Emission from the Circum-Galactic Medium:

Predictions of Multi-Wavelength Observables from zoom-in Cosmological Simulations

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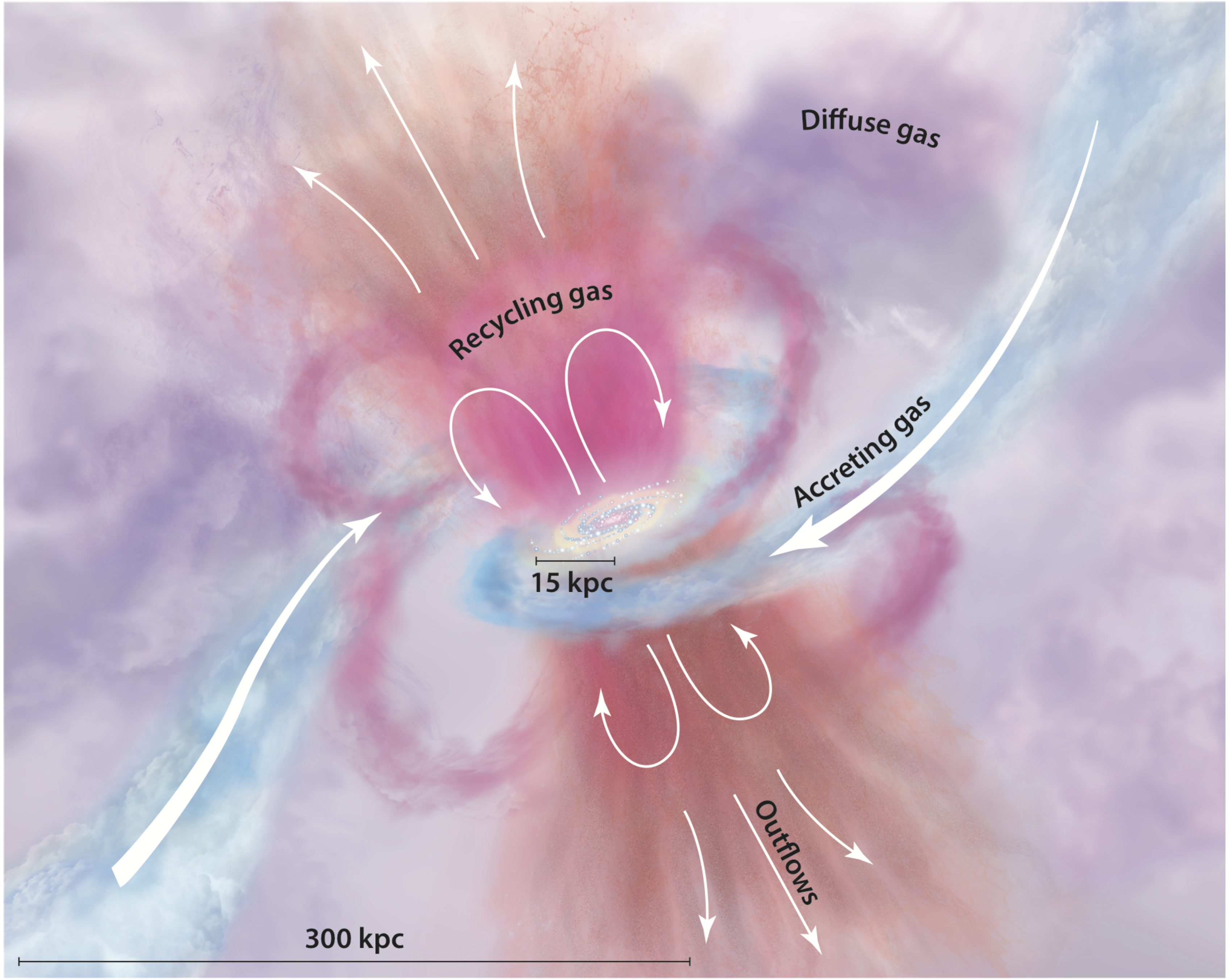
The Circum-Galactic Medium



Tumlinson et al. 2017

Two ways of investigating the CGM

Absorption

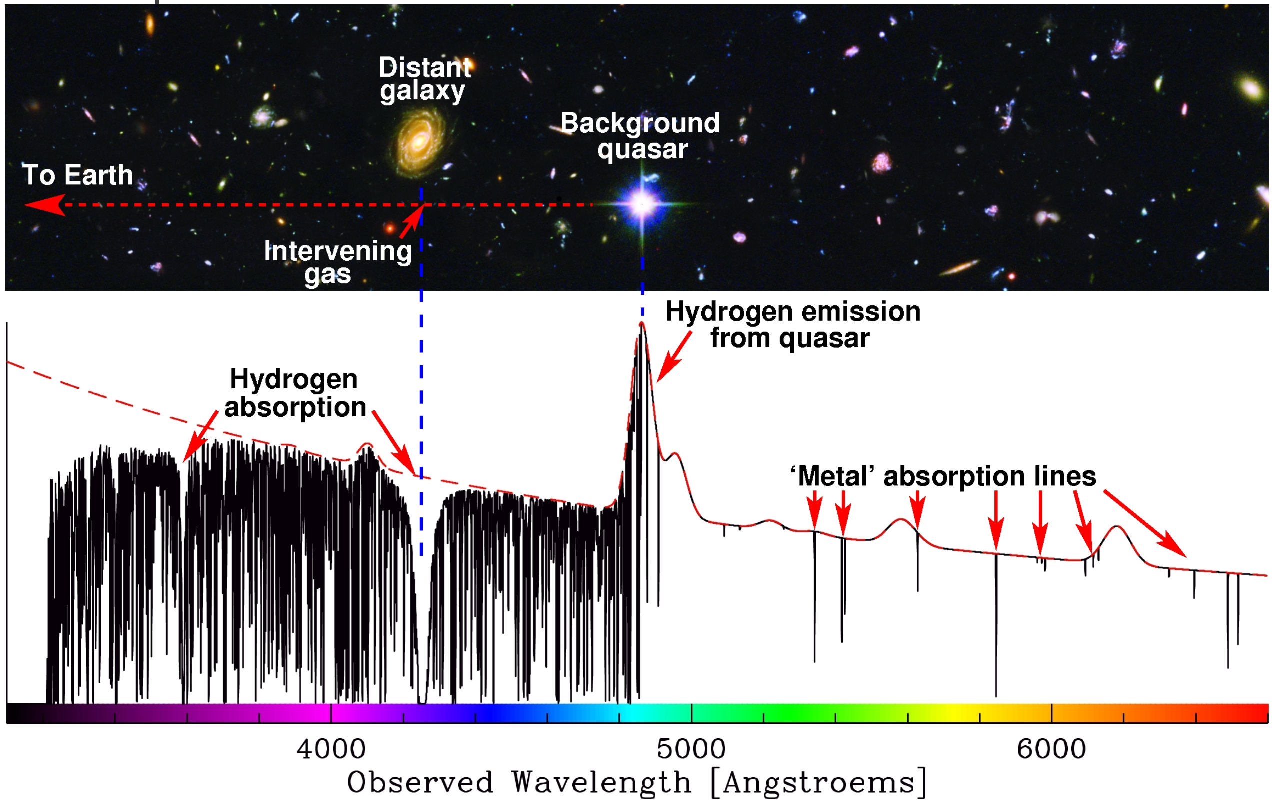


Figure: http://www.hs.uni-hamburg.de/jliske/qsoal/qsoabs.jpg

Emission

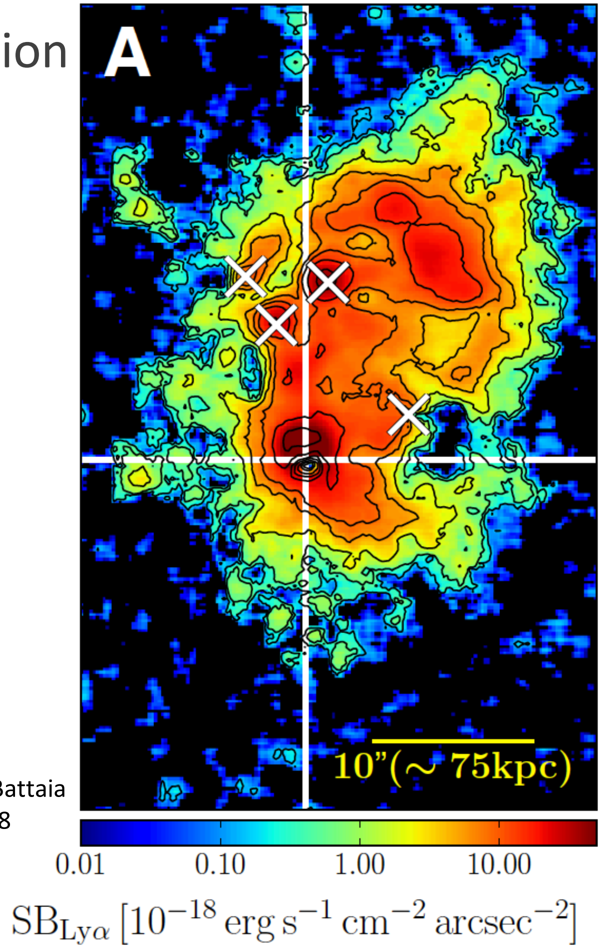


Figure: Arrigoni Battaia et al. 2018

Detections in Absorption:

e.g. DLA galaxies:
Christensen et al. 2014
Krogager et al. 2017
Augustin et al. 2018

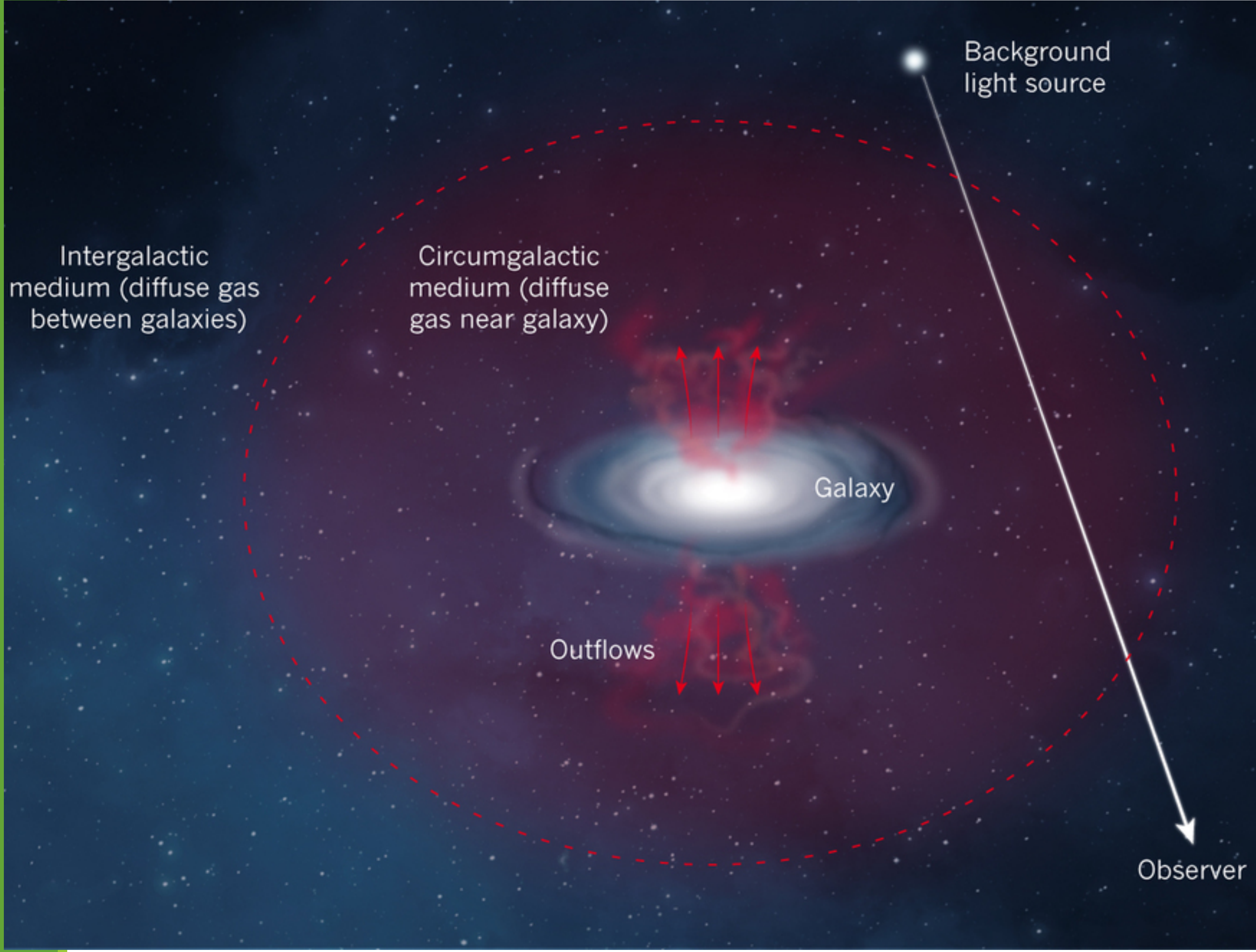
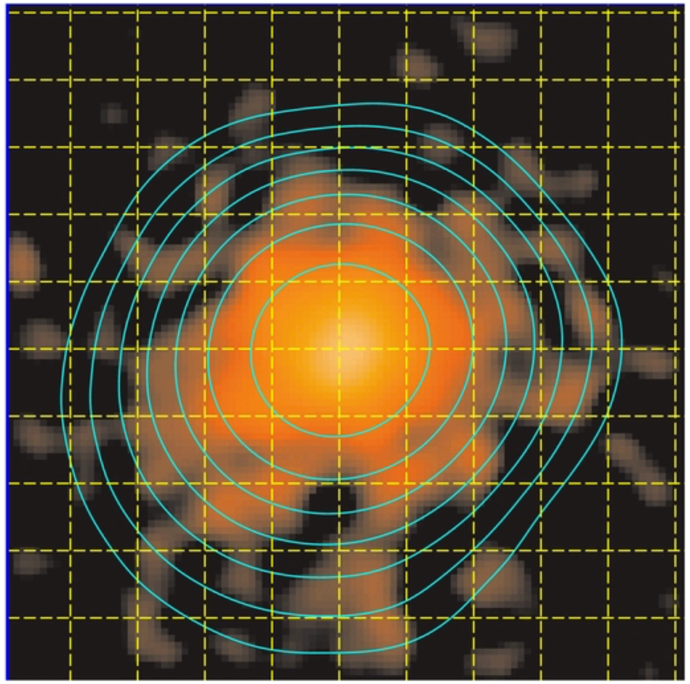


Figure from Molly S. Peeples 2015

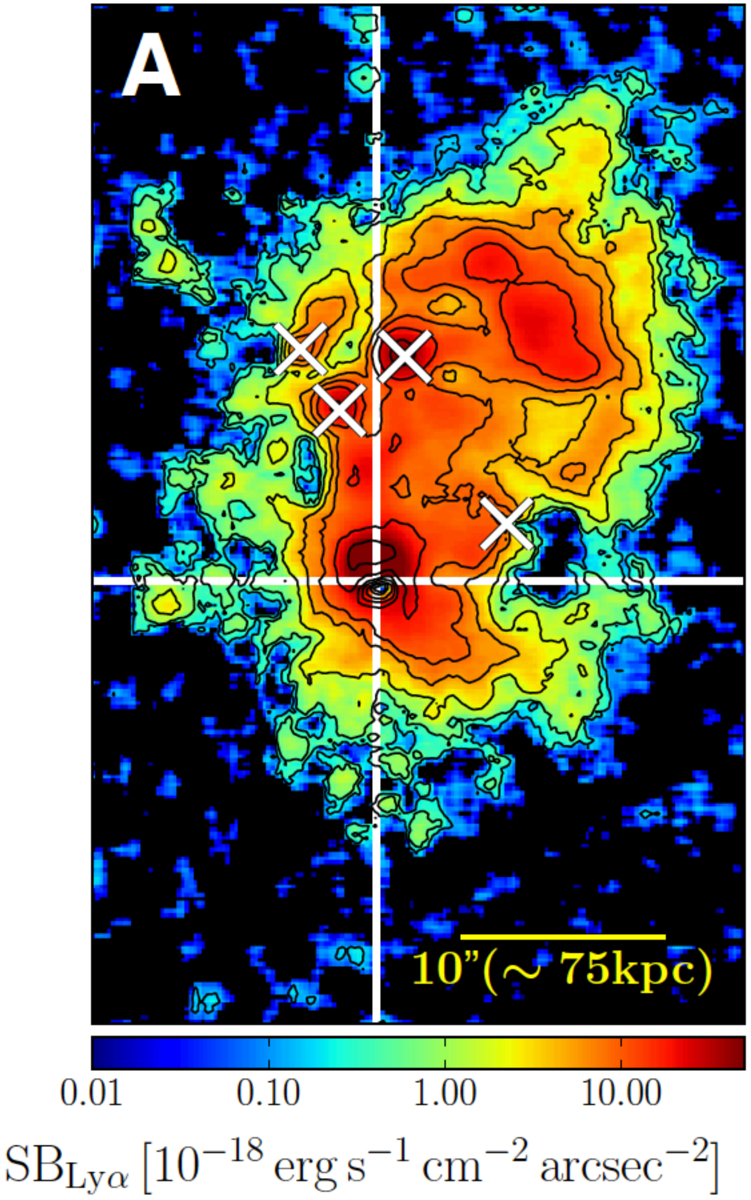
Detections in Emission

Stacking: e.g. Steidel et al 2011



Line emission maps using narrow band images (from IFU data) of the extended emission around quasars:

e.g. Cantalupo et al. 2014; Martin et al. 2014; Borisova et al. 2016; Arrigoni Battaia et al. 2015, 2016, 2018



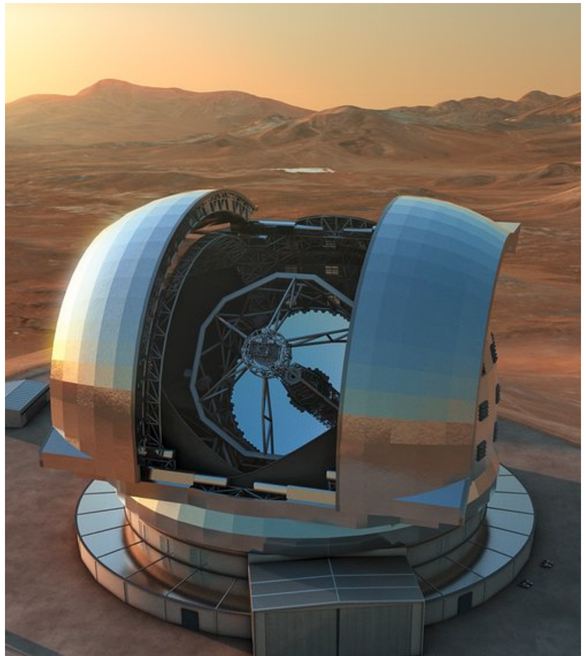
Challenges in observing the CGM

Low redshift → UV

Need Satellite or Balloon missions like FIREBall-2

High redshift → faint

Need big telescopes and sensitive detectors → ELT/Harmoni



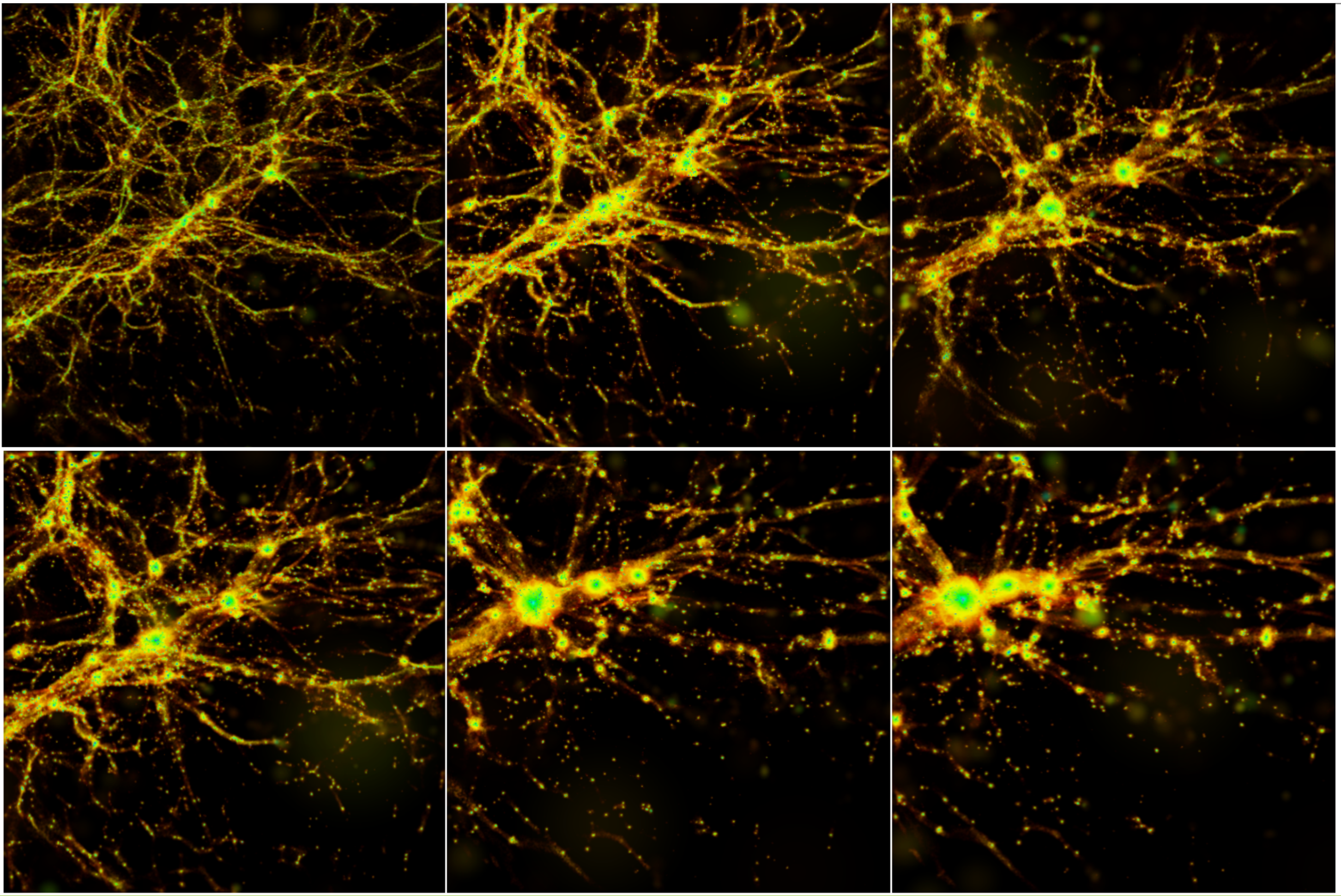
Credit: ESO

High temperatures → X-Ray

Need satellite missions like Athena

Credit: MPE, ESA and Athena Team

Cosmological zoom-in simulations



RAMSES Adaptive Mesh Refinement

Cosmological simulations down to z=0

~ 40 Mio CPU hours

Based on simulations from Frank et al. 2012

Zoom-in on a large cubic region with a box length of 13.92 Mpc/h.

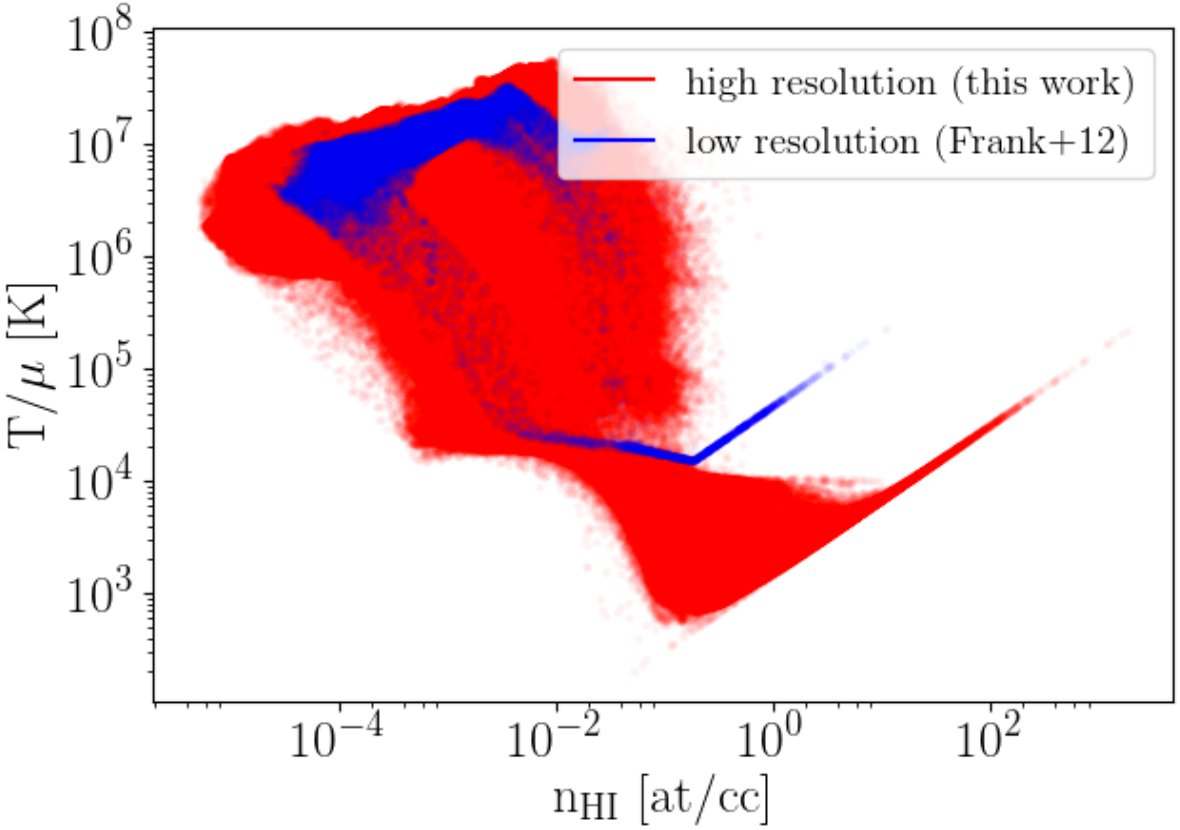
Non-thermal supernova (SN) feedback (Teyssier et al. 2013)

'on-the-fly' self-shielding for n_{HI} > 0.01at/cc

Maximum resolution of 380 h^{-1} comoving parsecs

Collaborators: S. Quiret, B. Milliard, C. Peroux, D. Vibert, J. Blaizot, Y. Rasera, R. Teyssier, S. Frank, J.-M. Deharveng

Cosmological zoom-in simulations



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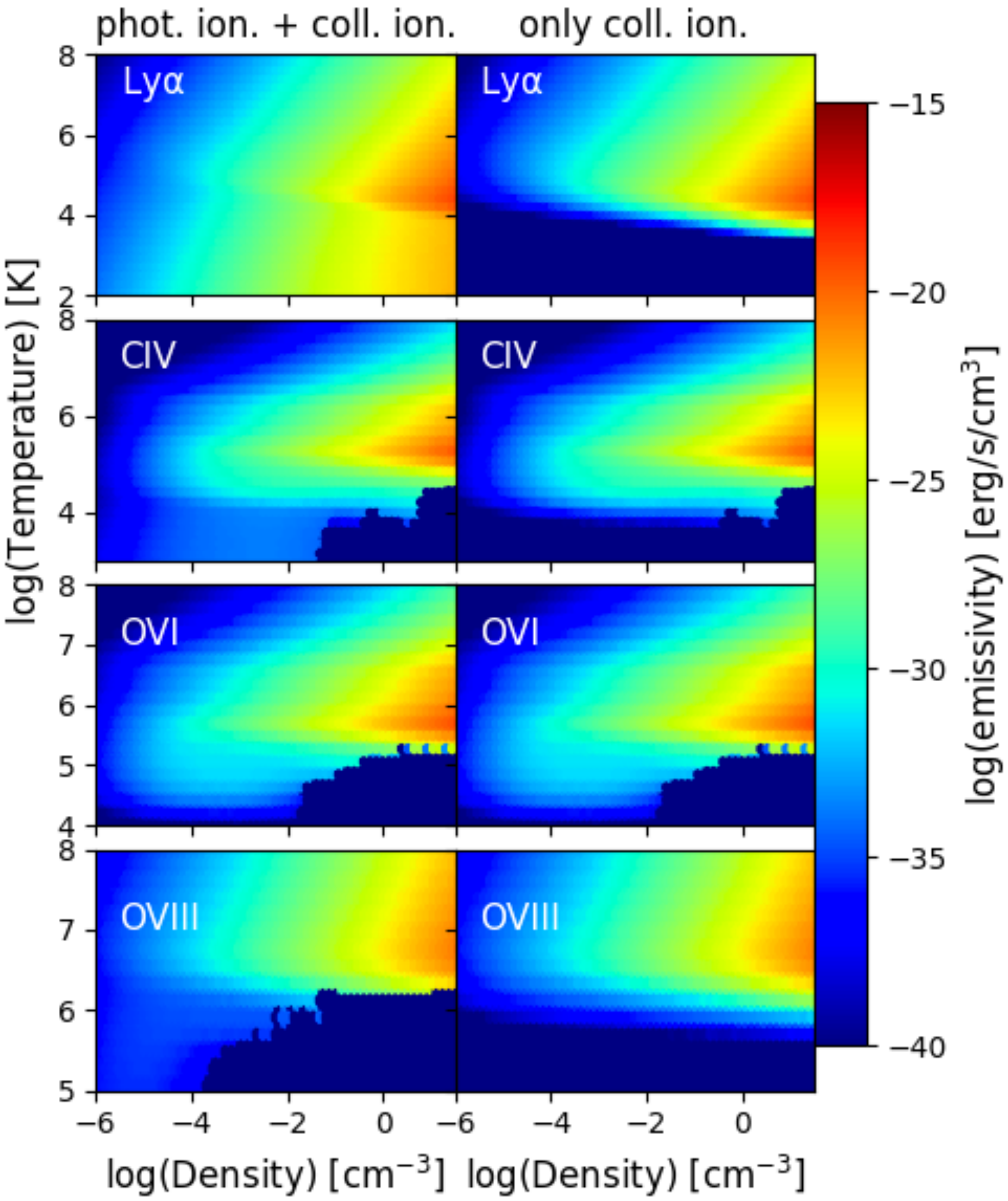
CLOUDY Model

- Photoionization + collisional ionisation

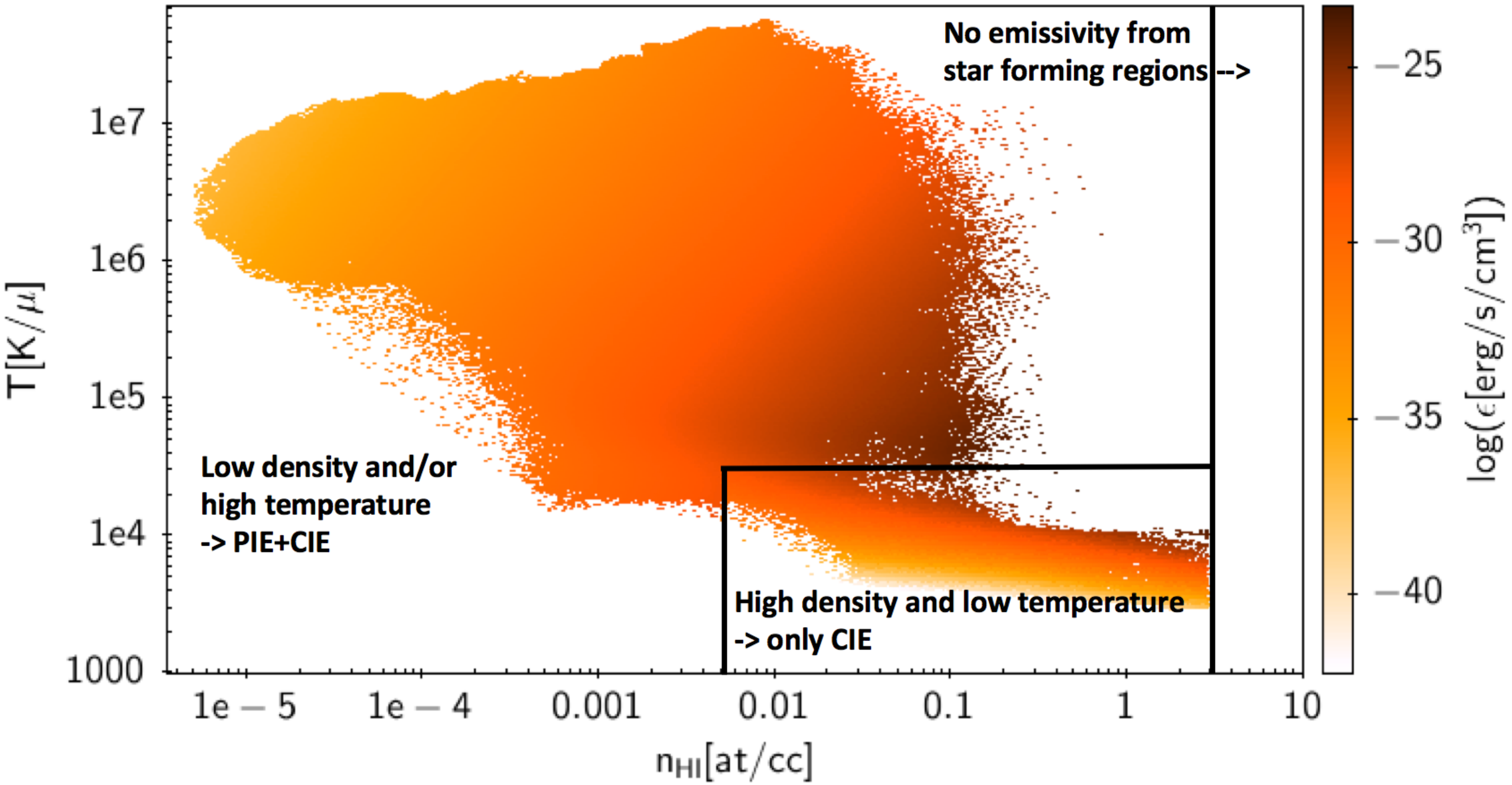
  →low density / high temperature gas

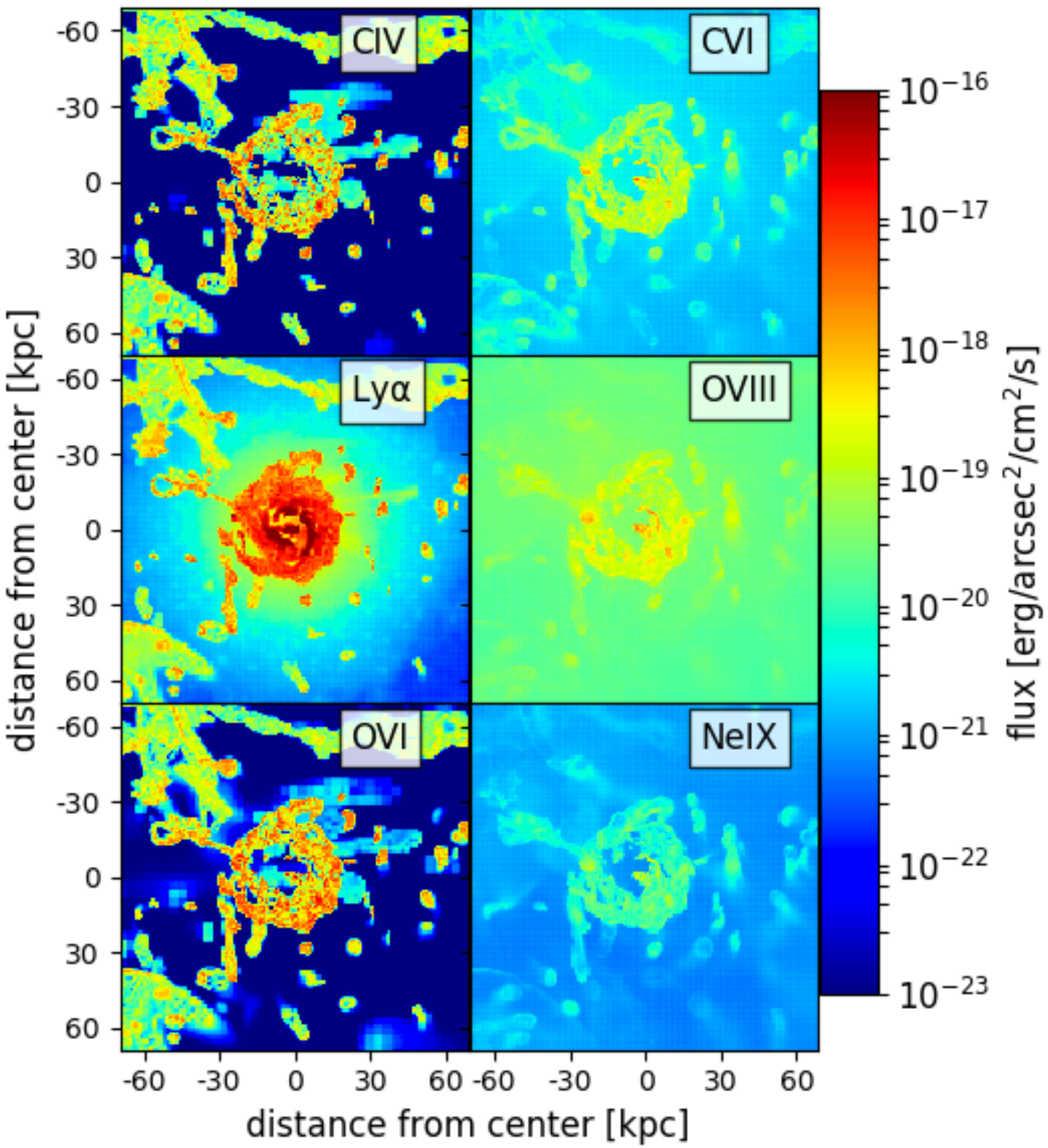
- only collisional ionisation

  → self shielded gas with high density / low temperature



Lyα emission from galaxy halo





Line Emission

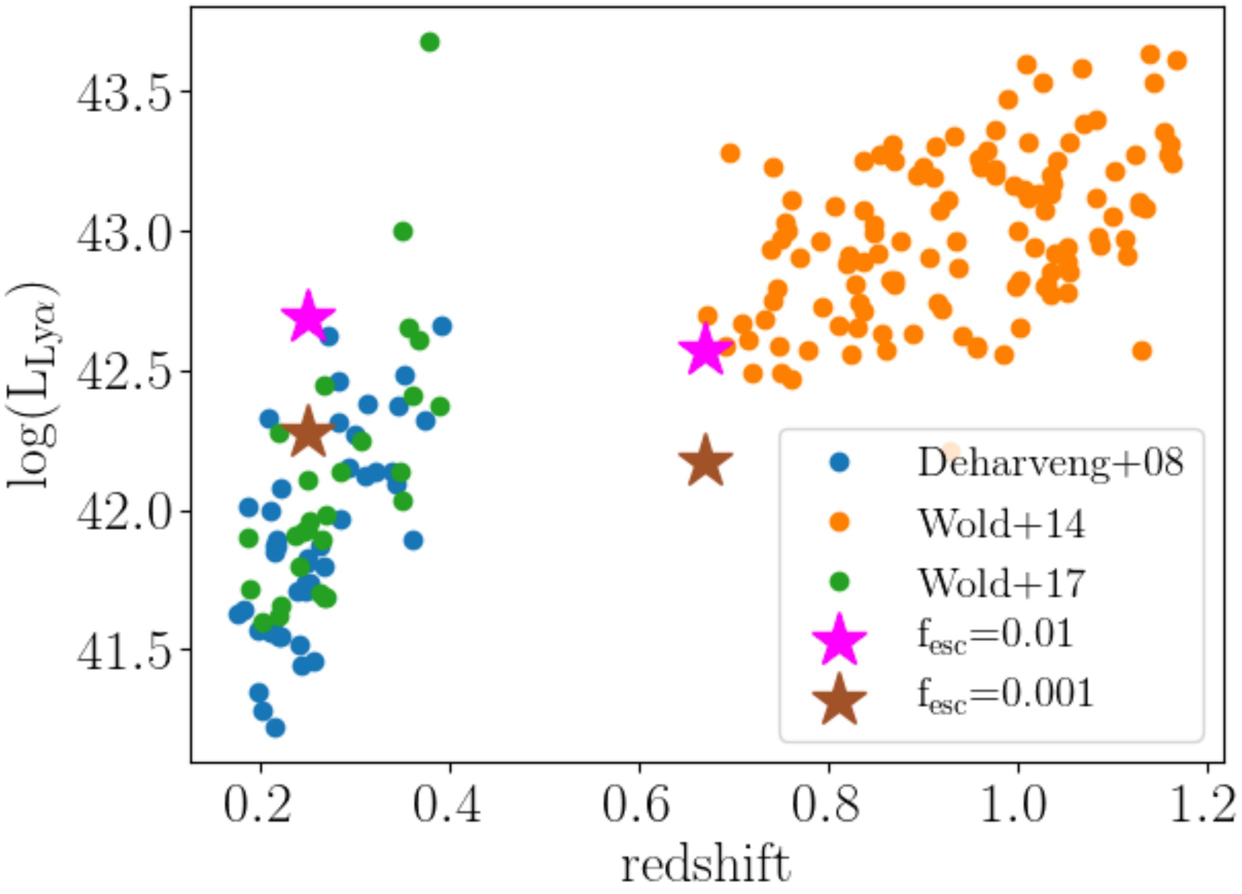
Lya brightest "cold" emission line

OVIII brightest "hot" emission line

→ cool gas clumpy

→ hot gas more homogeneous and extended

Simulation validation with observations at low redshift



UV observations with FIREBall-2

UV multi-object spectrograph on a balloon (~300 targets)

Designed to discover and map the faint emission from the CGM at low redshifts (0.3-1)

To be launched from Fort Sumner, New Mexico in September 2018

Narrow window around 2000 Å

- CIV at z=0.3
- Lyα at z=0.7
- OVI at z=1.0

FIREBall Team

Caltech:
C. Martin (PI)
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G. Kyne
K. Hoadley

Columbia:
D. Schiminovich
J. Gross
N. Melso

LAM:
B. Milliard
R. Grange
D. Vibert
C. Peroux
R. Augustin
V. Picouet

Credit: P. Balard (LAM)

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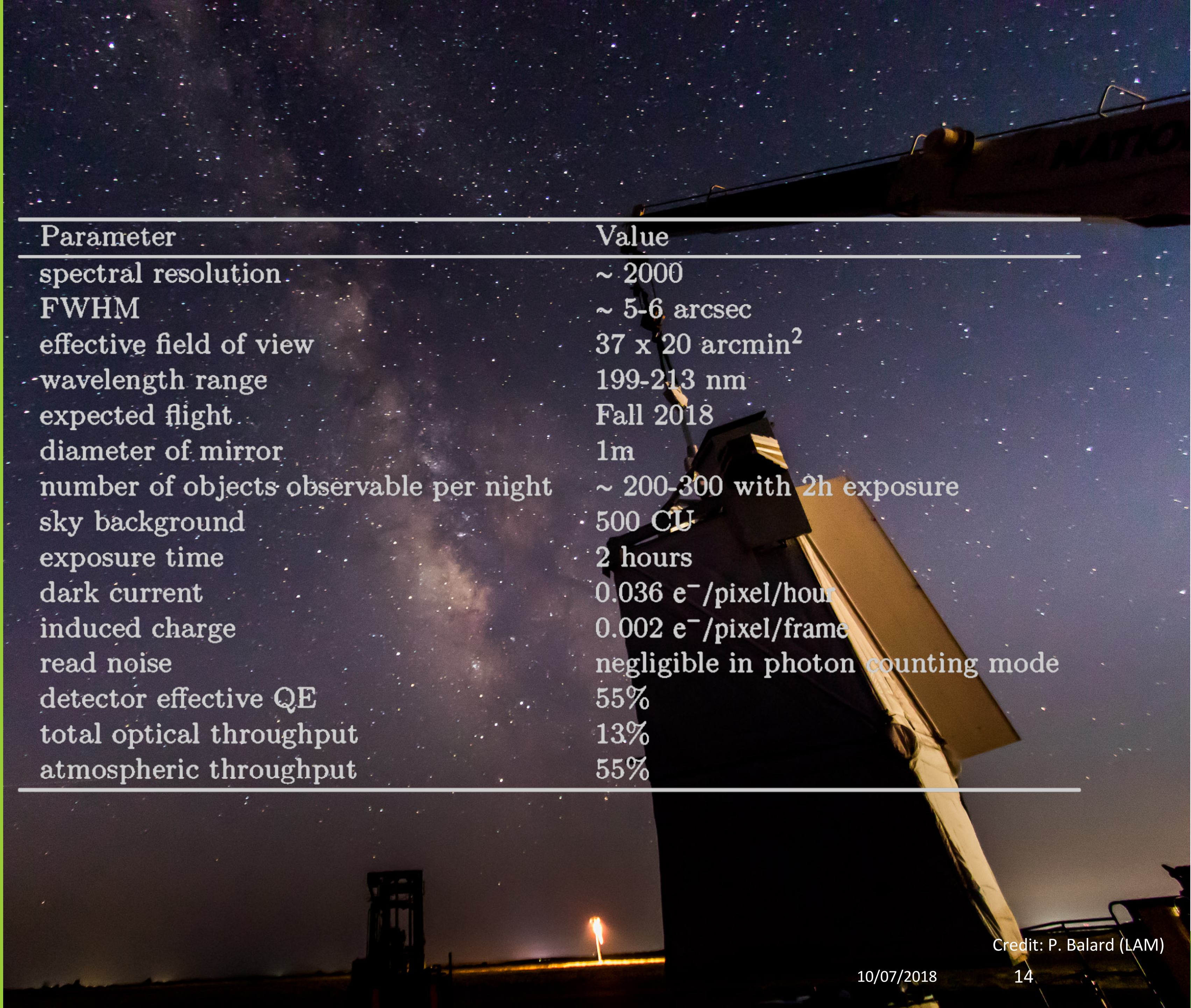
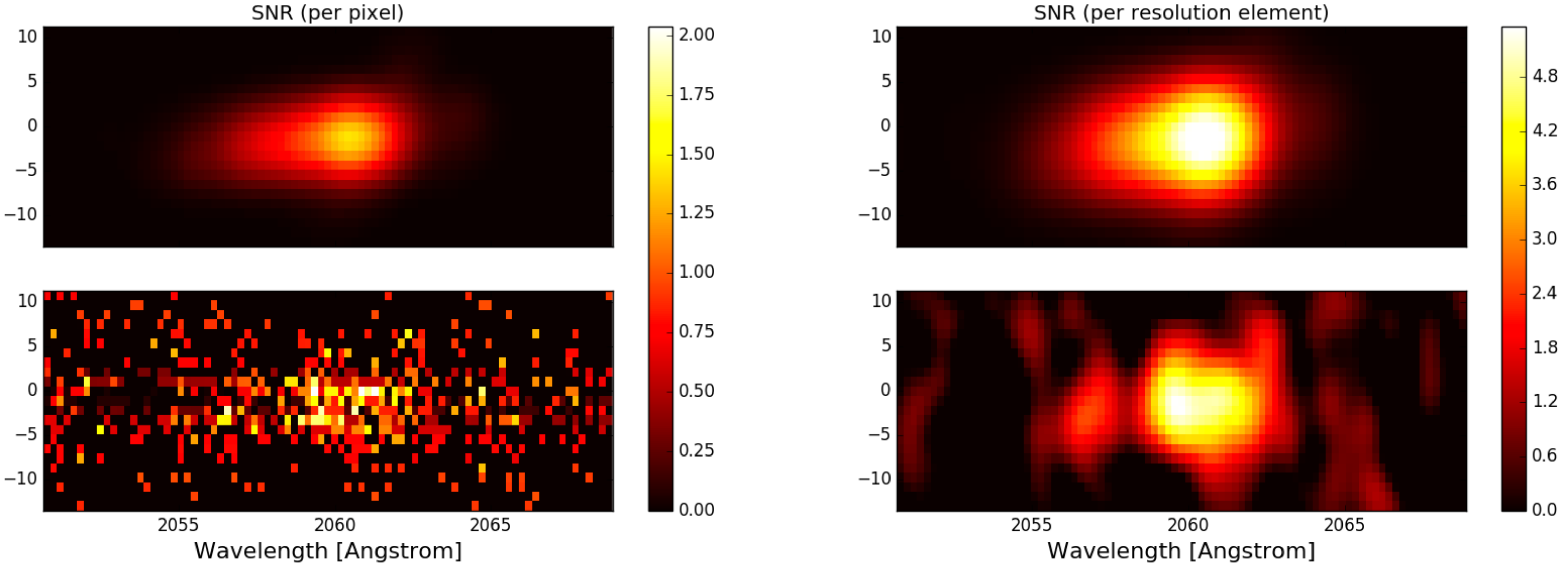
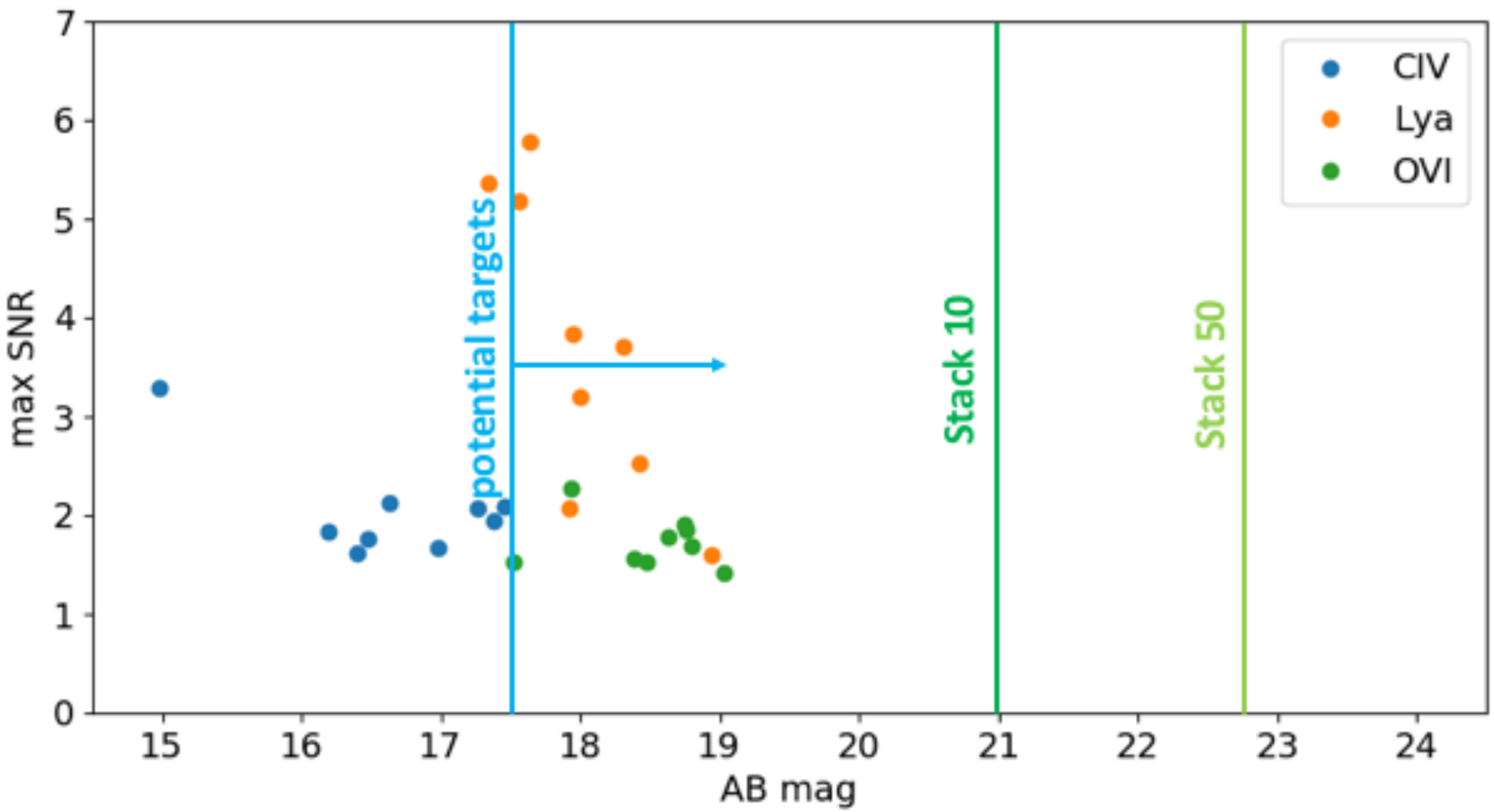


Parameter	Value
spectral resolution	$\sim$ 2000
FWHM	$\sim$ 5-6 arcsec
effective field of view	37 x 20 arcmin^2
wavelength range	199-213 nm
expected flight	Fall 2018
diameter of mirror	1m
number of objects observable per night	$\sim$ 200-300 with 2h exposure
sky background	500 CU
exposure time	2 hours
dark current	0.036 e$^-$/pixel/hour
induced charge	0.002 e$^-$/pixel/frame
read noise	negligible in photon counting mode
detector effective QE	55%
total optical throughput	13%
atmospheric throughput	55%

Credit: P. Balard (LAM)

Expected Signal for Lyα at z=0.7



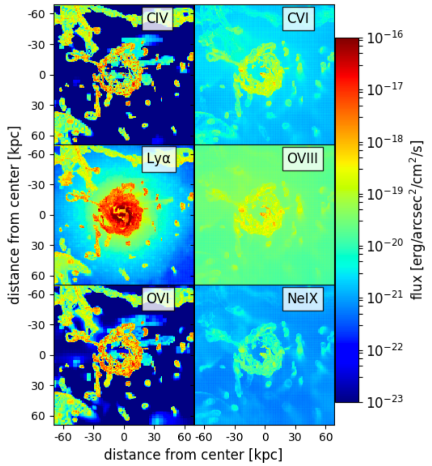


Signal of the emission from the CGM

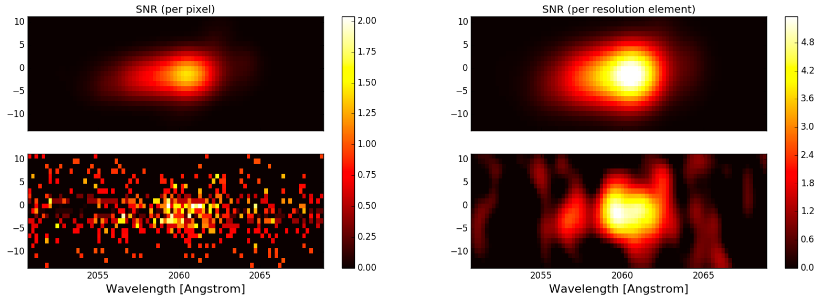
Summary and Conclusions

Cosmological zoom-in simulations with the AMR RAMSES code + Emission model from CLOUDY

→Post-processing of simulated galaxy halos to create mock observations



Use simulated observations as input for the instrument model of FIREBall-2



→ FIREBall-2 will observe the low-z CGM emission in UV for the very first time!

→Results:

- Bright sources such as quasars will give a good SNR of the CGM
- Fainter Lyα sources can be stacked to achieve a good SNR of the CGM
- Metal lines such as OVI and CIV remain very challenging to observe in emission