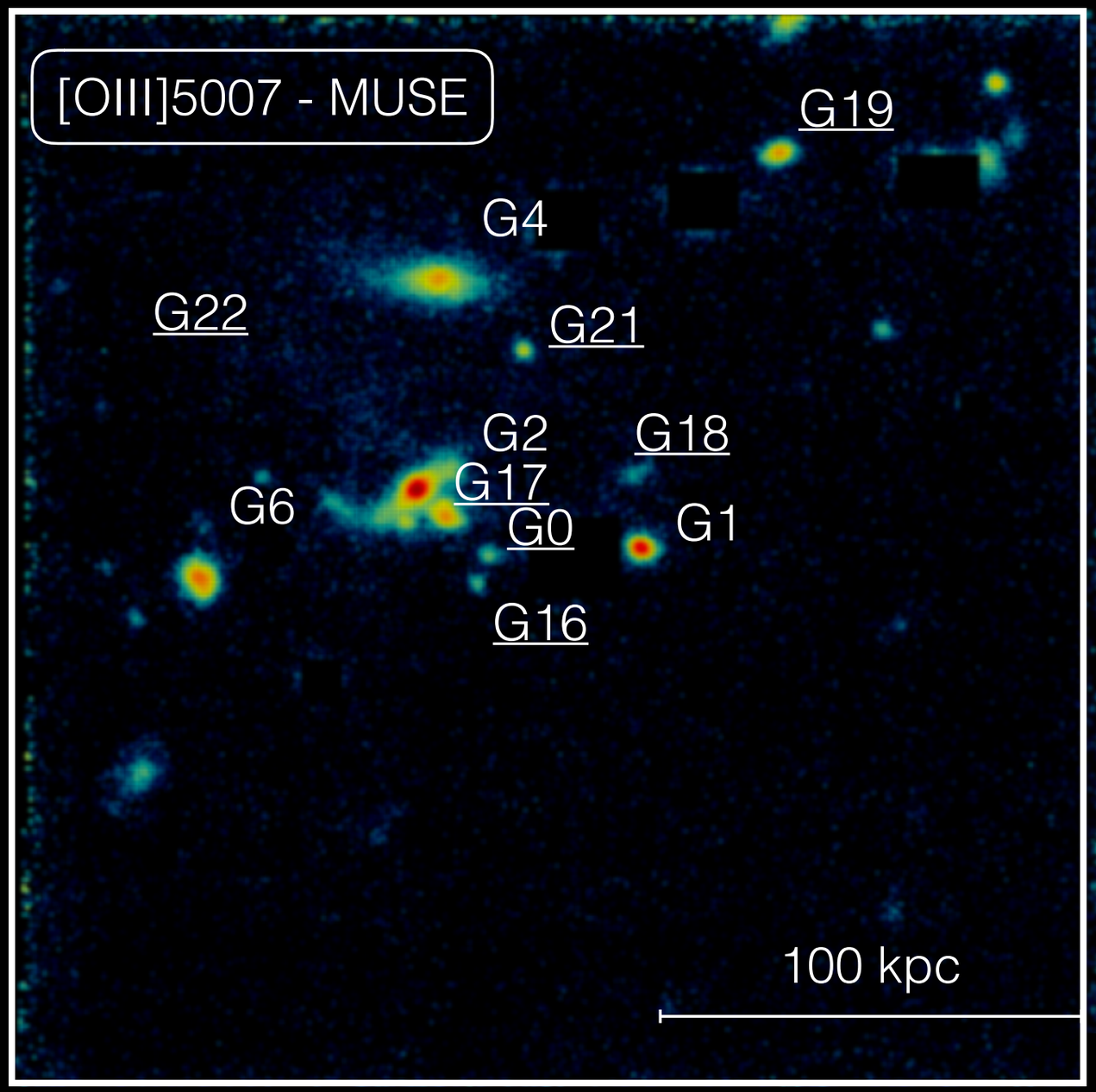


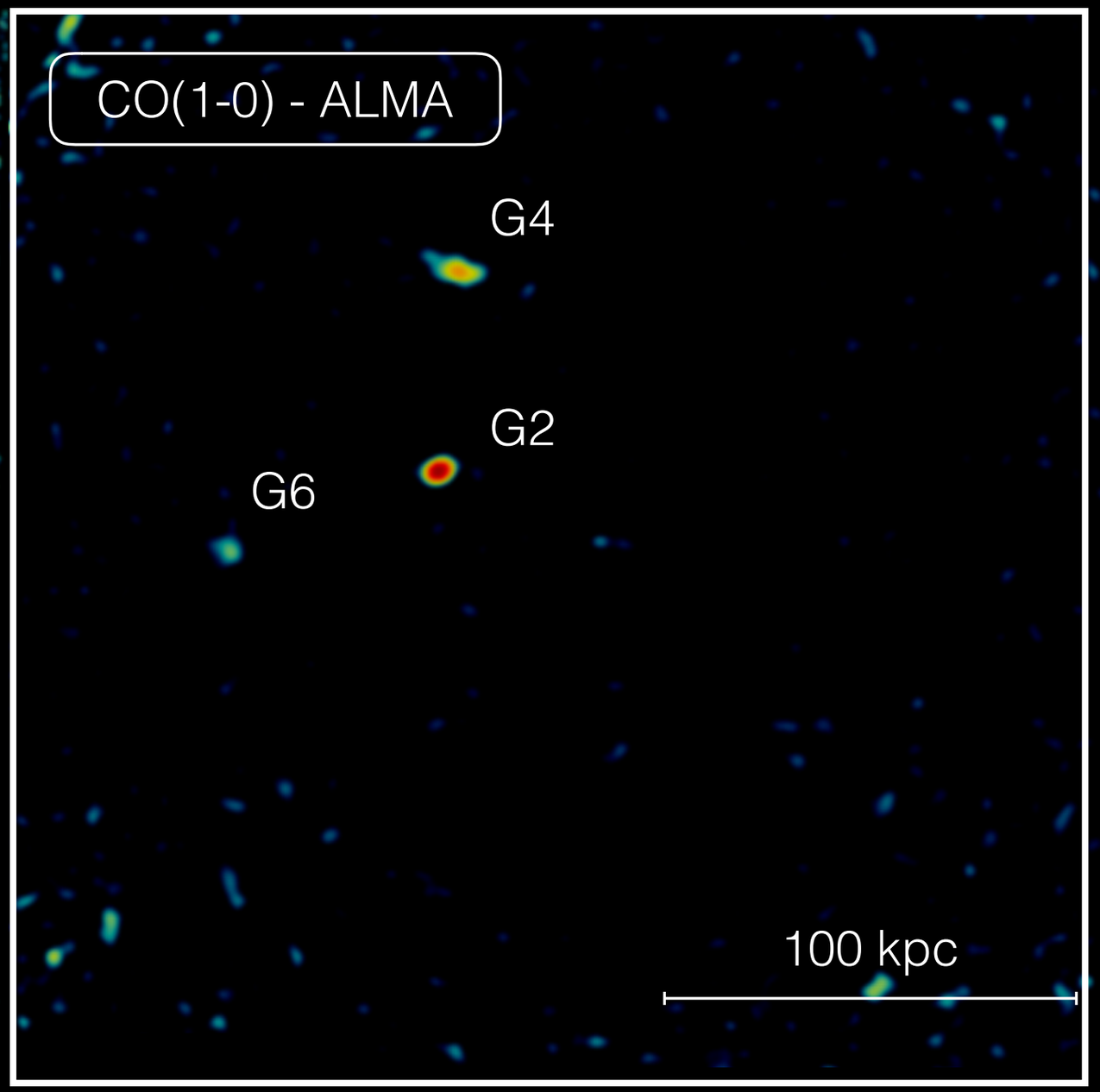
$z=0.3$, $\log N(HI)=21.7$, $Z_{neutral\_gas}=16\%Z_{\odot}$

Absorber related to Small Group

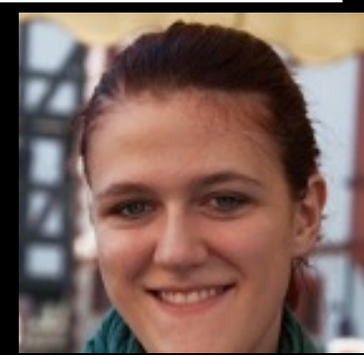


Large Molecular Gas Reservoirs

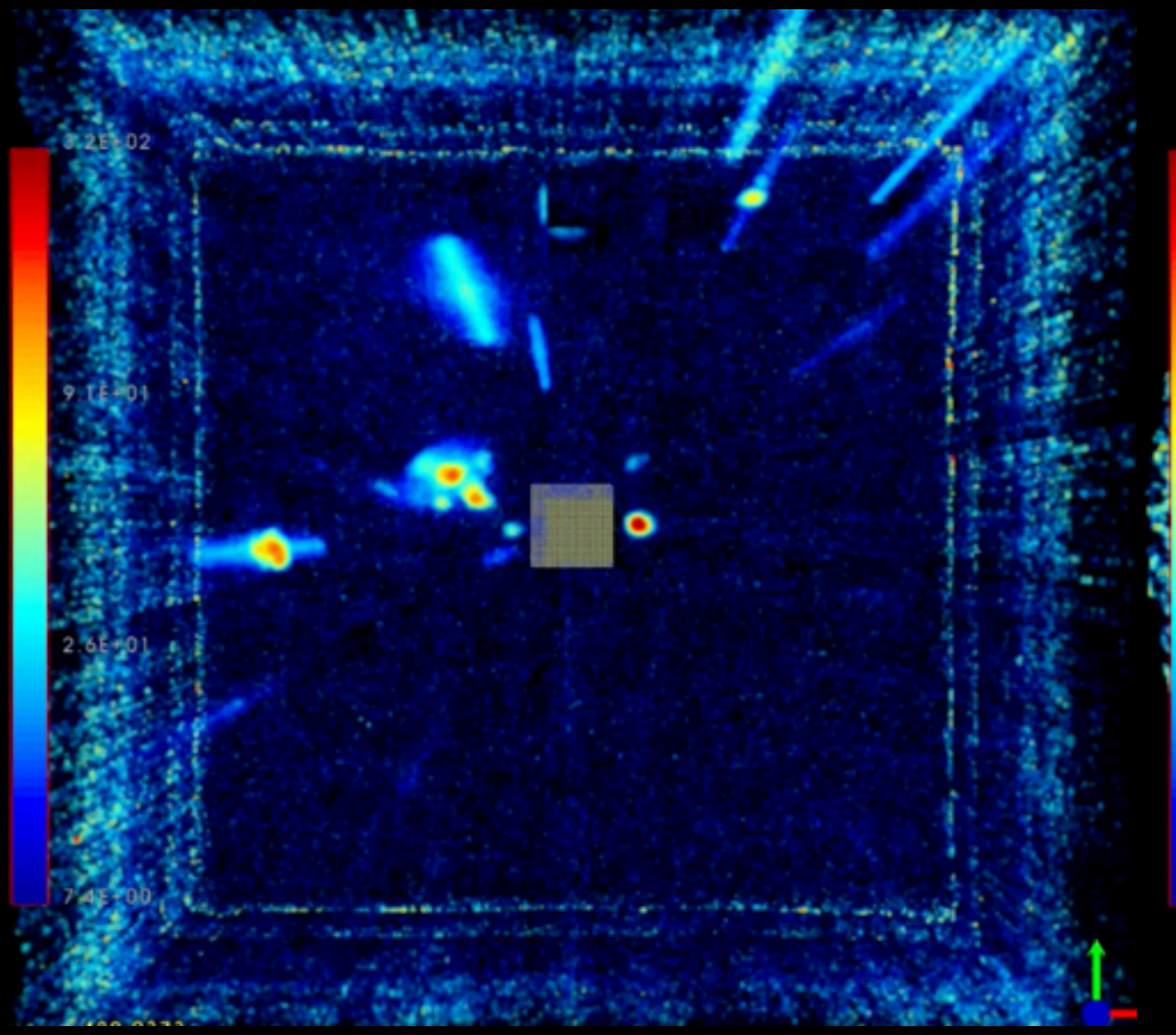




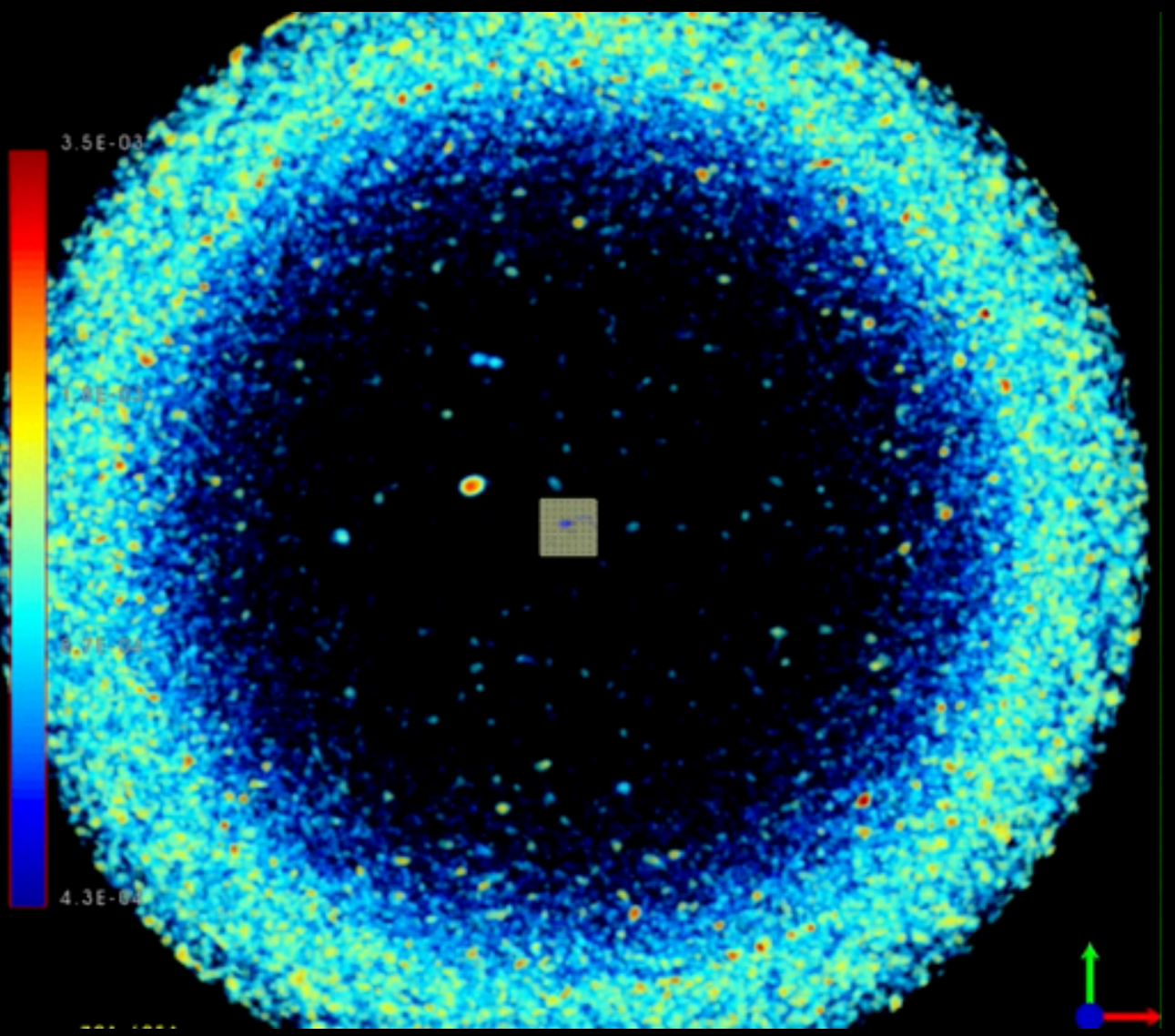
also Anne Klitsch+18



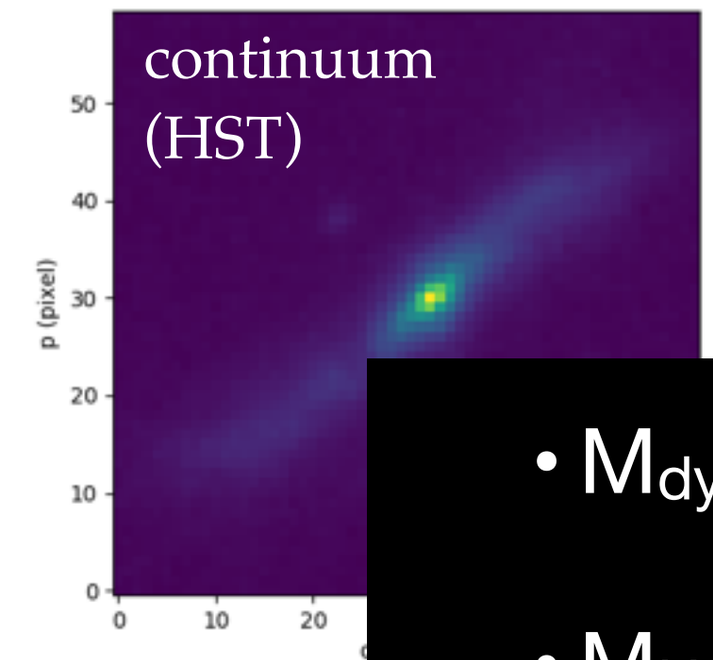
Ionised Gas

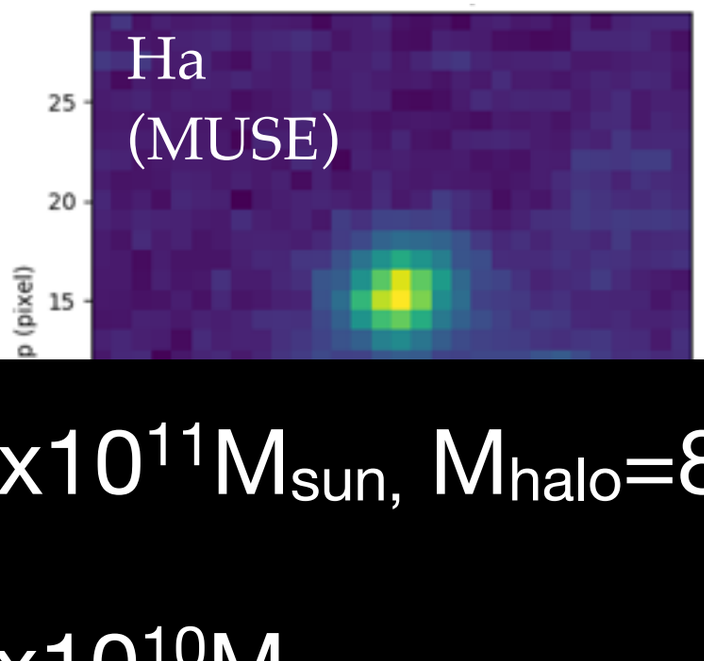


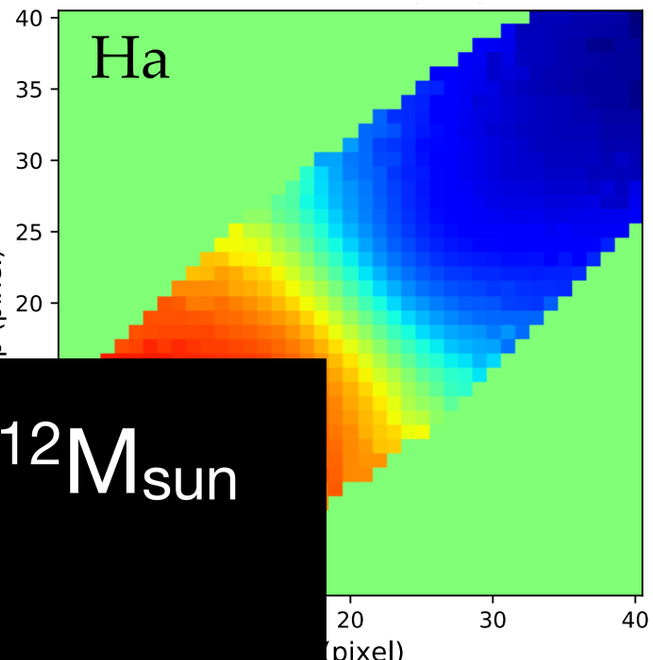
molecular gas



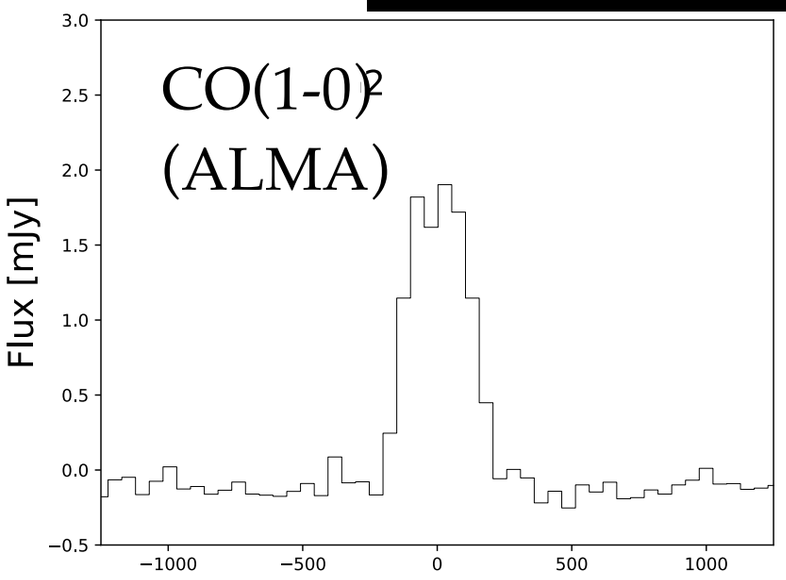
Molecular & Ionised Gas Kinematics

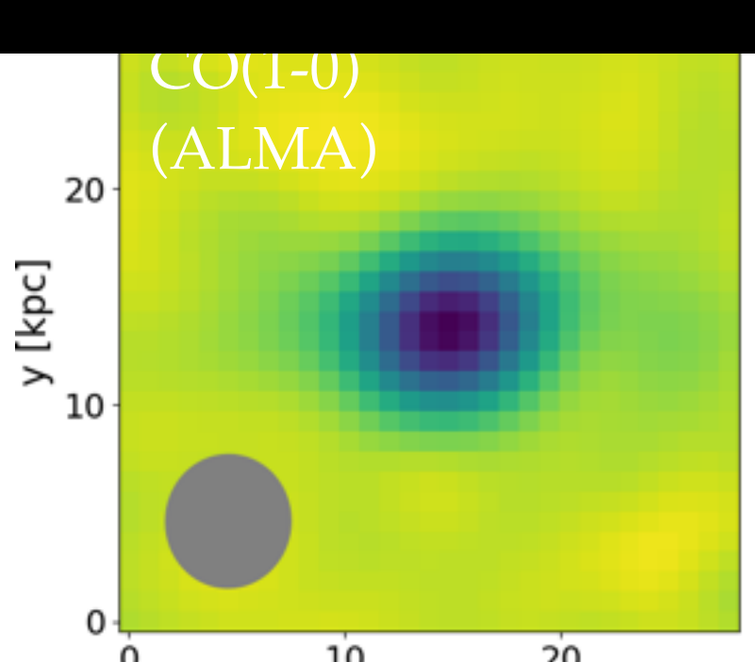


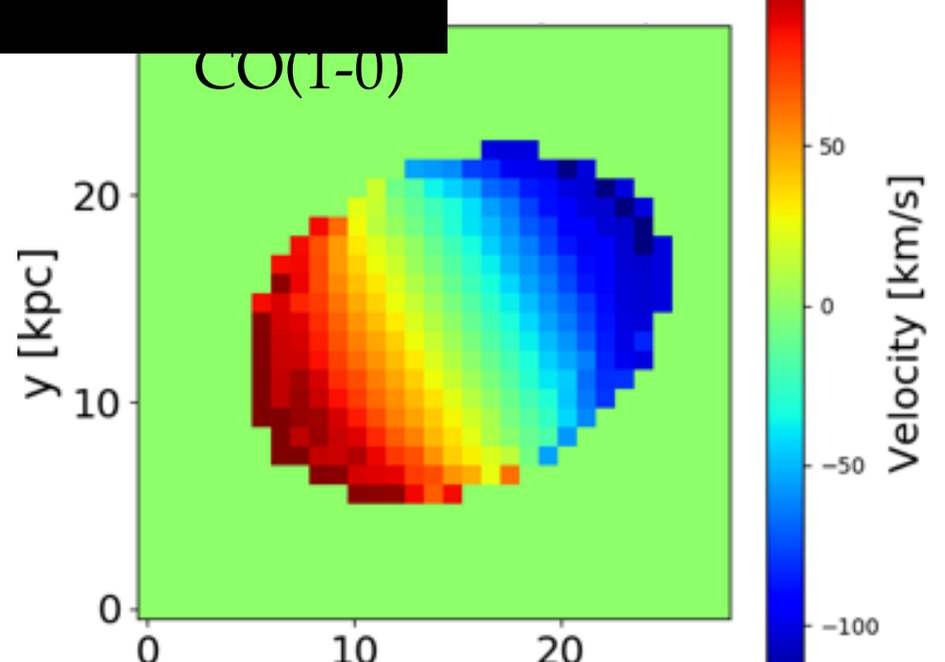




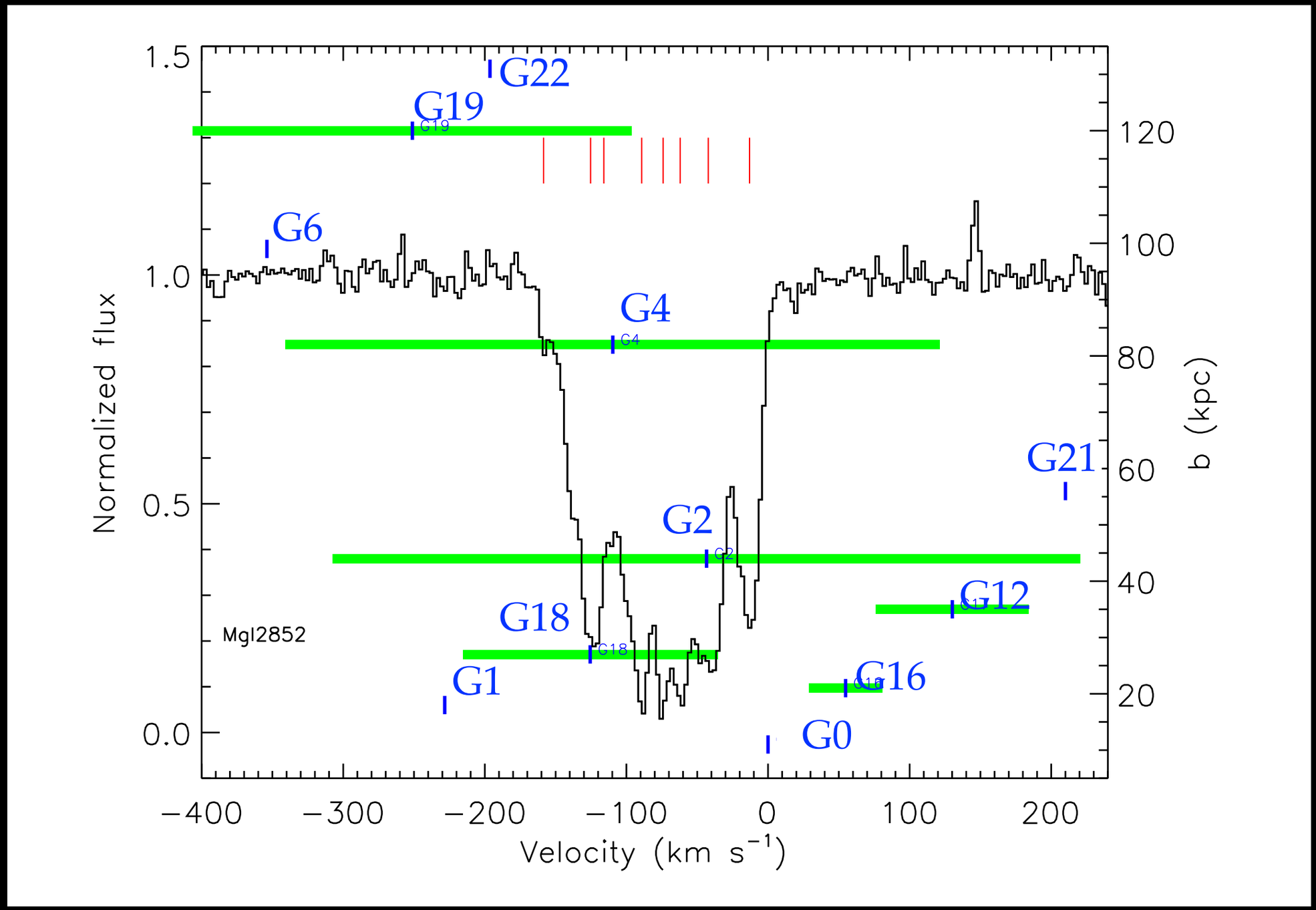
- $M_{dyn}=2x10^{11}M_{sun}$, $M_{halo}=8x10^{12}M_{sun}$
- $M_{H2}=2x10^{10}M_{sun}$



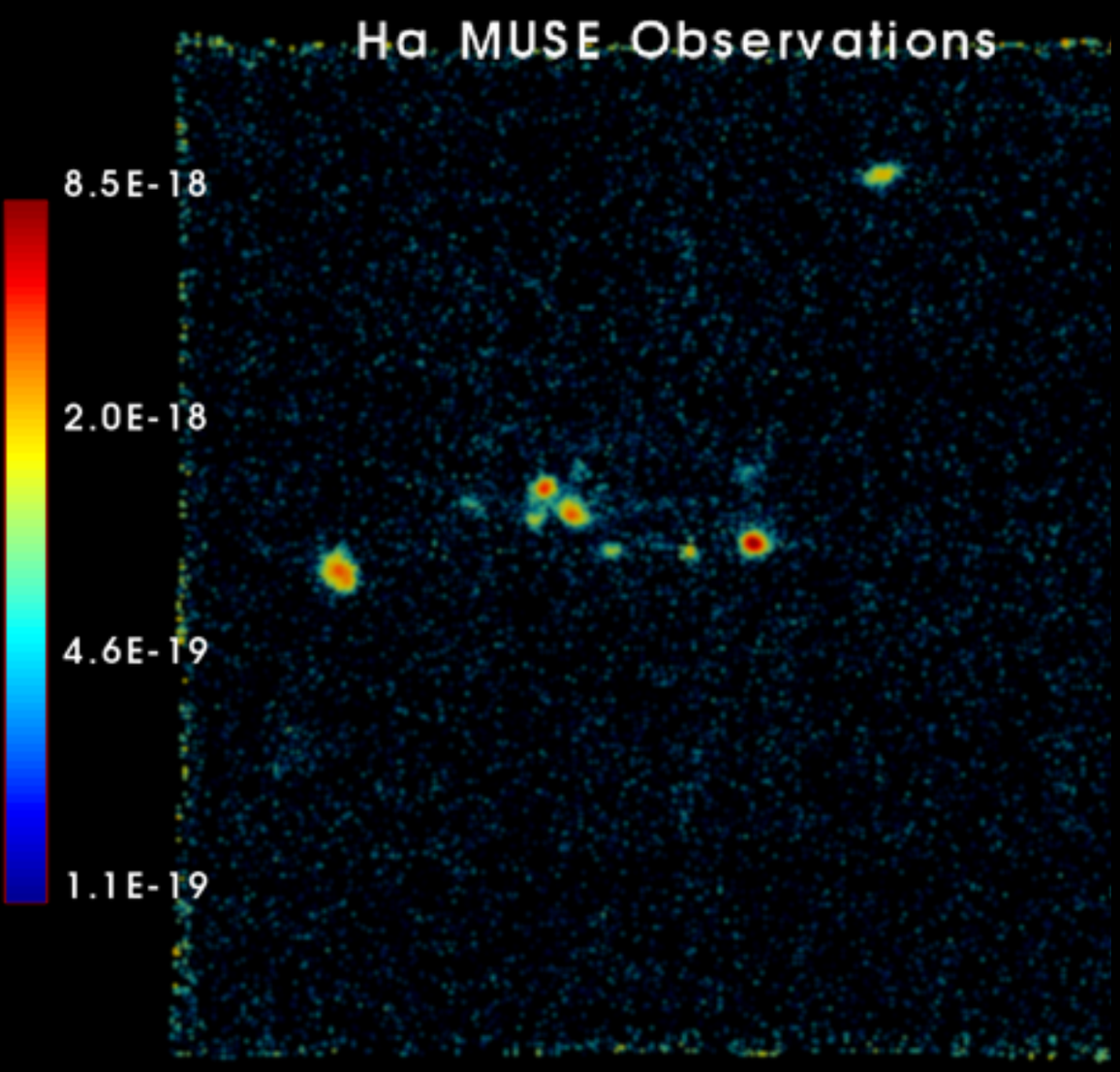


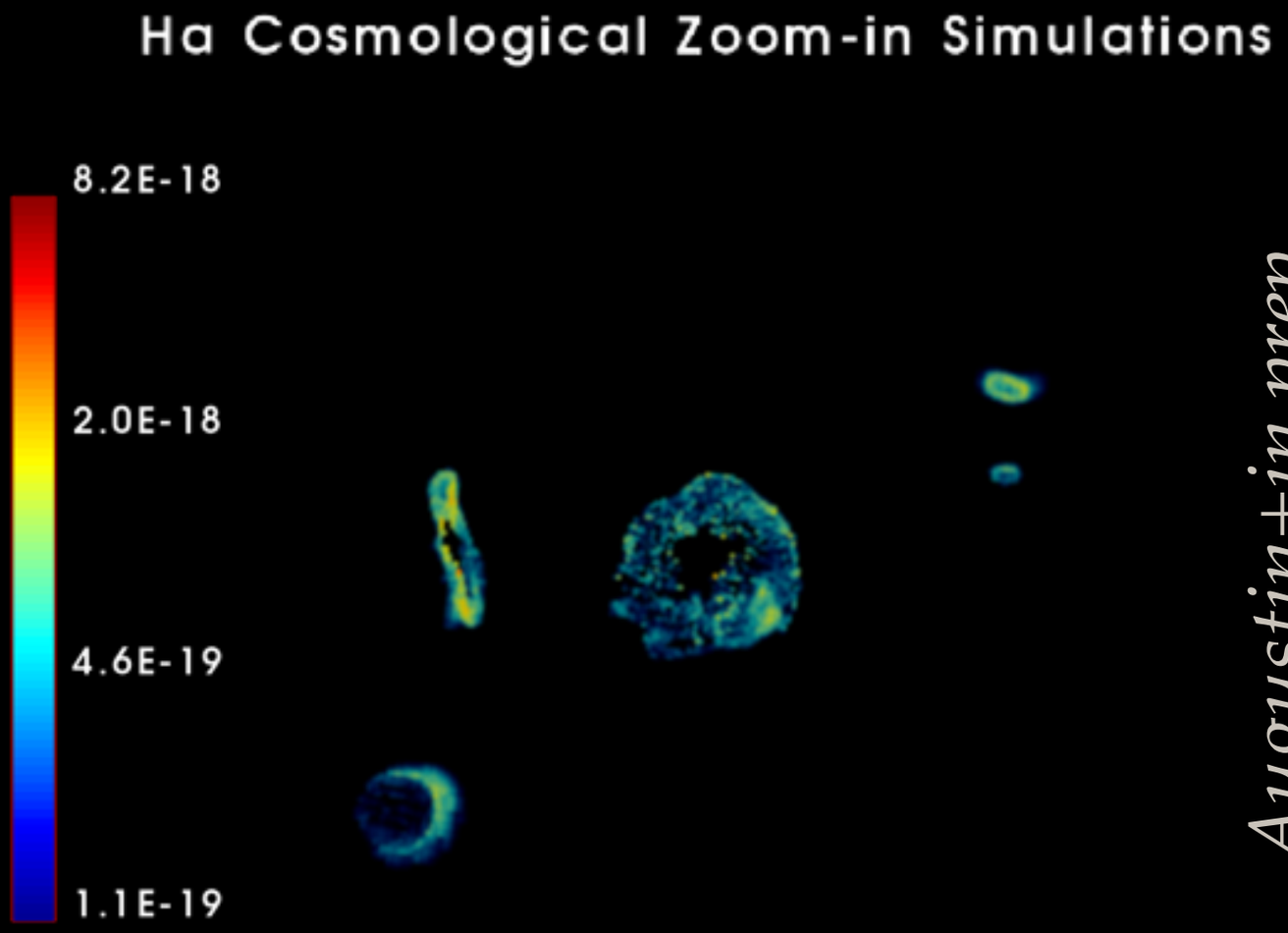


What is this Gas?



What is this Gas?

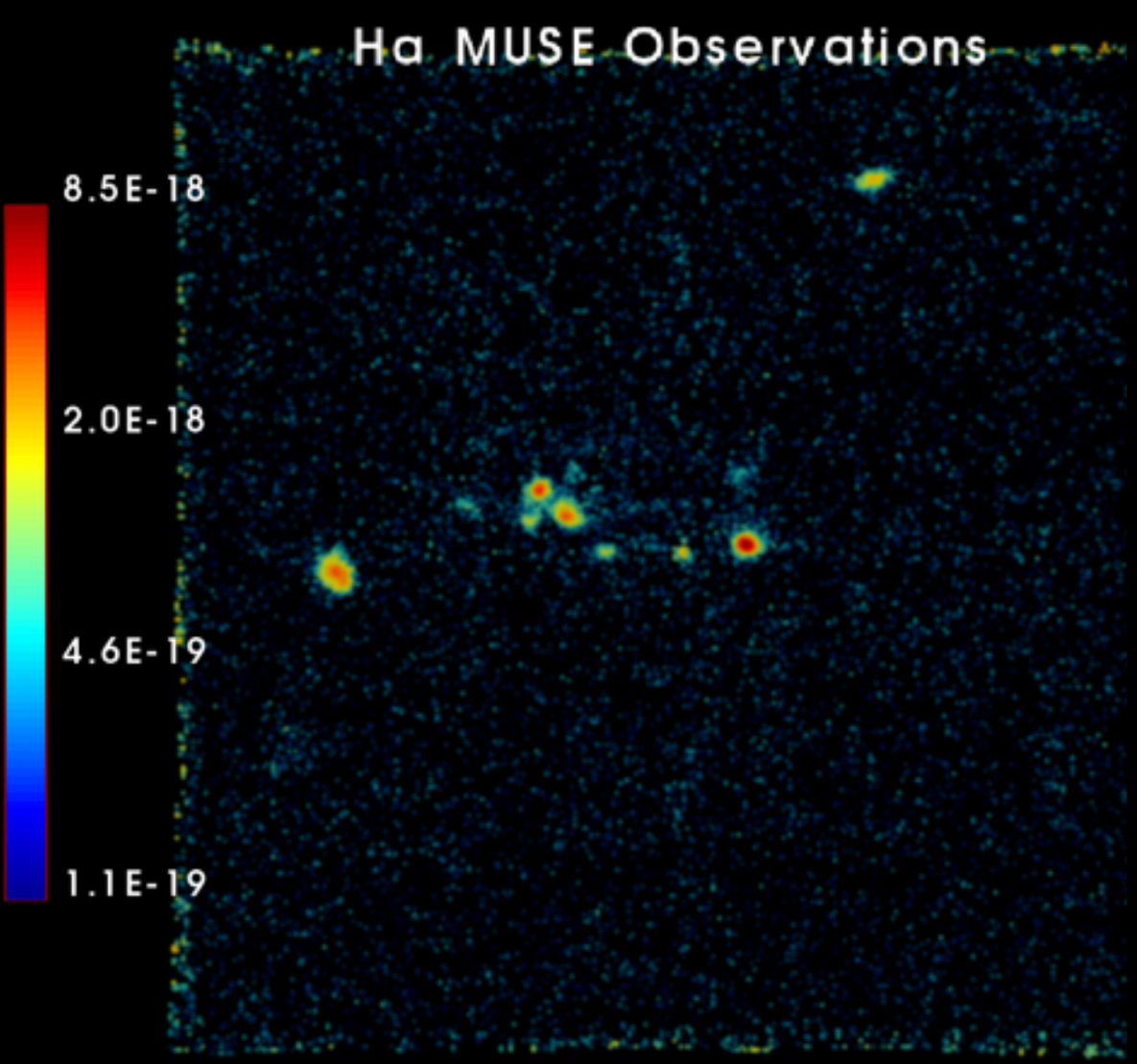


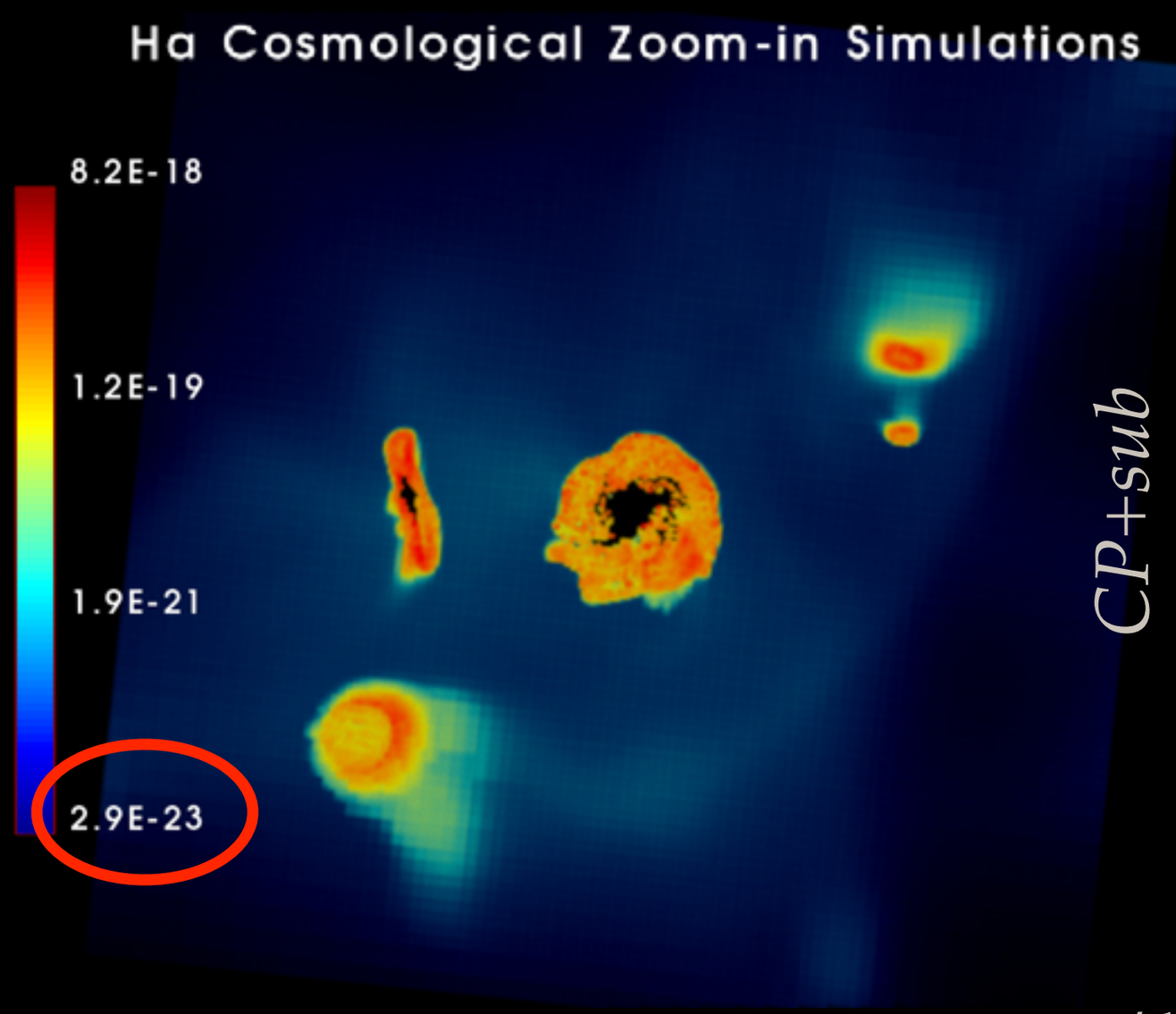


resolution=380 pc/h

erg s^{-1} cm^{-2} $arcsec^{-2}$

Low Surface-Brightness Tidal Gas





resolution=380 pc/h

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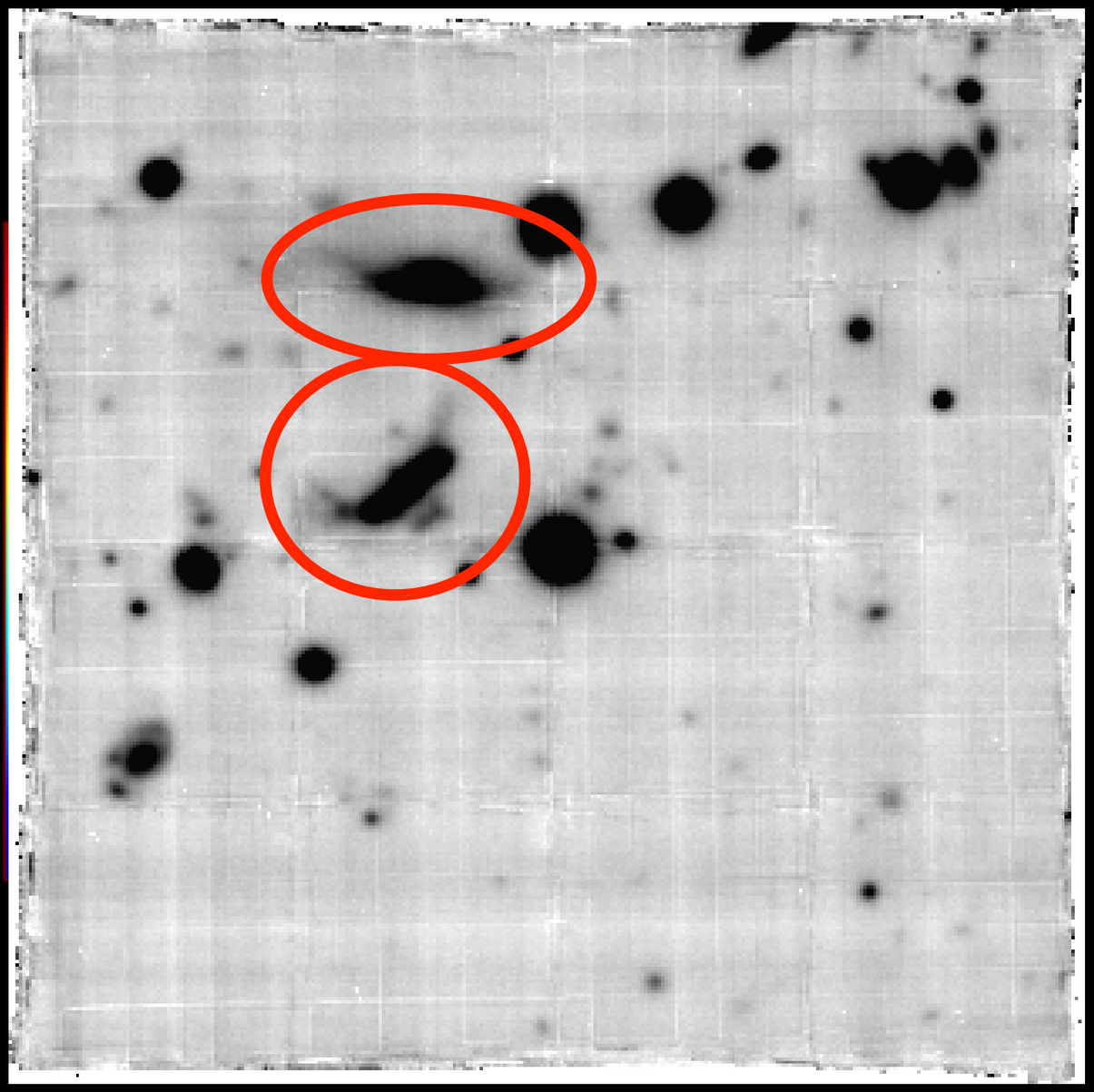
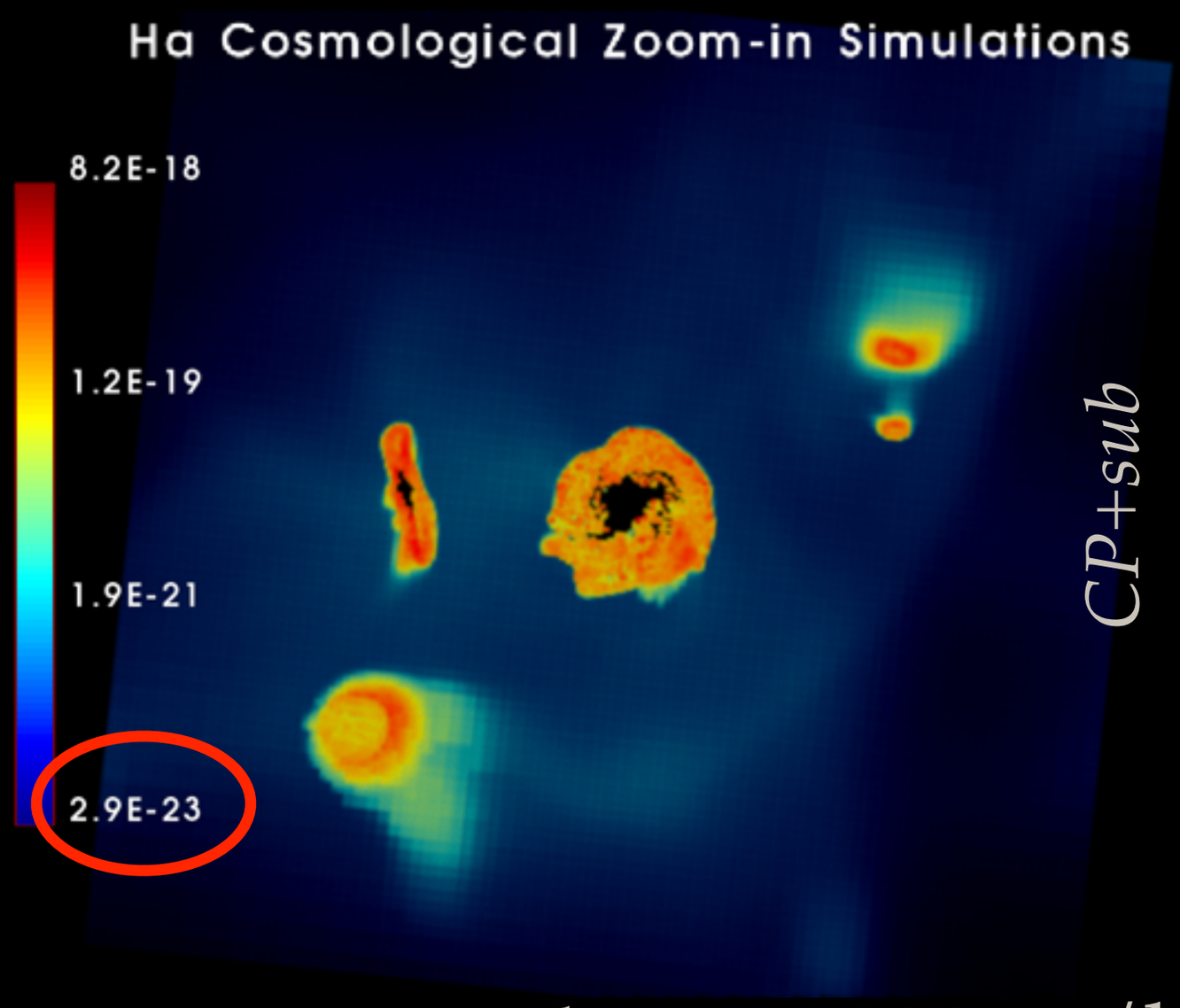
Low Surface-Brightness Tidal Gas





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Questions to Address

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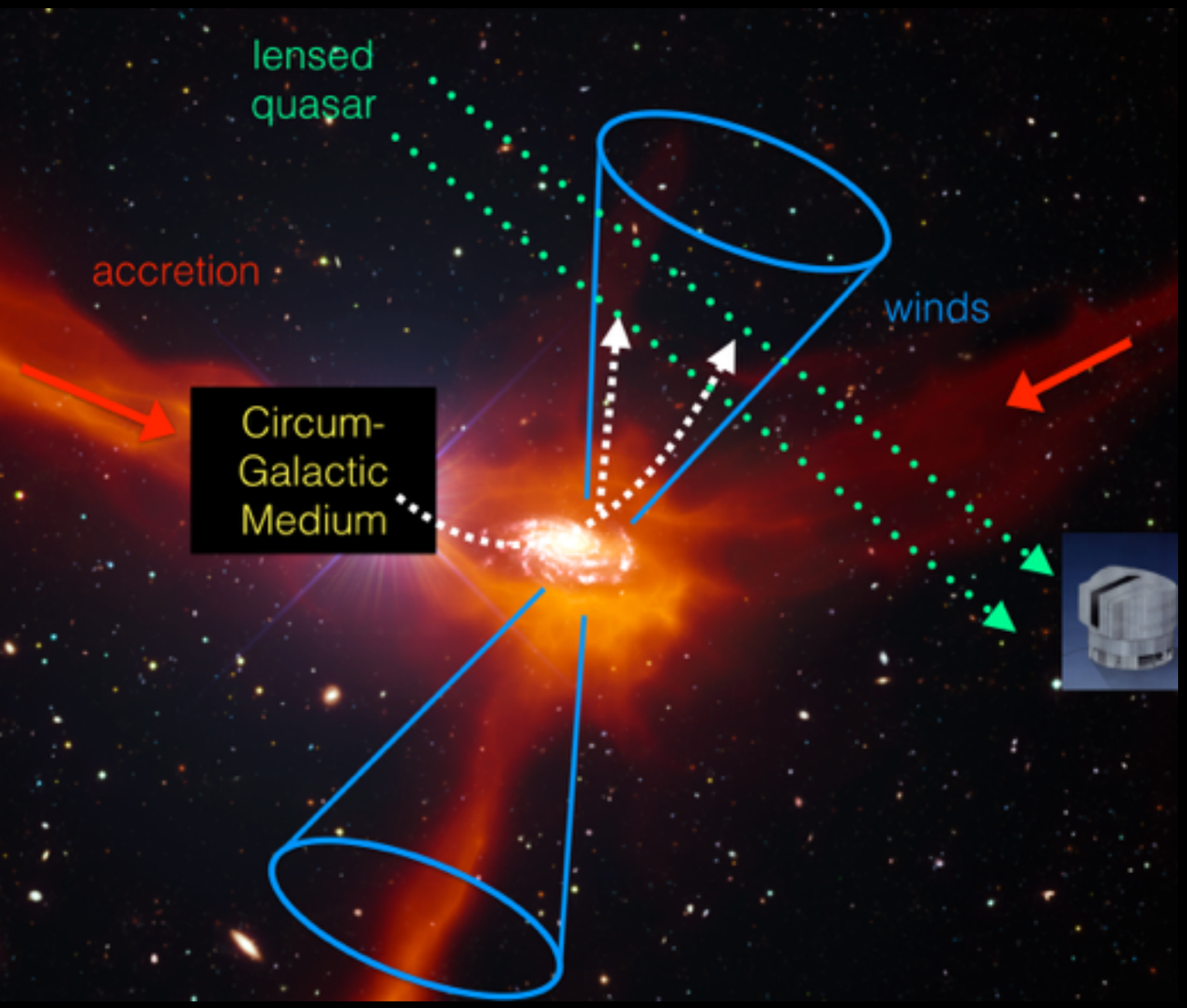
2- On which scales are metals mixed in the CGM?

3- Can we detect CGM emission at z<1?

Cold Gas Mixing

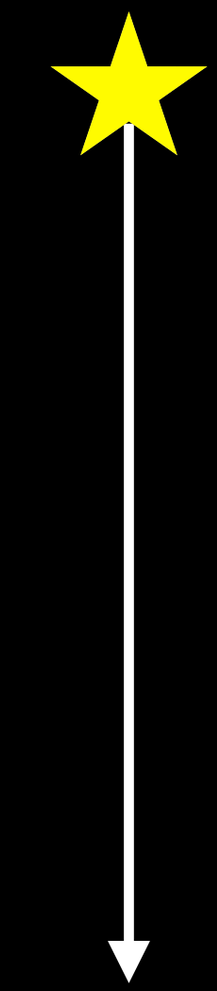


- poor metal mixing on kpc-scale [Schaye07]
- pc-scale cloudlets (shattering) [Gronke+17, McCourt+18]

=> lensed quasars to probe coherence scales

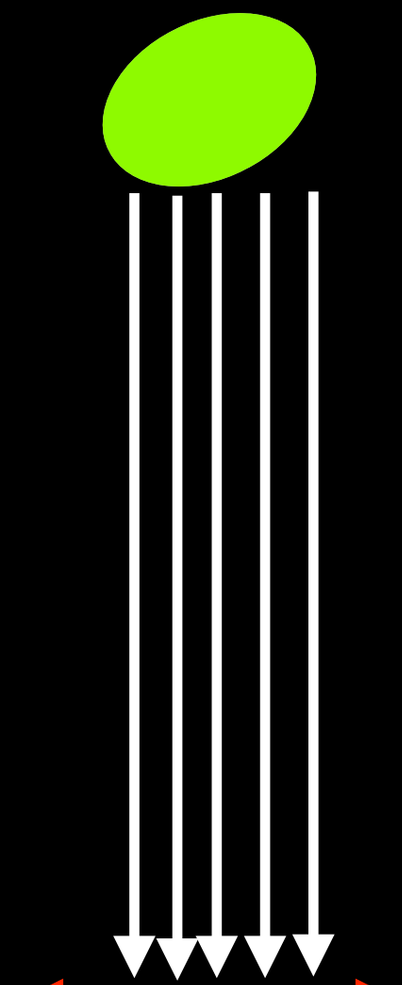
Beyond 1D along the Line-of-Sight

quasar (pt-like)



kpc-scale
in transverse
direction

extended source



z_{QSO}=3.33
Background Quasar

z_{BG}=1.15
Background Galaxies

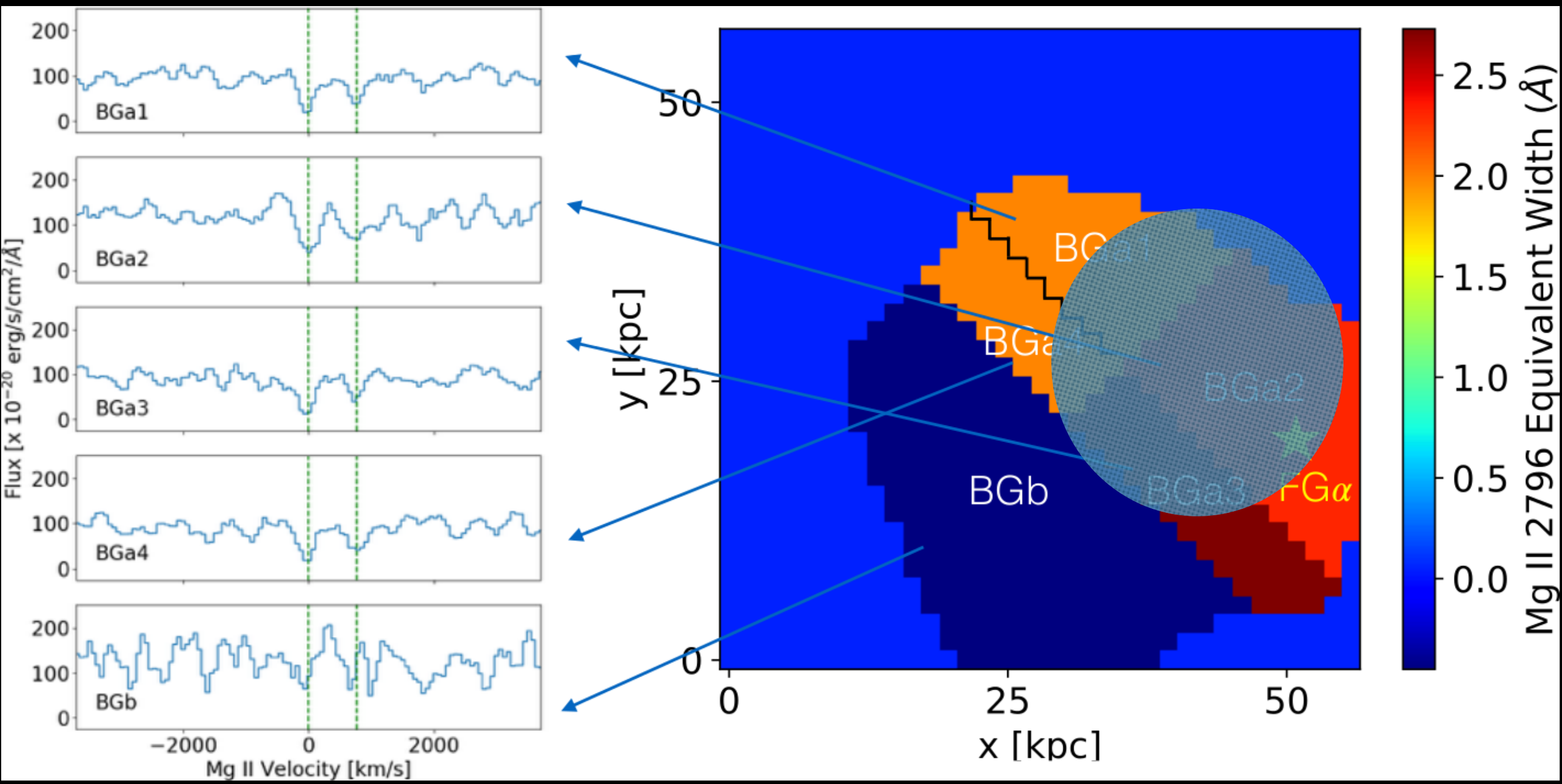
z_{FG}=1.07
Foreground Galaxies

z_{abs}=1.07
absorbers in
Background
Galaxy spectra

Spatially Resolved Metal Clouds

Cloud Gas Mass < 2×10^9 M_{sun}

CP+18



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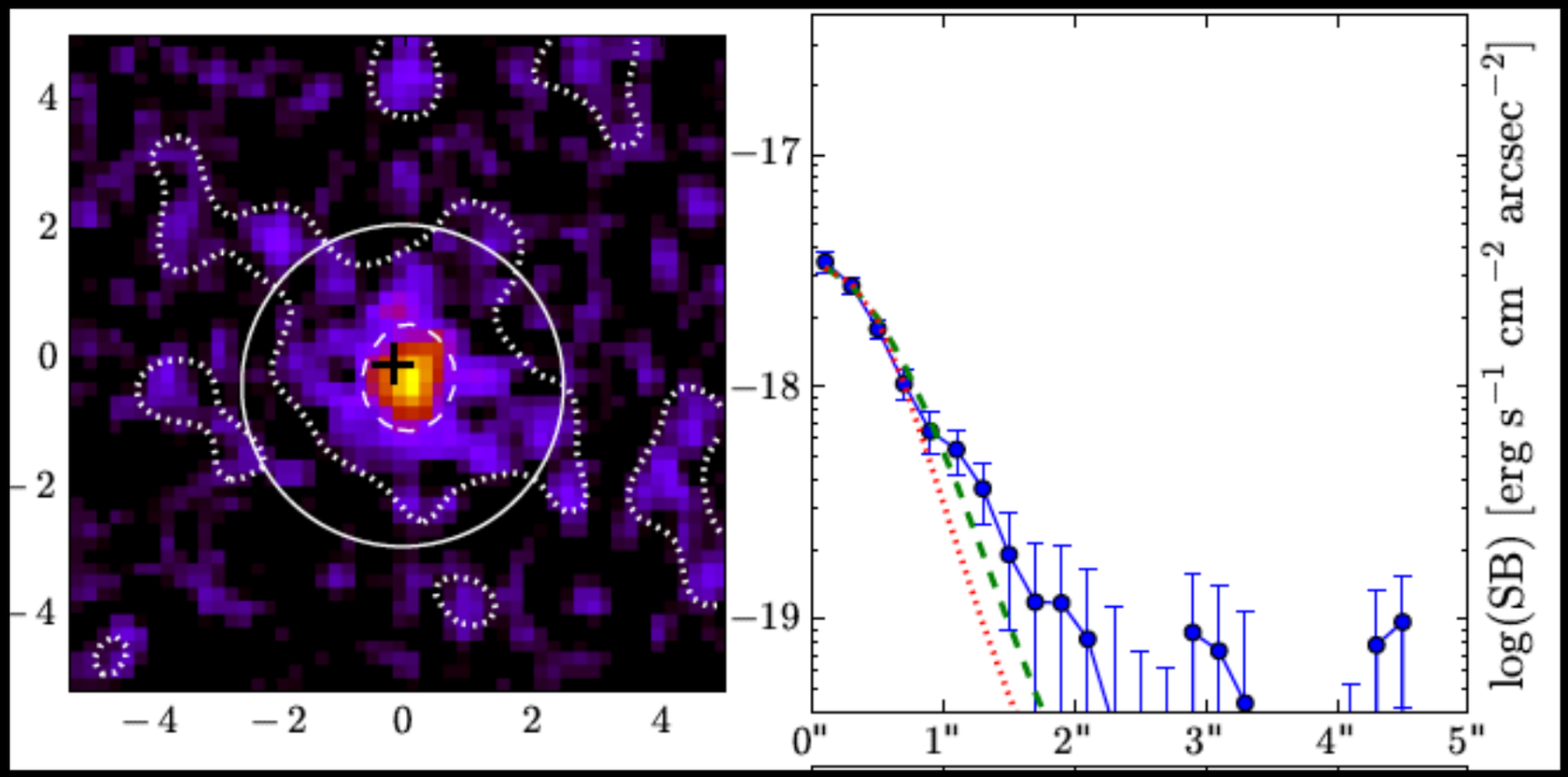
Emission vs. Absorption

- map the CGM
- reach metal-free CGM

BUT

- expected signal is faint
- require dedicated instrument

Faint Lya halos at z=3

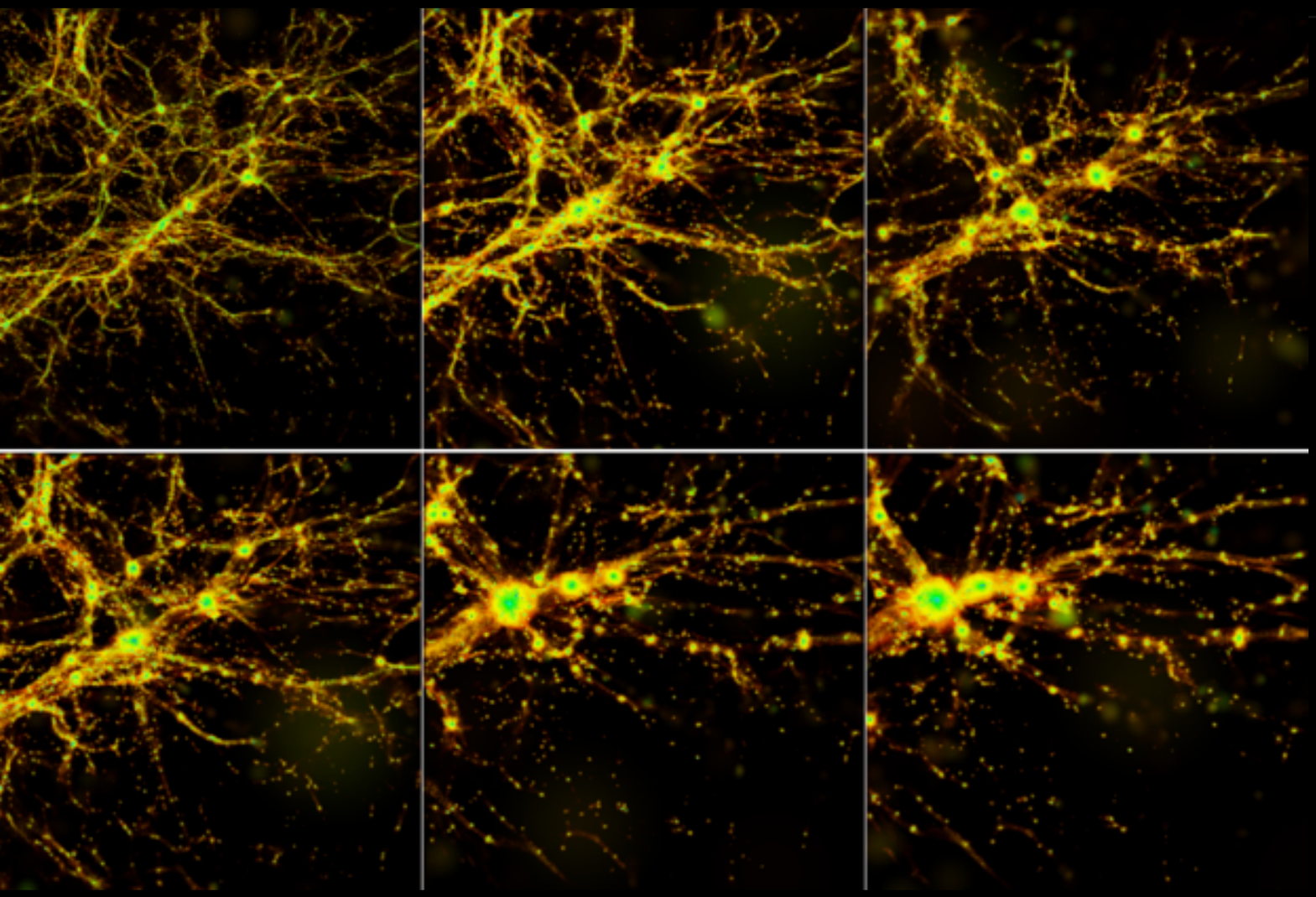


Wisotzki+16, Leclerq+17

Low redshift requires UV

- 1m mirror, UV stratospheric balloon
- MOS, λ=200nm
  => Lya at z=0.7
- CalTech, Columbia, Marseille (PI: C. Martin)

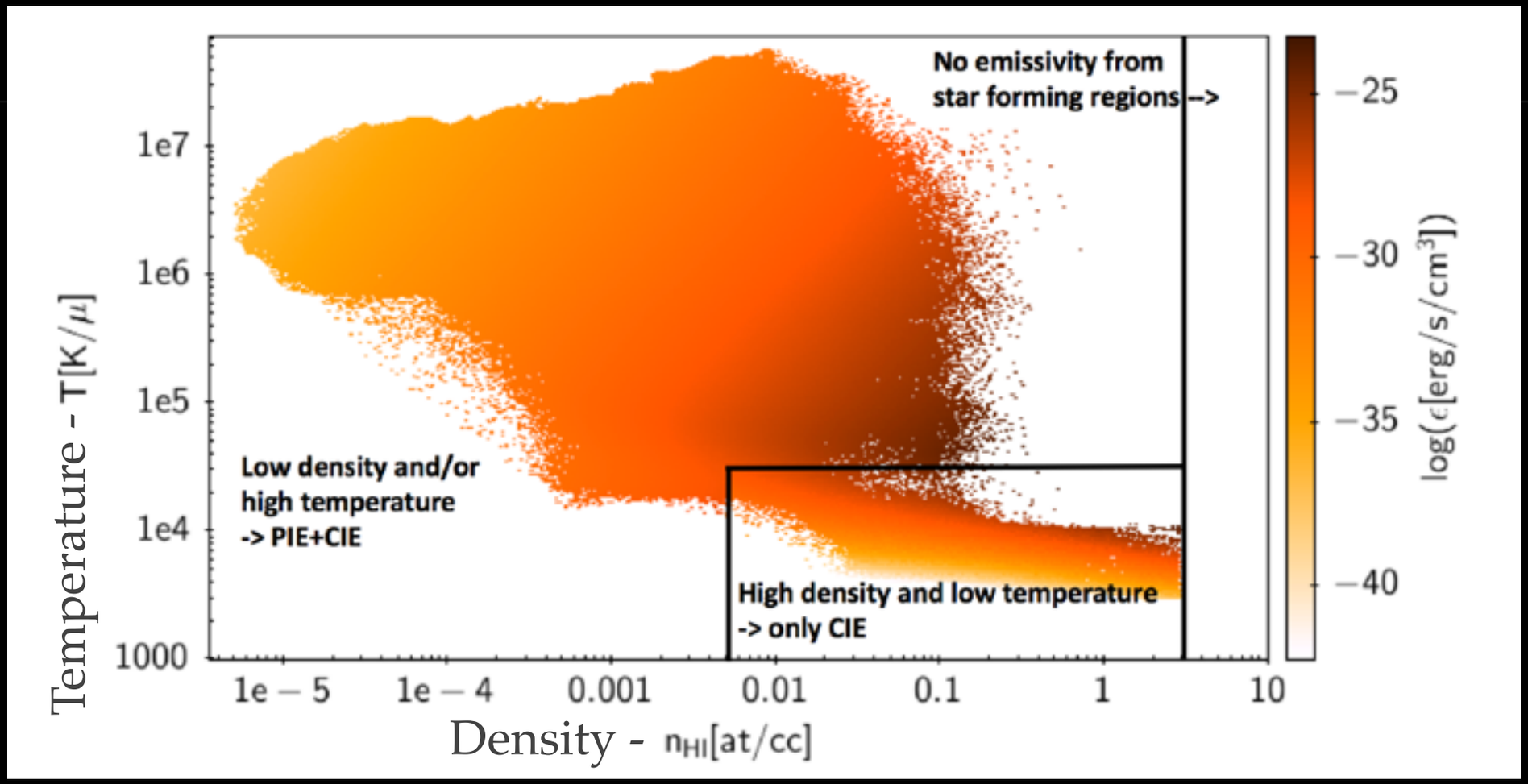
Cosmological zoom simulations



- RAMSES AMR, **down to z=0** [Frank+12]
- 13.92 Mpc/h box, spatial resolution 380pc/h
- non-thermal supernova feedback [Teyssier+13]
- 'on-the-fly' self-shielding

Augustin, Quiret, Milliard, Peroux, Vibert, Blaizot+ (in prep)

CGM Emissivity Predictions



- Conservative post-processing

  photo-ionisation from UVB

  collisional ionisation from gravitational collapse (cooling radiation) and feedback

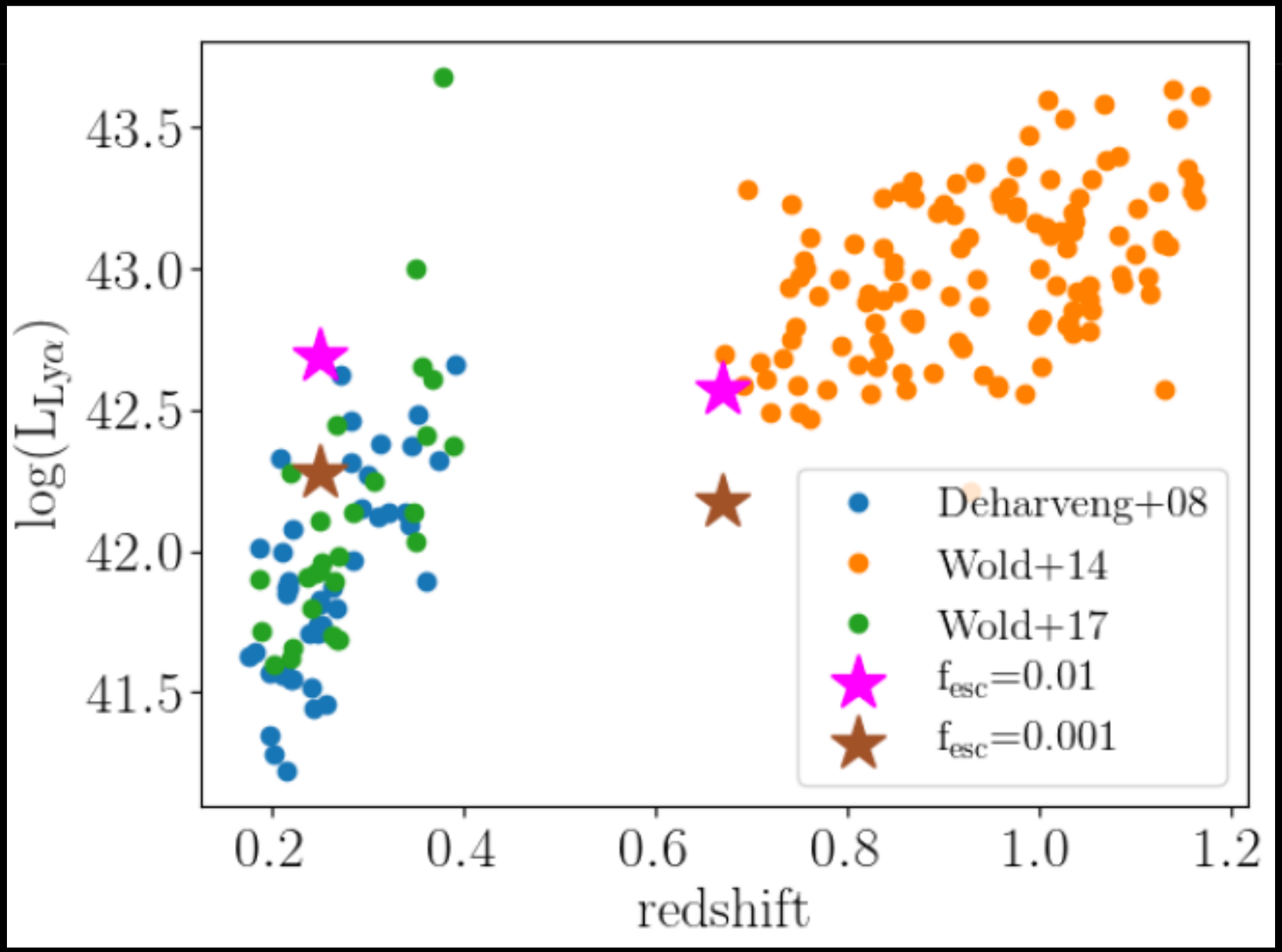
  scattering of Lya photons escaping the ISM (stellar contribution)

Ramona Augustin

zoom-in simulations
Lyα, z=0.7

Augustin+in prep

CGM Lya emission depends on fesc



Hayes+11, Wofford+13, Naidu+17

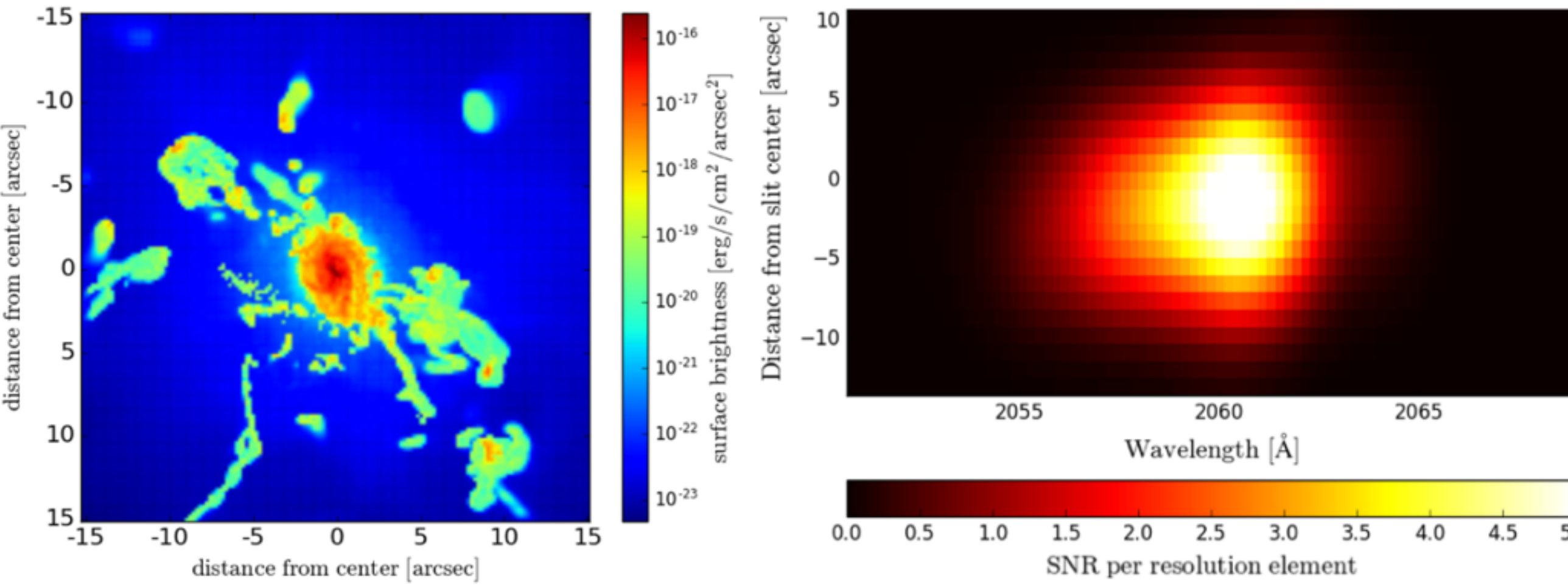
Verhamme+06,12, Rosdahl+13, Lake+15

End-to-end simulations

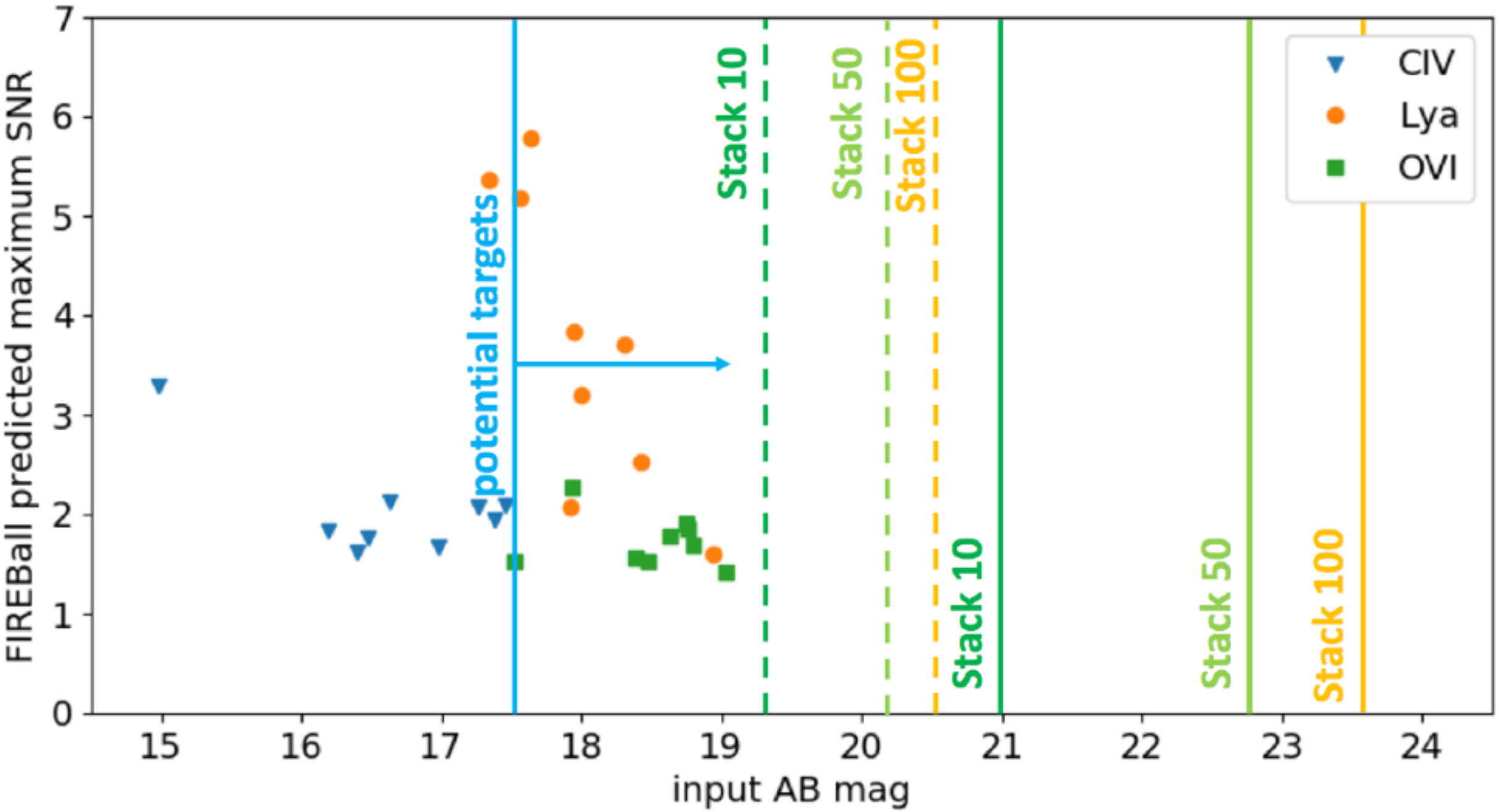
instrument model

input mock obs

output SNR cube

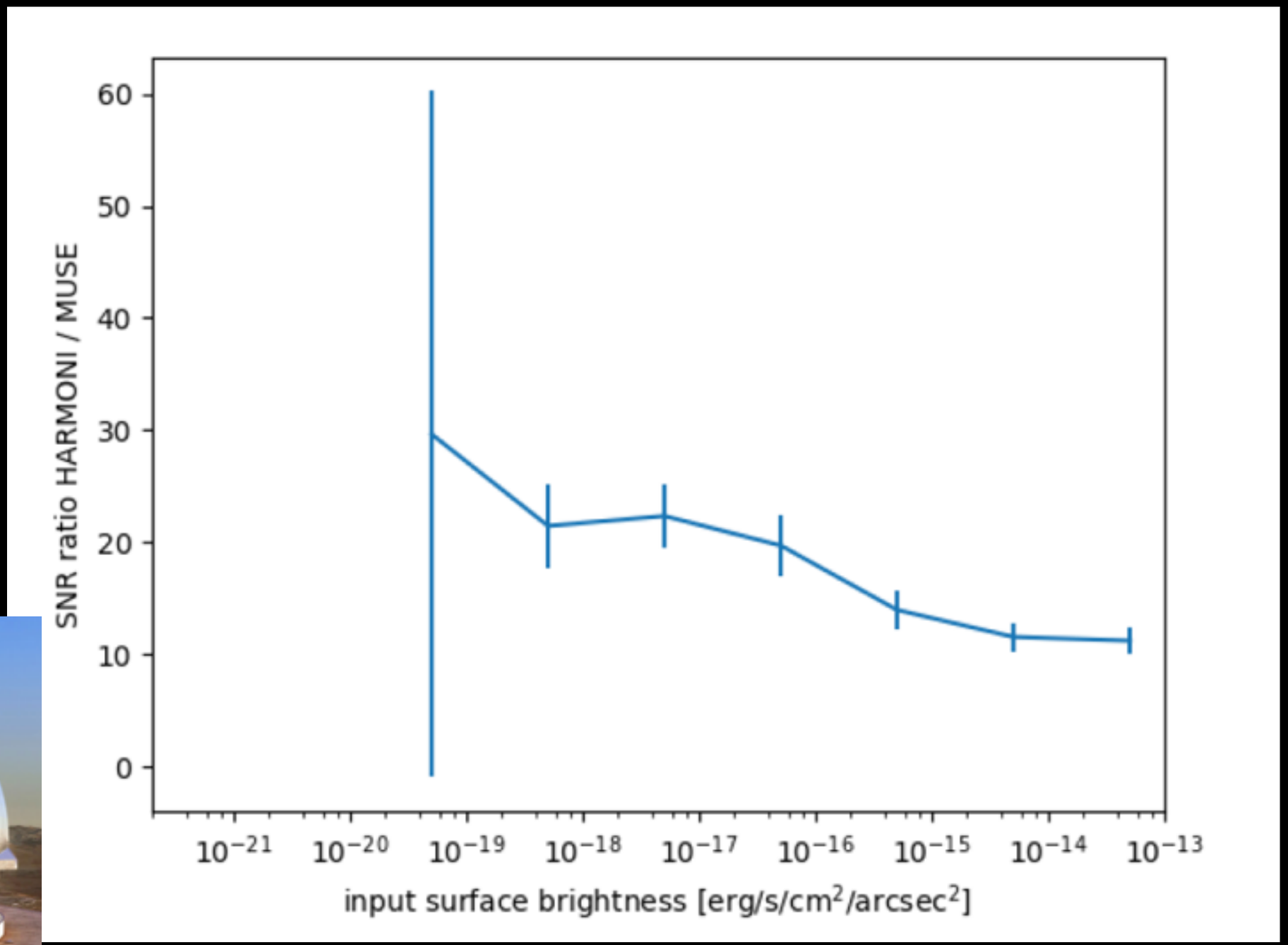


FIREBall will detect CGM Lya emission at z=0.7



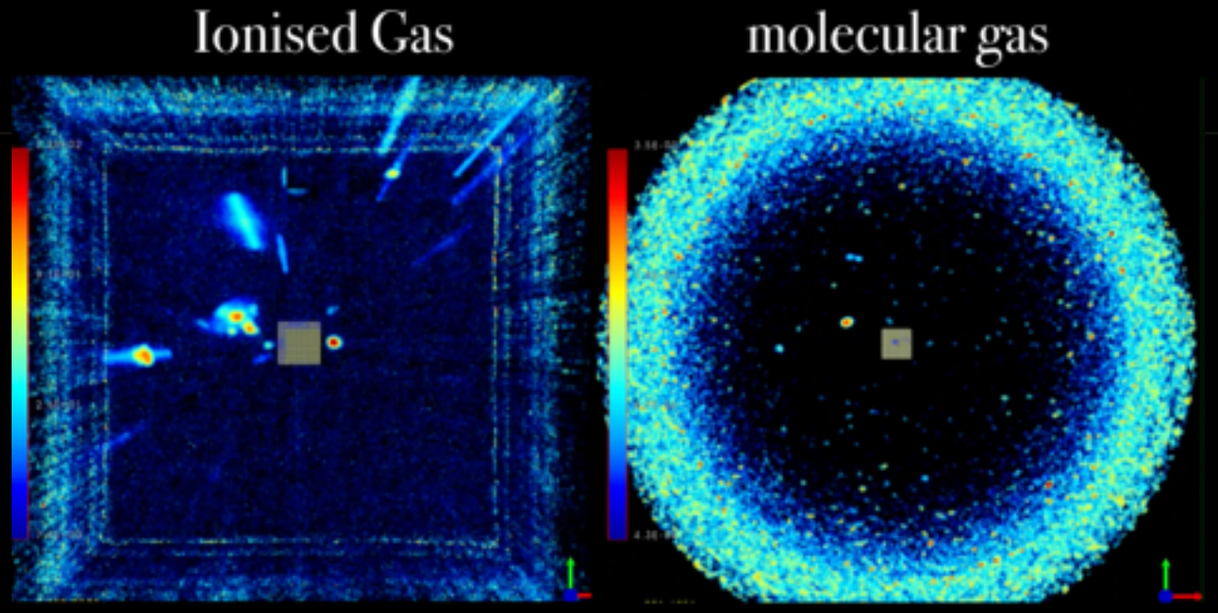
MUSE FoV 60x HARMONI FoV

HARMONI 20x more sensitive than MUSE



Take Home Messages

Absorbers inefficiently convert gas into stars



Good efficiency of the metal mixing as traced by cold gas

Prospect to detect CGM Lya emission at z=0.7 with FIREBall