Using Lyman-α to probe LyC escape from galaxies

Anne Verhamme

Assistant Professor, Geneva University
Associate Researcher, CRAL Lyon

Simulations and Observations: complementary approaches to understand the nature of the sources of cosmic reionisation

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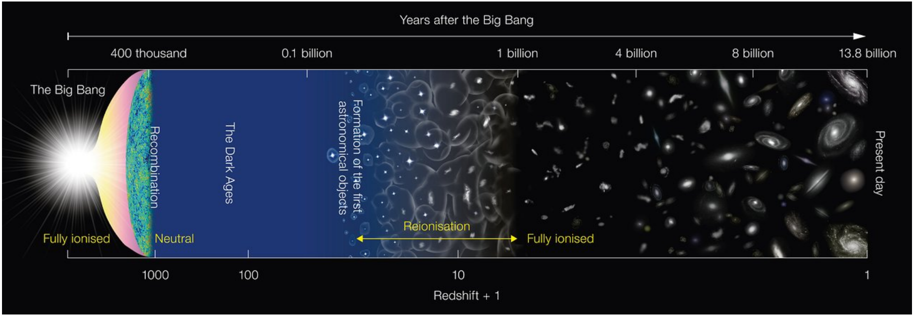
What is Cosmic Reionization ? Why is it important ?



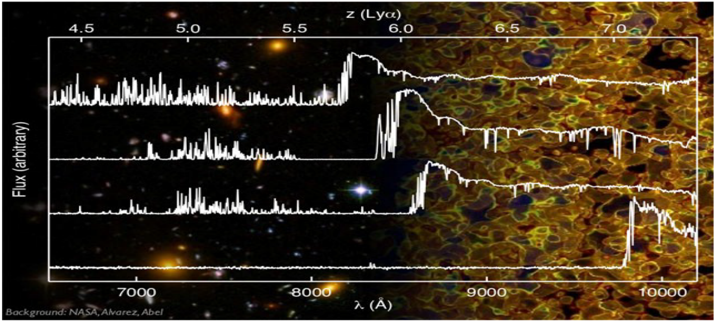
* major phase transition in the history of the Universe
* strong impact on galaxy formation and evolution
* main unknown : the nature of the sources of Reionization

z ~ 5.7

z ~ 5.9

z ~ 6.1

z ~ 7.1



* Intergalactic medium (IGM) opacity increases with redshift
* direct detection of LyC impossible from galaxies at $z > 6$

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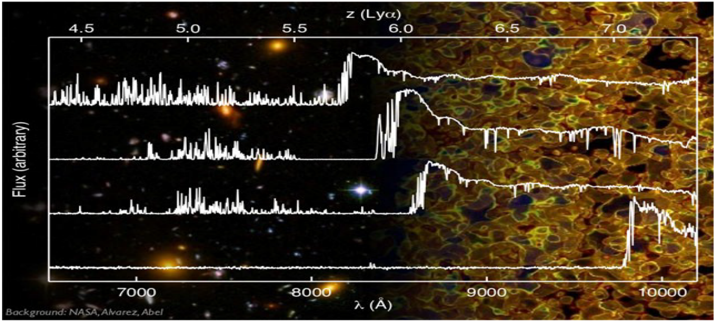
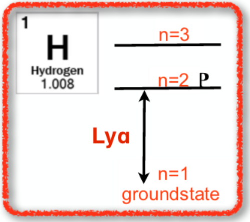


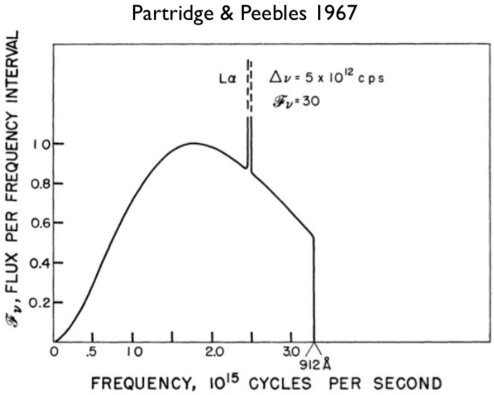
* Intergalactic medium (IGM) opacity increases with redshift
* direct detection of LyC impossible from galaxies at $z > 6$

$\longrightarrow$ need for indirect diagnostics of LyC leakage from galaxies

Lyα escape from galaxies : strong line

M. Dijkstra, Saas Fee Advanced School 2016

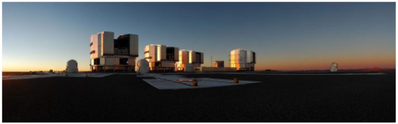




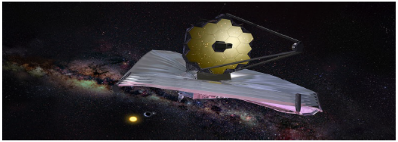
~7-40% (!) of bolometric luminosity of young galaxies in Lyα emission line

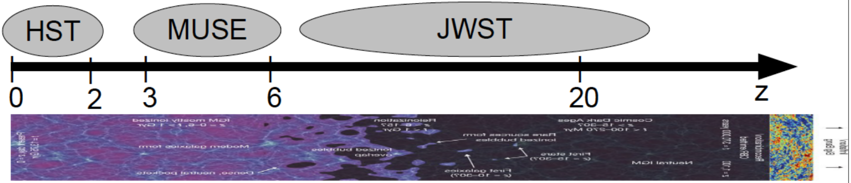
Lya in UV with HST

Lya in optical from the ground



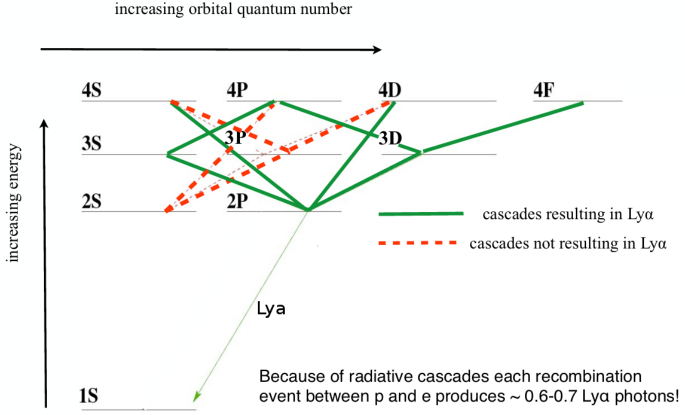
Lya in IR with JWST





Lyα escape from galaxies : resonant line

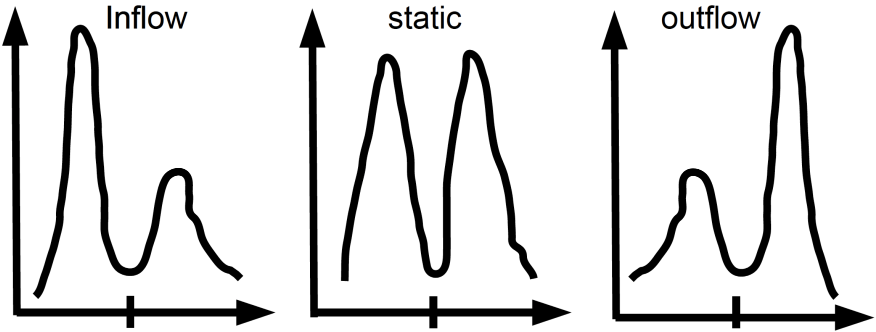
M. Dijkstra, Saas Fee Advanced School 2016



The basics of Lyα RT : kinematics

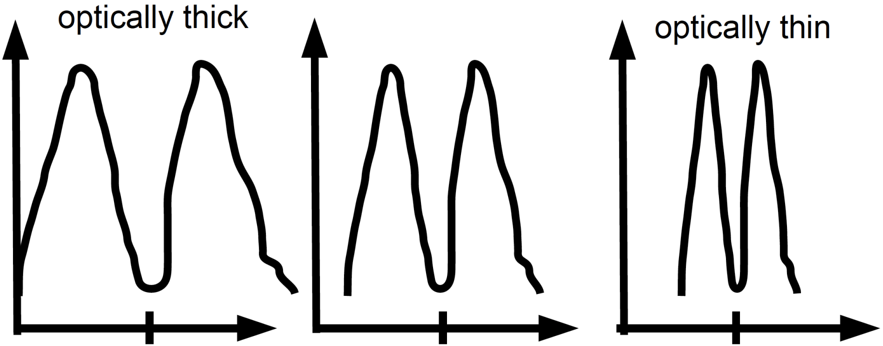
* Lyα is never tracing line of sight velocity, as an absorption line would do, but the bulk velocity of the scattering medium with respect to the Lyα source

effect of kinematics of the scattering medium



* Lyα spectrum= distribution of the minimun necessary shifts for escape : always follows/traces the path of least opacity

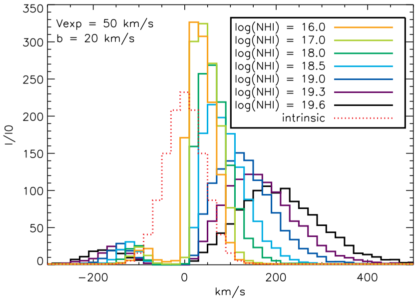
effect of density of the scattering medium



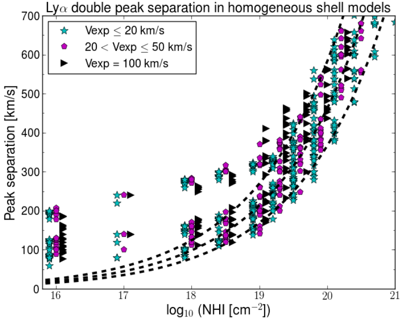
The basics of Lyα RT through expanding shells

Verhamme+15

synthetic Lyα spectra from expanding shells



correlation between peaks separation and NHI

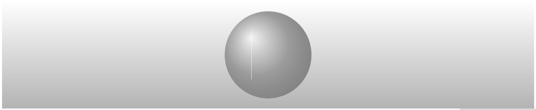


Outline

* the Lyα luminosity indicates LyC emission
* the Lyα spectral shape indicates LyC emission
* the Lyα spatial extend indicates LyC emission
* BlueMUSE : what fraction of LAEs at z$\sim$ 3 to 3.8 are LCEs ?
* BlueMUSE : test MgII properties of LCEs at z$\sim$ 0.3

SPHINX : RHD cosmological simulations of reionisation

Rosdahl+18



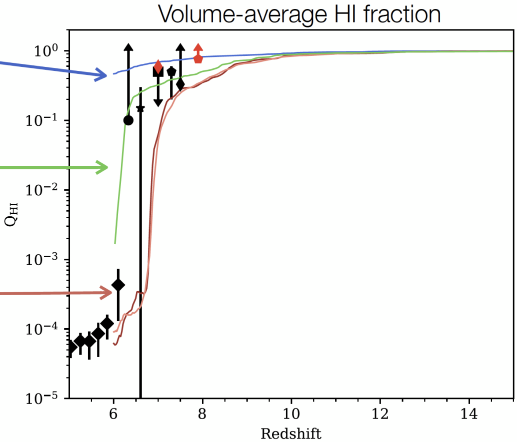
* full RHD
* 10pc resolution
* Published runs (Rosdahl+18) : 5 and 10 cMpc boxes.
* New SPHINX20 has reached z=6.15 in 20 cMpc.

SPHINX : RHD cosmological simulations of reionisation

Stellar population without binary stars

Stellar population with 70% binaries (BPASS v2) **SPHINX[20]**

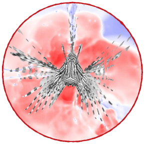
Stellar population with 100% binary stars (BPASS v1)



Larger binary fractions => more ionizing photons are emitted after the star-forming clouds are disrupted, i.e. in an optically thin environment.

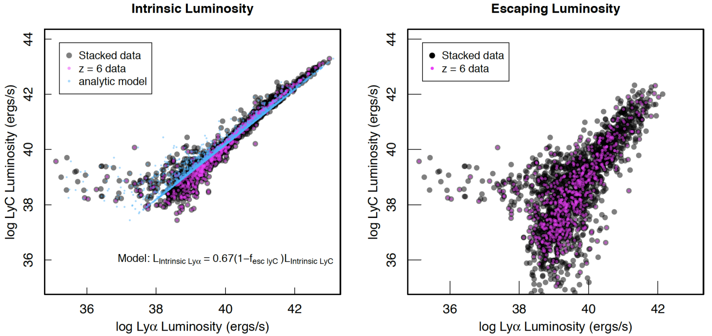
Lyα luminosity correlates with LyC luminosity

Moupiya Maji et al in prep.



Lyα properties of a sample of virtual galaxies

* from the SPHINX RHD simulation *Rosdahl+18*
* Lyα RT simulations done with RASCAS *Michel-Dansac+20*
* $\sim$ 2000 galaxies with masses M$>10^6 M_\odot$
* integrated quantities : Lyα budget



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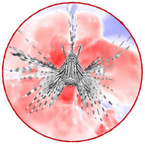

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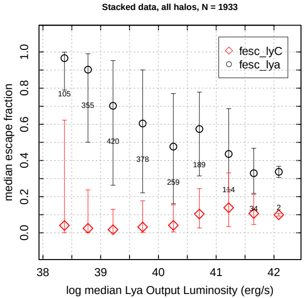
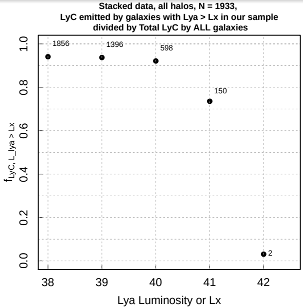
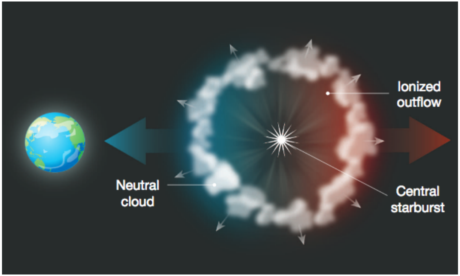


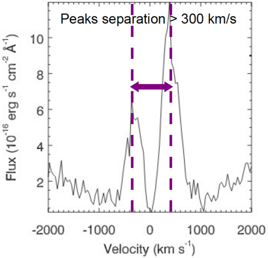


Lyα spectral shape correlate with LyC escape

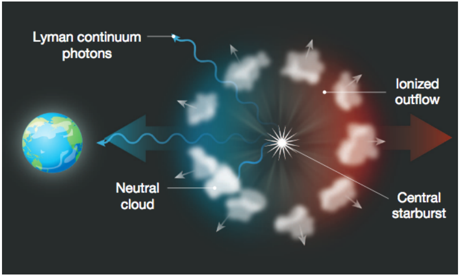
Verhamme+15, *figures adapted from Erb15, Jaskot+14*

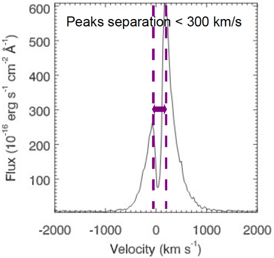
fesc(LyC) = 0





fesc(LyC) > 0

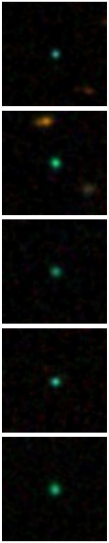


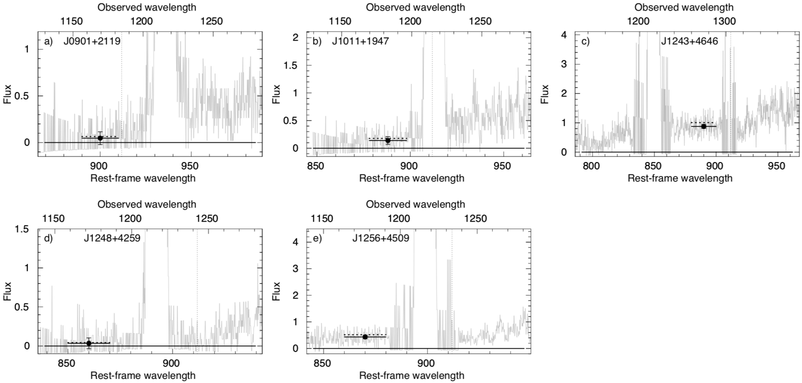


Green Peas : 11/11 LyC emitters, fesc(Lyc) 2-73%

Izotov+16ab, Schaerer+16, Verhamme+17, Chisholm+17, Izotov+18ab

OIII/OII > 4





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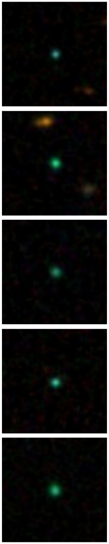
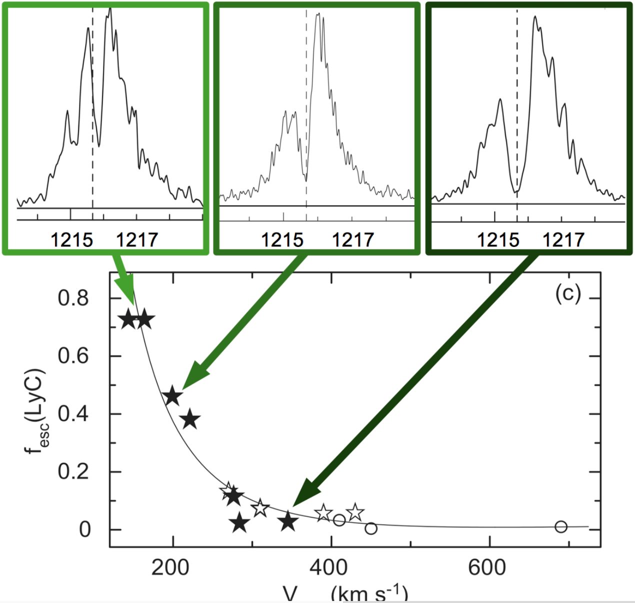




LyC emitters should have no Lyα halo

Marchi+17, Kerutt+ in prep

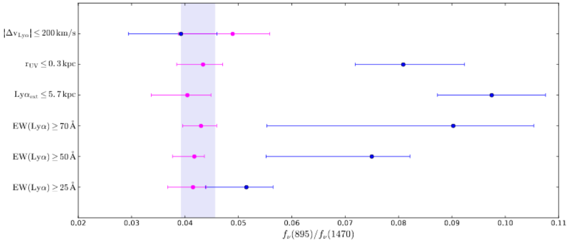
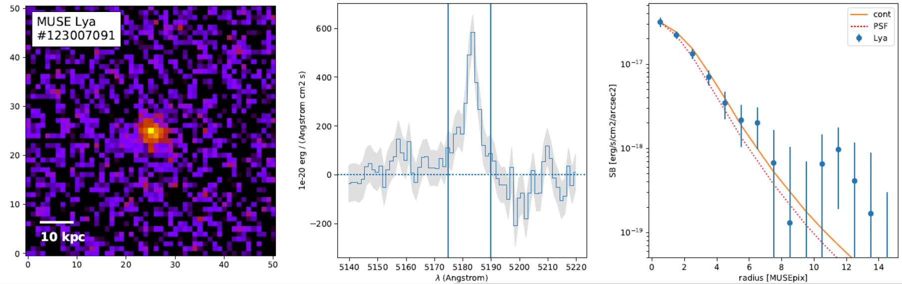


Fig. 3. Flux density ratios evaluated from the stacks of the samples in the y-axis (blue dots) and from the complementary samples (magenta dots) as indicated in Table 1. The lavender vertical band is the 1σ confidence interval evaluated for the total sample of 201 galaxies.

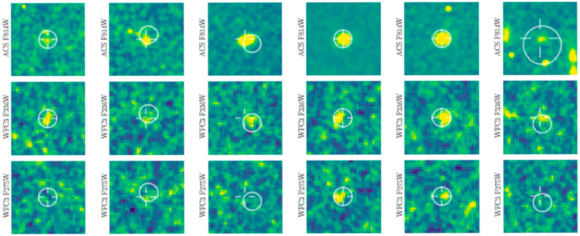


BLUE
MUSE
multi unit spectroscopic explorer

Searching for LyC emission from $z \sim 3$ to 4 LAEs with MUSE

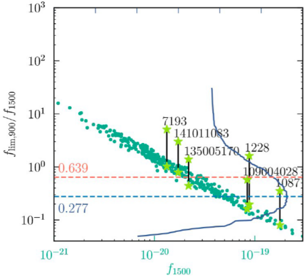
Kerutt+ in prep, see also Naidu+17 for similar z$\sim$ 2 study

- we find 6 individual candidates



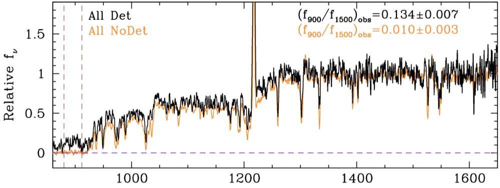
<u>Selection</u>

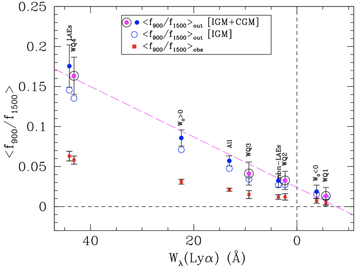
- high flux at 1500 Å
- to contribute significantly
- more will decrease signal



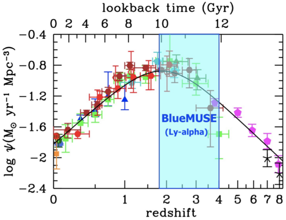
Searching for LyC emission from $z \sim 3$ to 4 LAEs with BlueMUSE

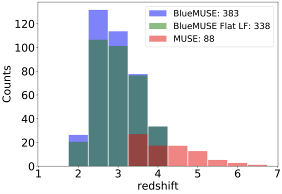
Steidel+18

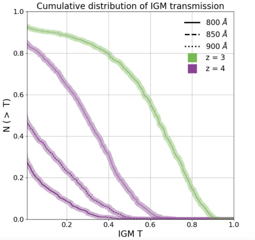


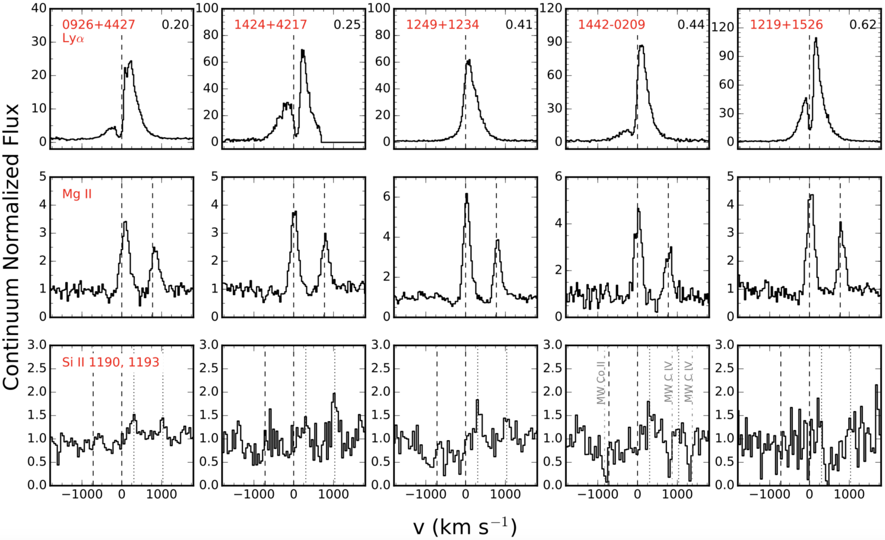


BlueMUSE white paper Feb 2020 + Josie's highlight talk









0926+4427
0.20
Lyα
1424+4217
0.25
1249+1234
0.41
1442-0209
0.44
1219+1526
0.62
Mg II
Si II 1190, 1193
MW Co II
MW C IV
MW C IV
Continuum Normalized Flux
v (km s^{-1})

Conclusions : Searching for LyC emitters wiht BlueMUSE

* Deep Fields : long integration times required to reach very faint flux limits (f900/f1500 < 0.1 from Steidel+18)
* Statistics : the bigger the field of view, the better
* Spectral resolution : R$\sim$3500 enough to resolve small peaks separation in Lyα.
* probing the LyC shape on long wavelengths : the lower the blue cut off the better to probe lyC at $\lambda < 800$Å.