

Exploiting 21cm - Lyman- α emitter synergies: constraints on reionization

arXiv 1605.01734

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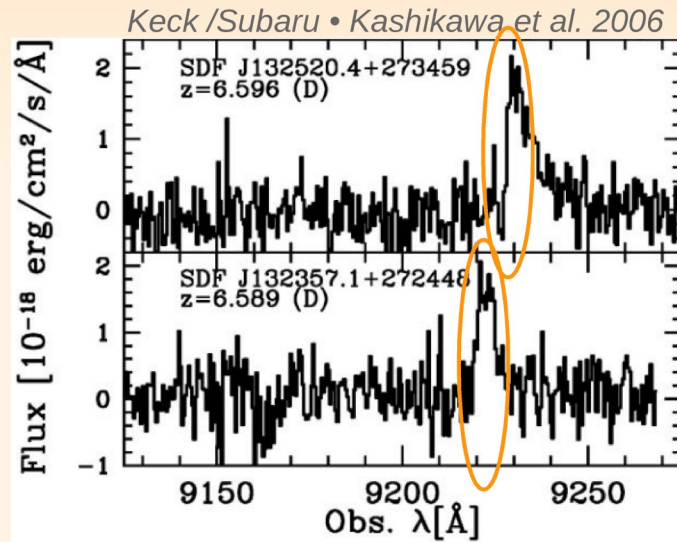
² Kapteyn Astronomical Institute Groningen

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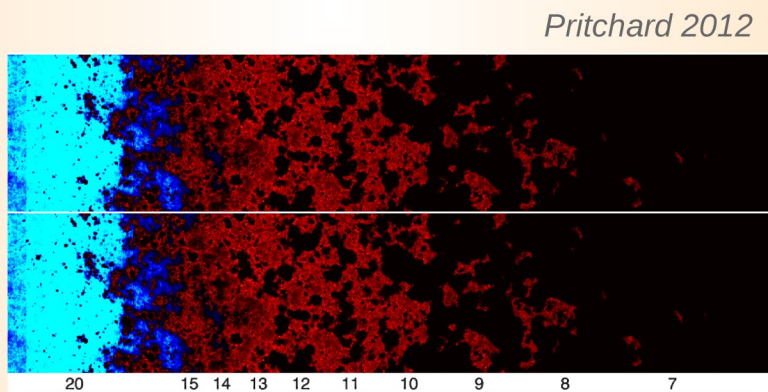
⁴ ICRAR, Curtin University Perth

Constraining reionization & high-z galaxies

OBSERVATIONS

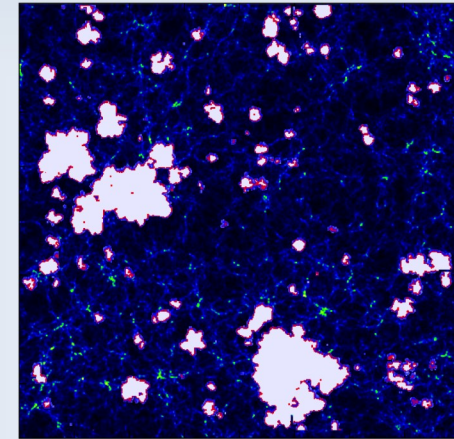


LYMAN ALPHA EMITTERS (LAEs)



21cm RADIATION

C
O
M
P
A
R
I
S
O
N



INTERGALACTIC MEDIUM

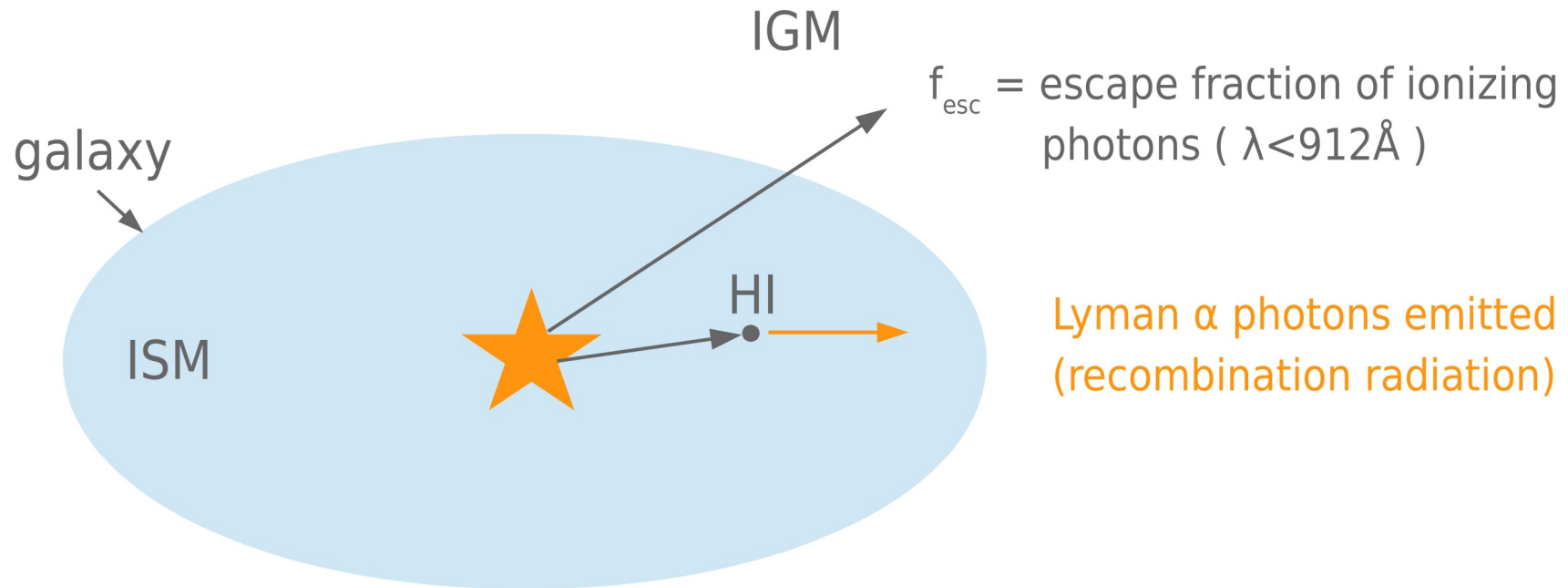


GALAXY PROPERTIES

C. Howk (JHU), B. Savage (U. Wisconsin),
A. Sharp (NOAO/WIYN/NOAO/NSF)

MODELS & SIMULATIONS

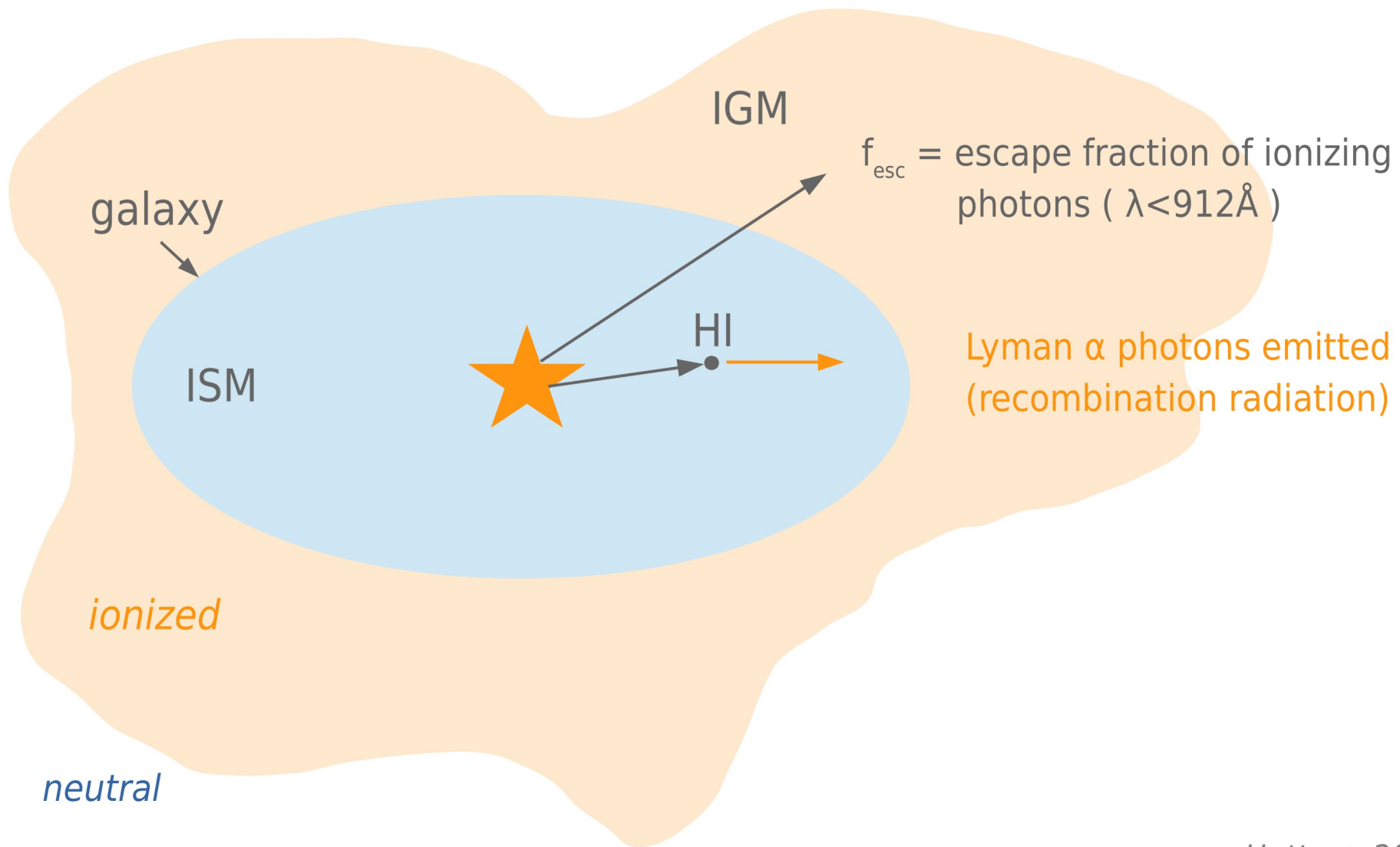
Lyman α emitters (LAEs) in the intergalactic medium



ISM = interstellar medium
IGM = intergalactic medium

Hutter+ 2014

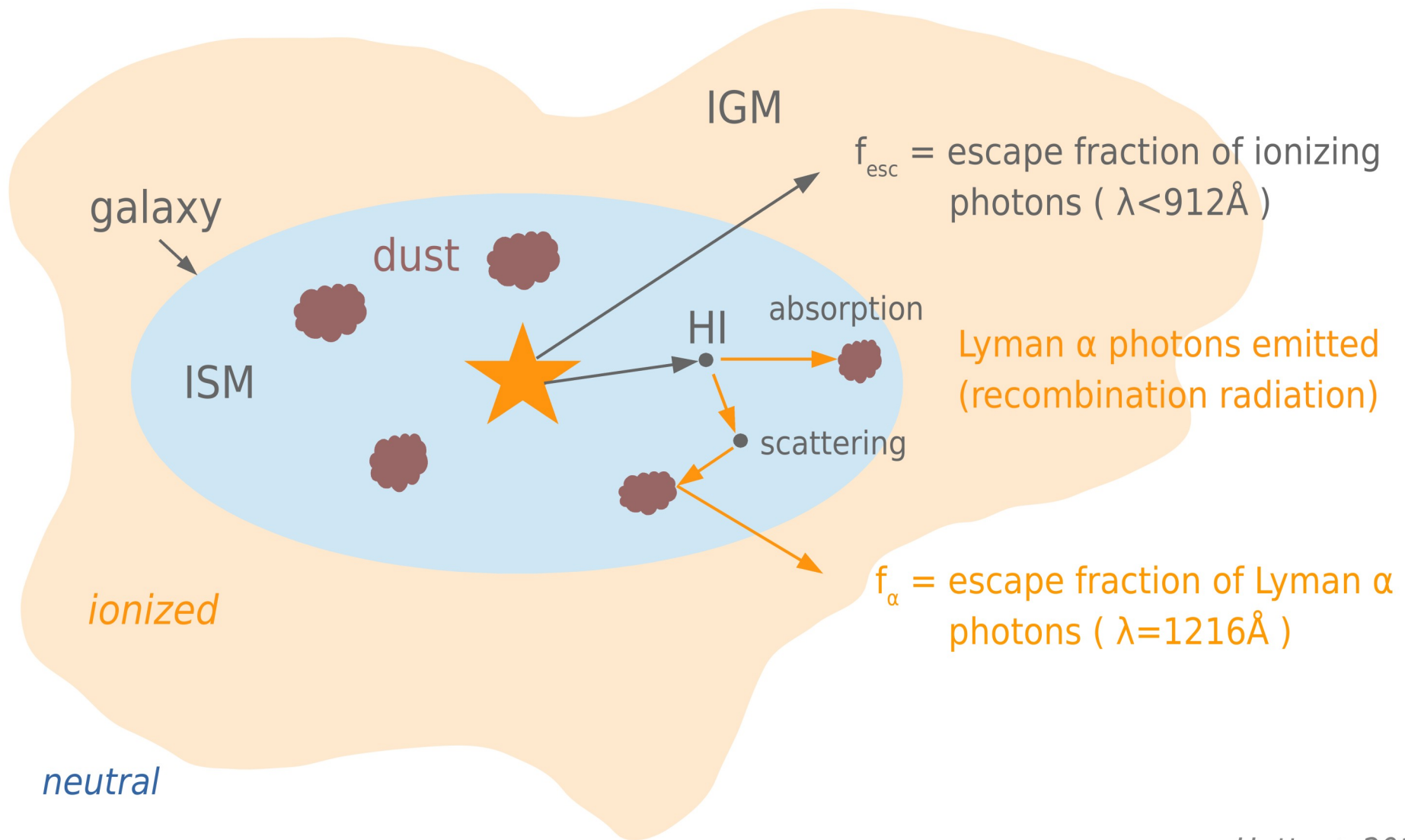
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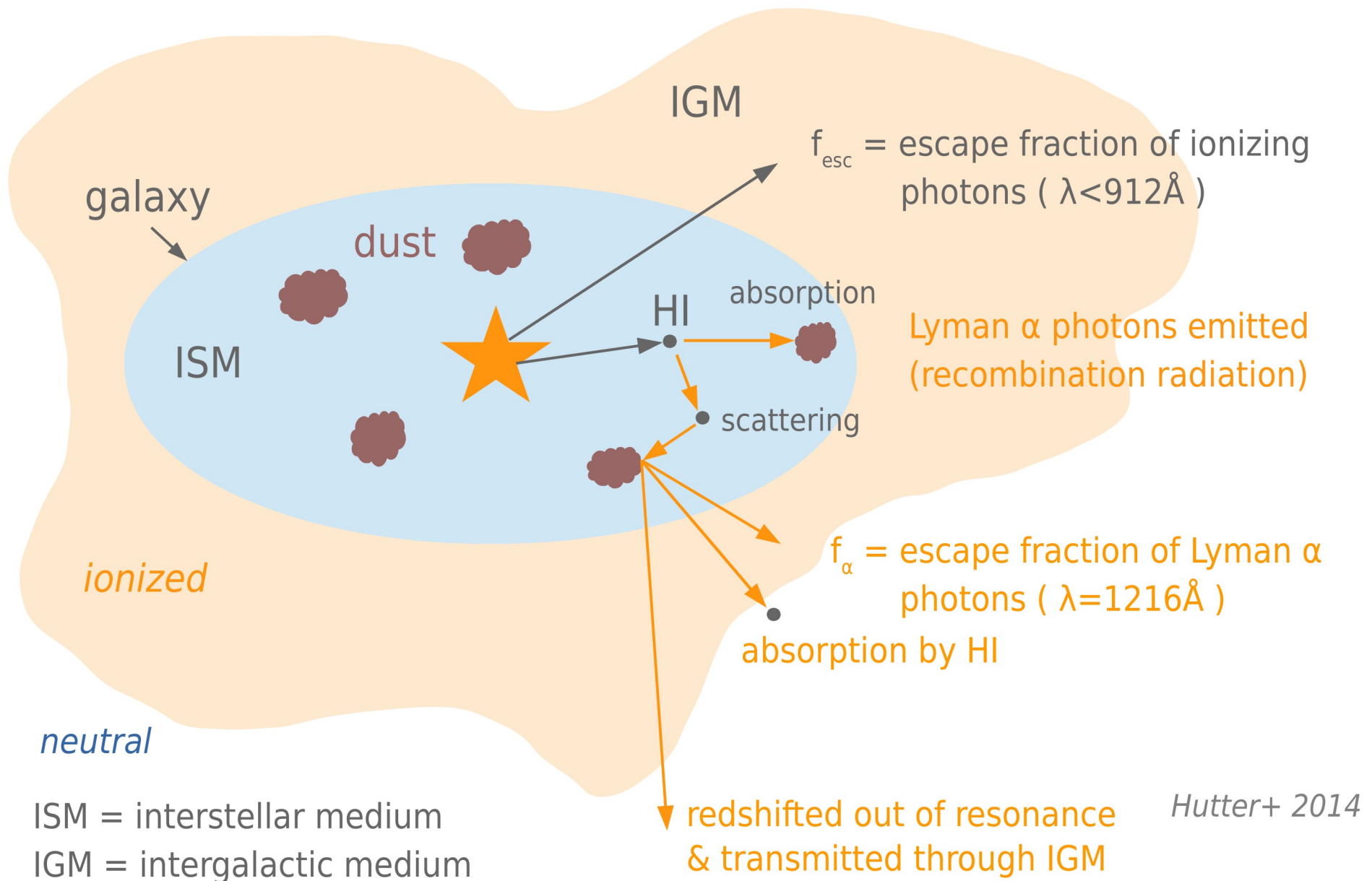
Lyman α emitters (LAEs) in the intergalactic medium



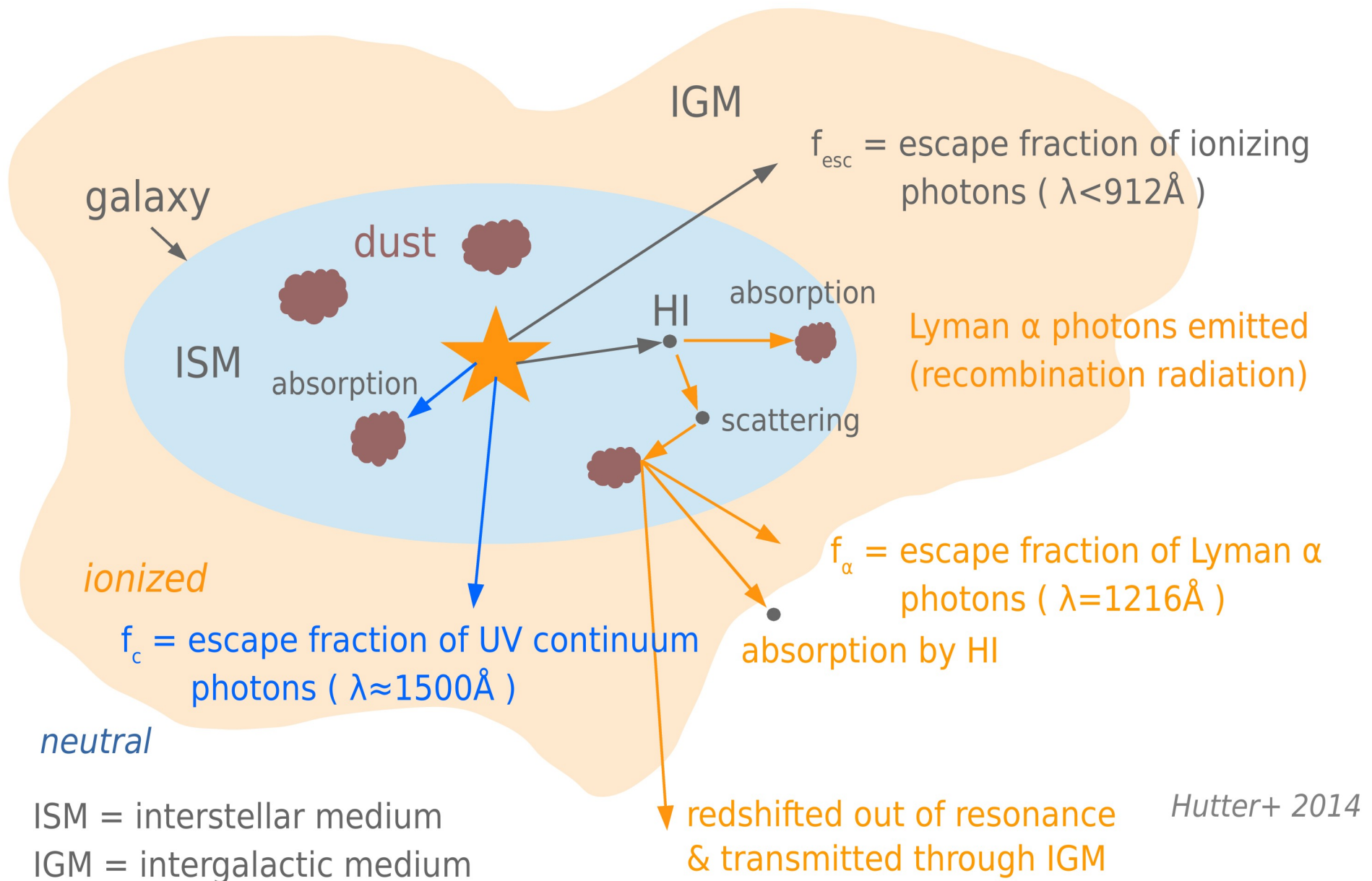
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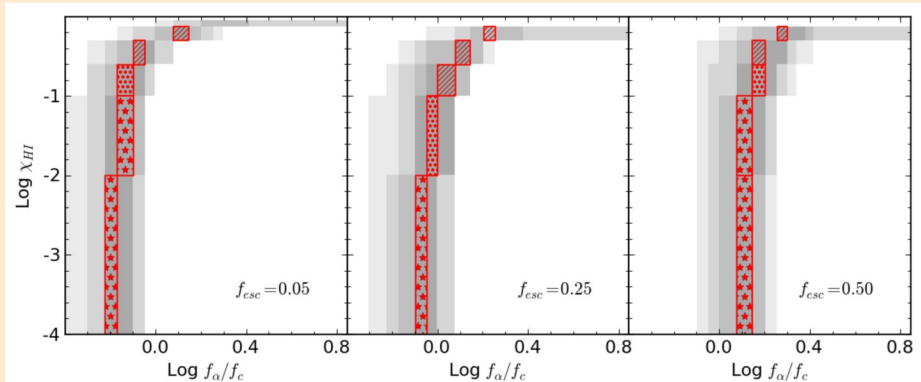
Lyman α emitters (LAEs) in the intergalactic medium



Lyman α emitters (LAEs) in the intergalactic medium



21cm-LAE synergies

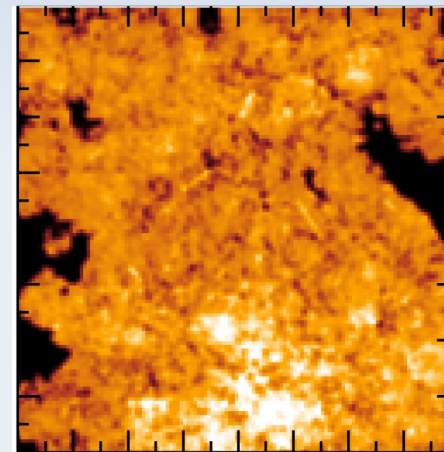


Constraints from Ly α luminosity function
& LAE angular correlation function at $z \approx 6.6$

LAEs

3D DEGENERACY between
reionization $\langle \chi_{HI} \rangle$,
escape fraction of ionizing photons f_{esc}
& dust f_{α}/f_c

Hutter+ 2014, 2015



Ionization fields differ for different f_{esc}

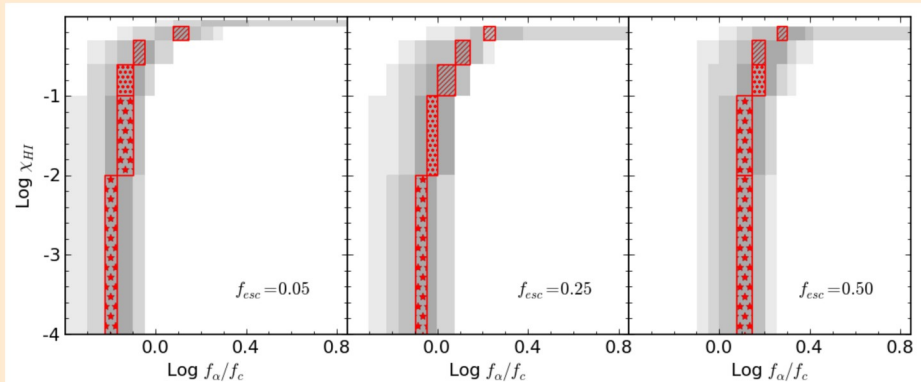
21cm

Differential 21cm brightness
temperature:

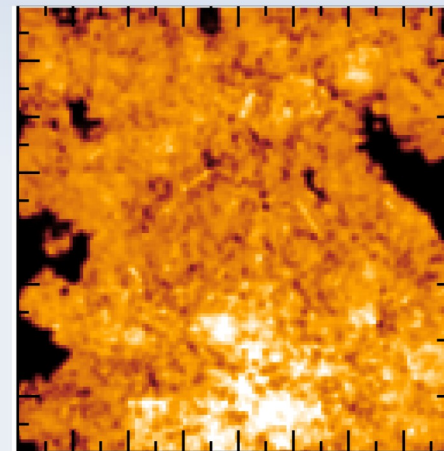
$$\delta T_b = T_0 \langle \chi_{HI} \rangle (1+\delta) (1+\delta_{HI})$$

Hutter+ 2016

21cm-LAE synergies



Constraints from Ly α luminosity function & LAE angular correlation function at $z \approx 6.6$



Ionization fields differ for different f_{esc}

LAEs

Connection between galactic & intergalactic properties imprinted in

21cm

3D DEGENERACY between reionization $\langle \chi_{\text{HI}} \rangle$,

escape fraction of ionizing photons f_{esc} & dust f_{α}/f_c

Hutter+ 2014, 2015

21cm-LAE cross correlations?

Differential 21cm brightness temperature:

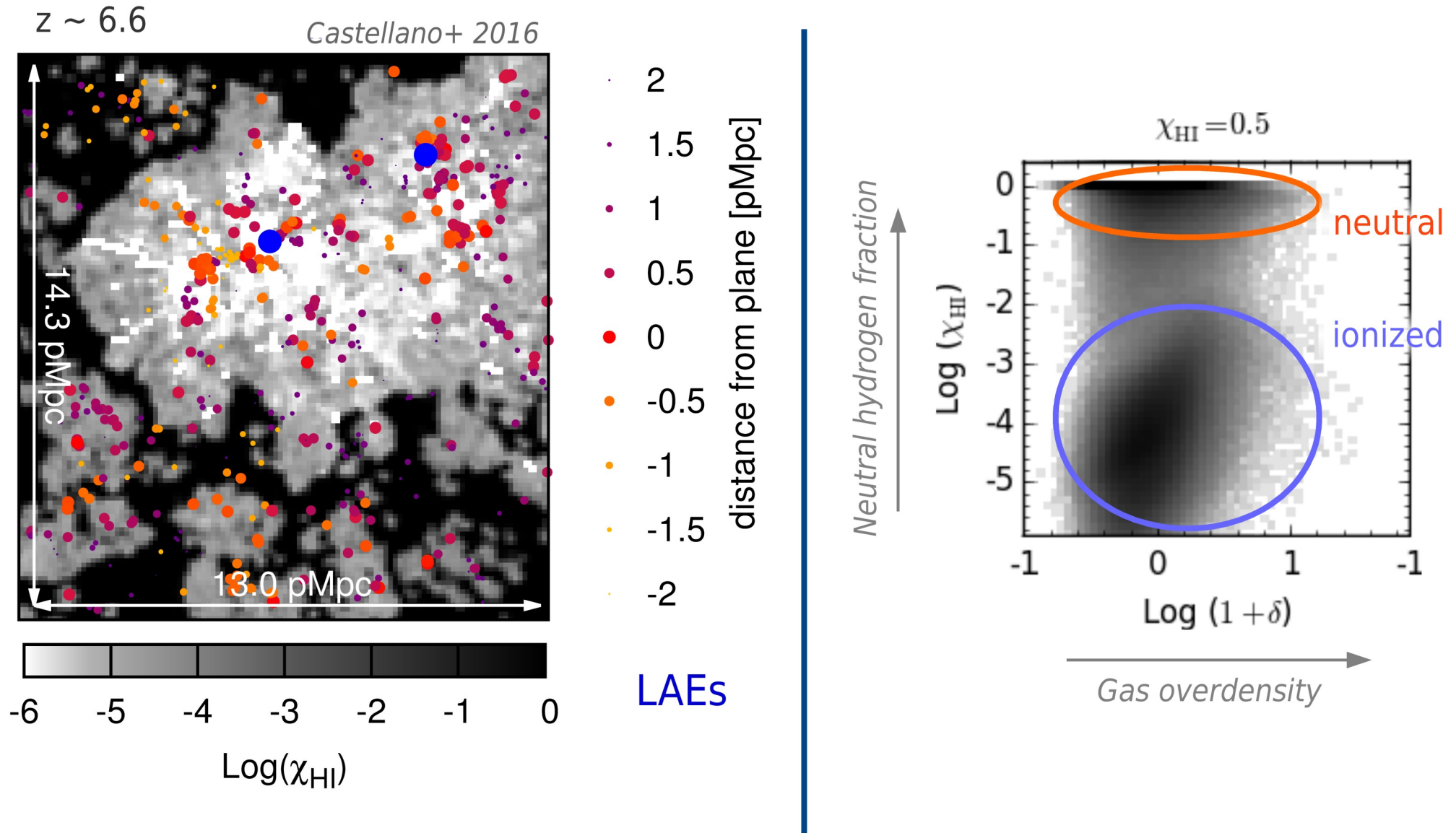
$$\delta T_b = T_0 \langle \chi_{\text{HI}} \rangle (1+\delta) (1+\delta_{\text{HI}})$$

Hutter+ 2016

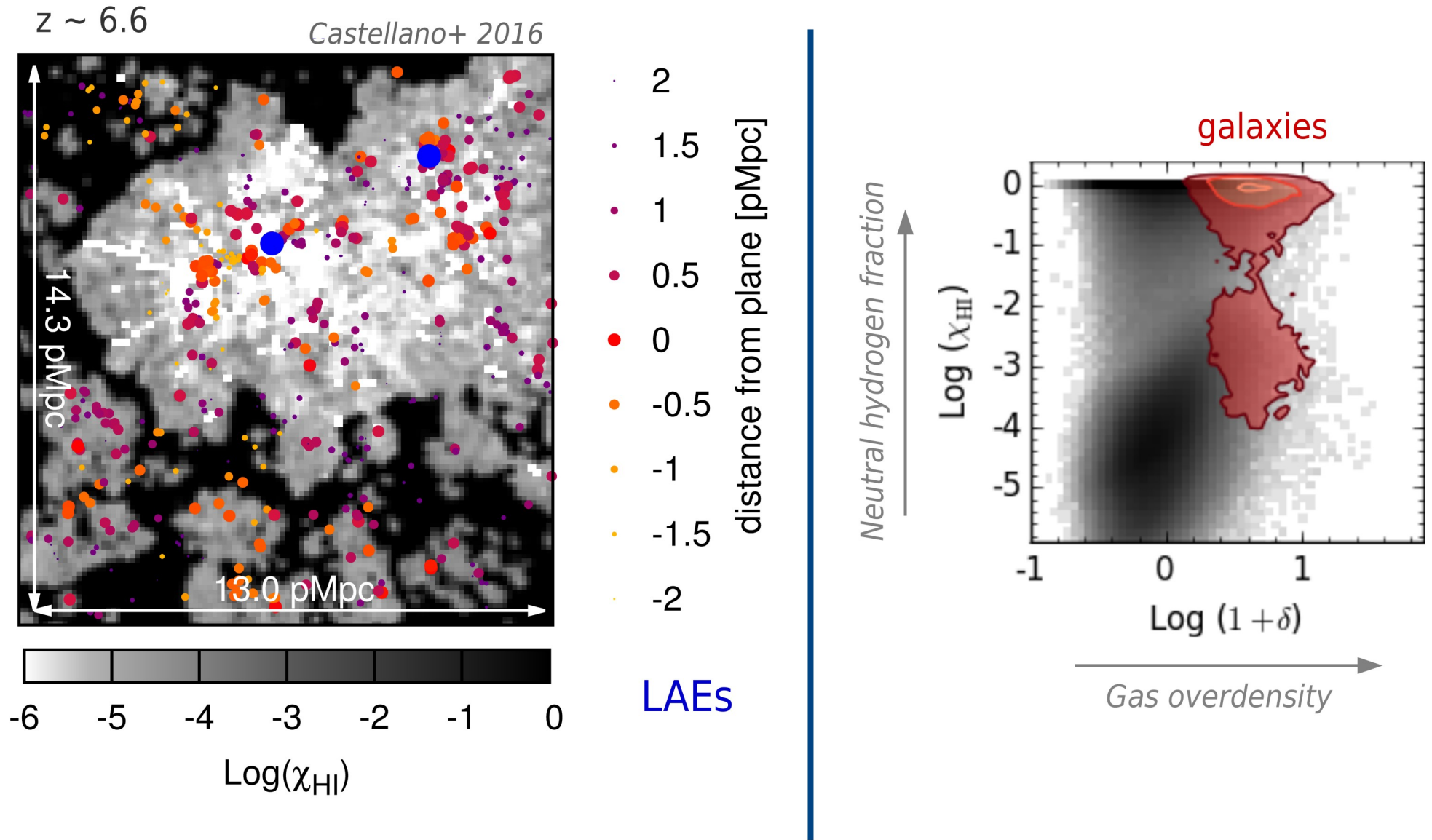
Questions

- Where in the IGM are LAEs located during reionization?
Is this reflected in the cross correlations between LAEs and 21cm signal?
- Can we constrain galaxy properties by cross correlating LAE and 21cm data?
- Can we learn something about reionization topology from cross correlating LAE and 21cm data?

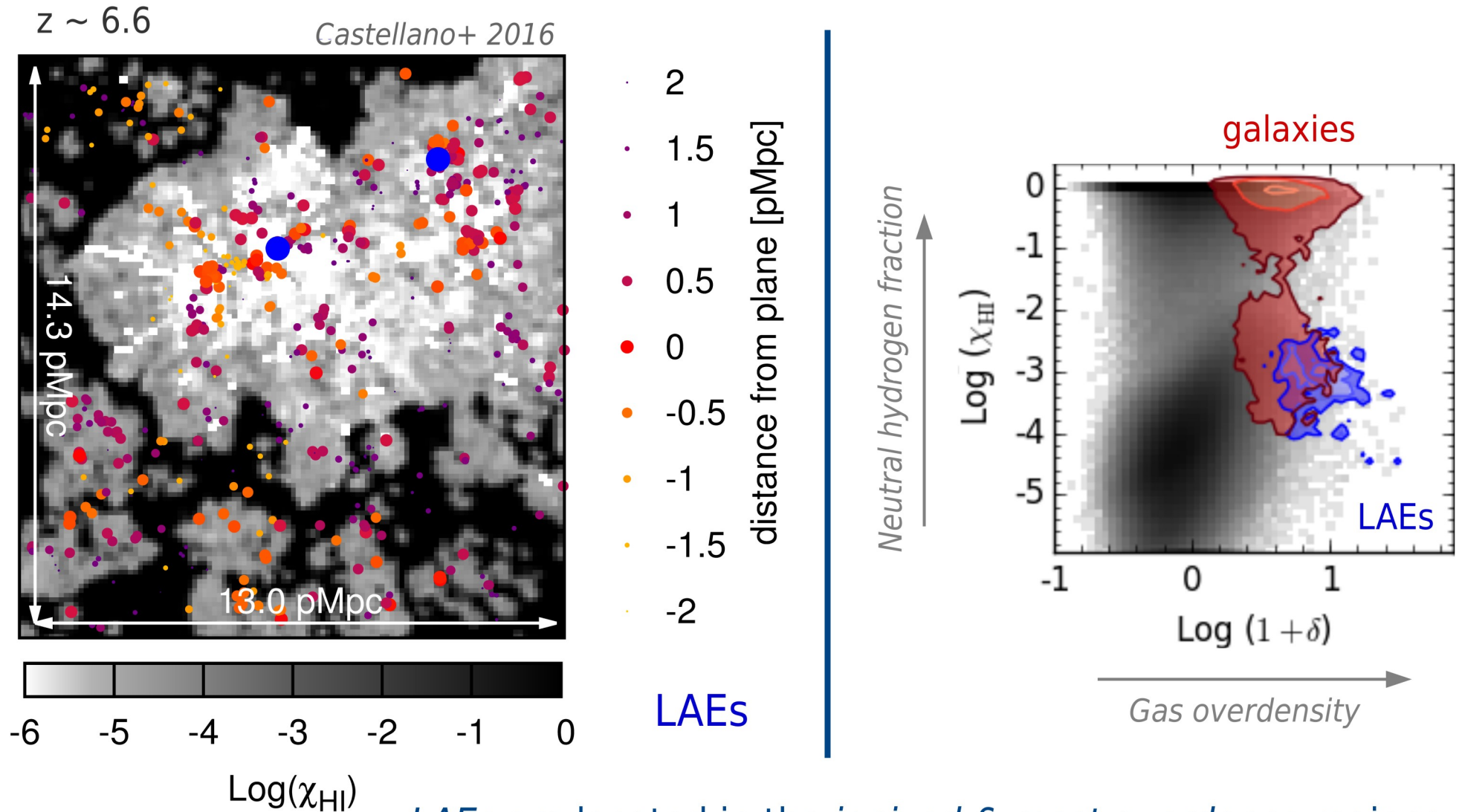
Where are LAEs located in the IGM?



Where are LAEs located in the IGM?



Where are LAEs located in the IGM?

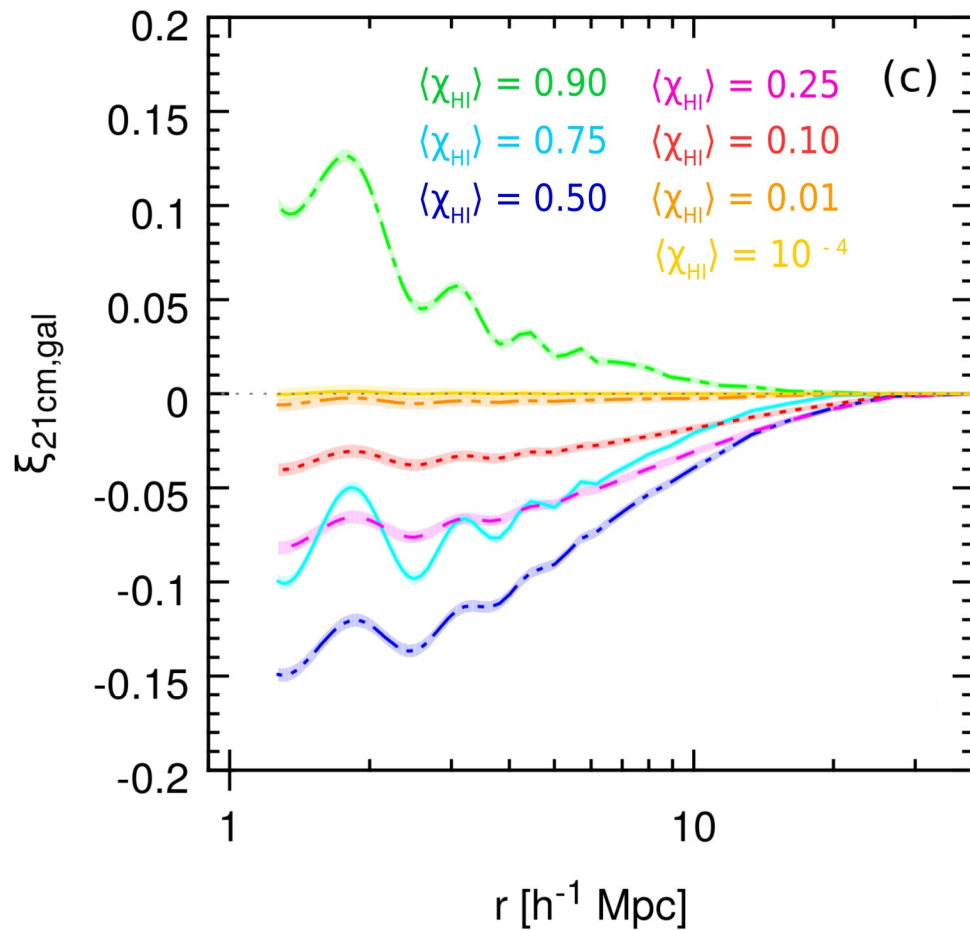


LAEs are located in the *ionized & most overdense* regions

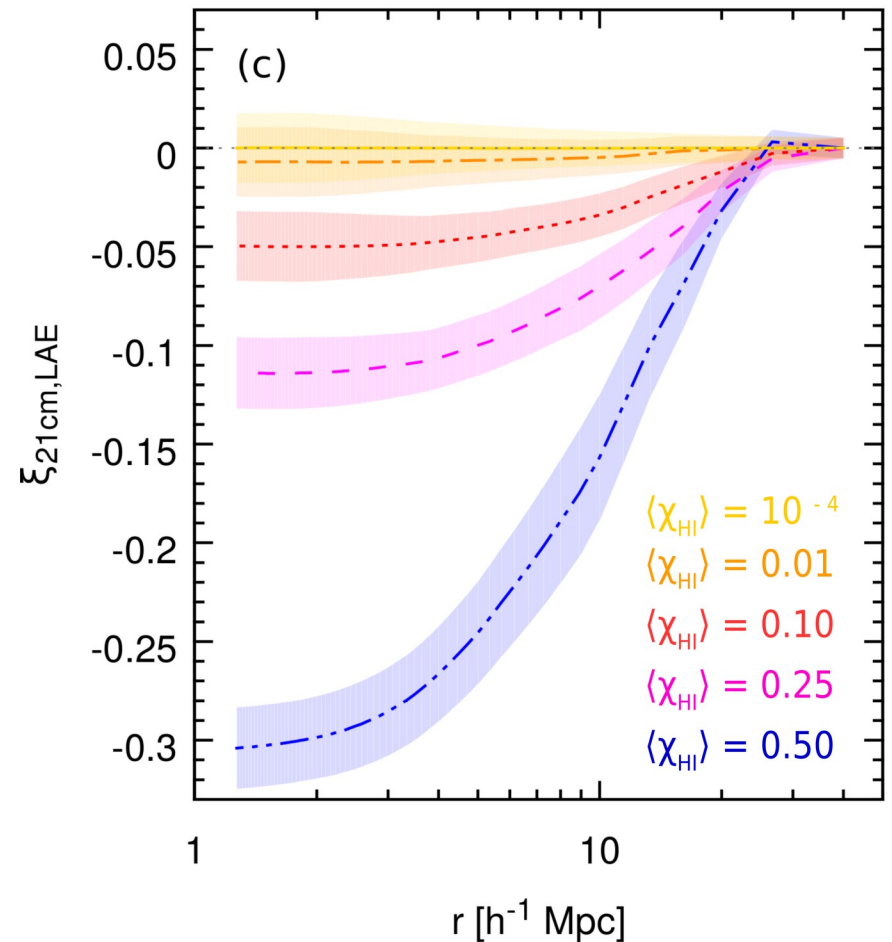
Where are LAEs located in the IGM?

21cm cross correlations with galaxies and LAEs

galaxies

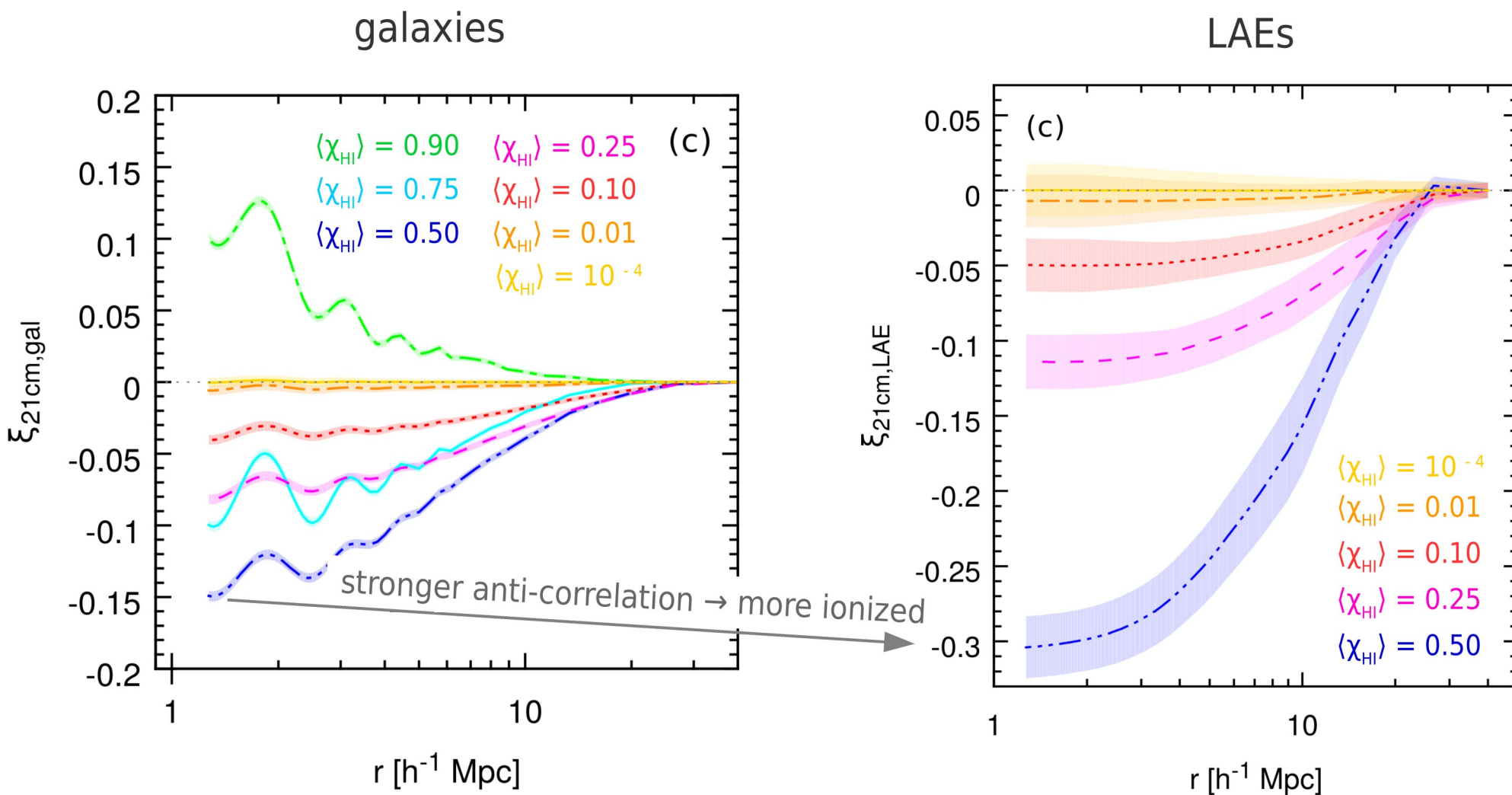


LAEs



Where are LAEs located in the IGM?

21cm cross correlations with galaxies and LAEs



21cm - LAE cross correlations depend on f_{esc} ?

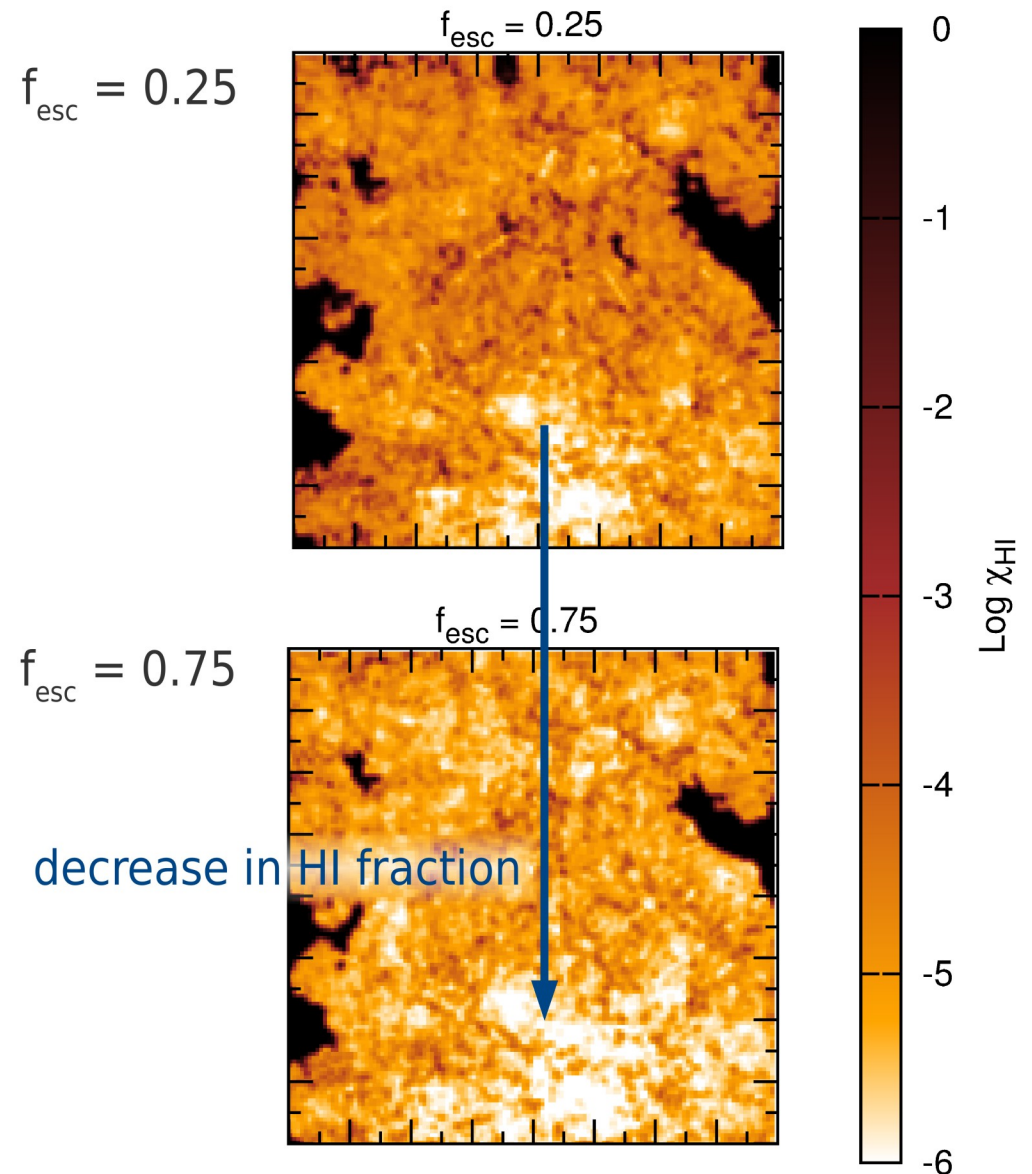
Differential 21cm brightness temperature:

$$\delta T_b = T_0 \langle \chi_{\text{HI}} \rangle (1+\delta) (1+\delta_{\text{HI}})$$

χ_{HI} decreases with increasing f_{esc}



21cm differential brightness temperature decreases with increasing f_{esc}



21cm - LAE cross correlations

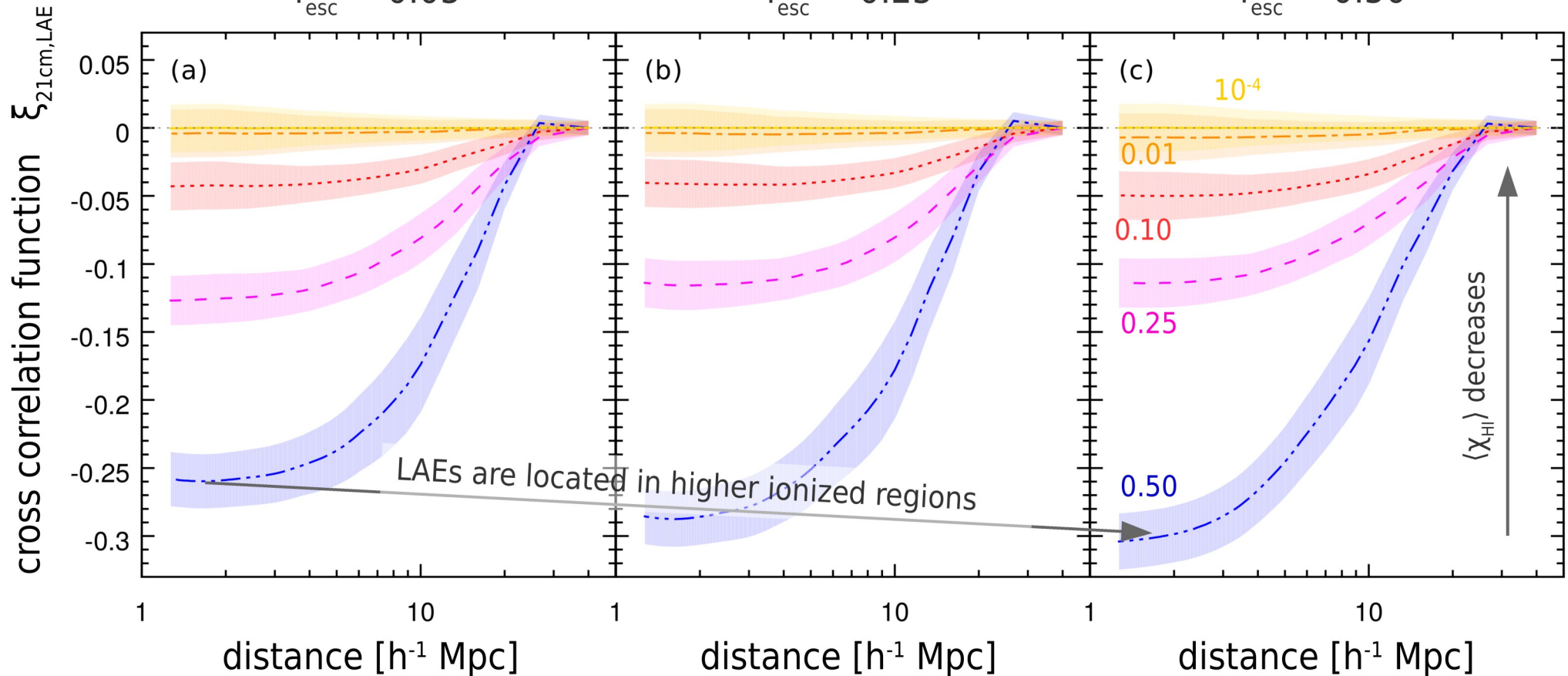
f_{esc} increases

χ_{HI} in ionized regions decreases

$f_{\text{esc}} = 0.05$

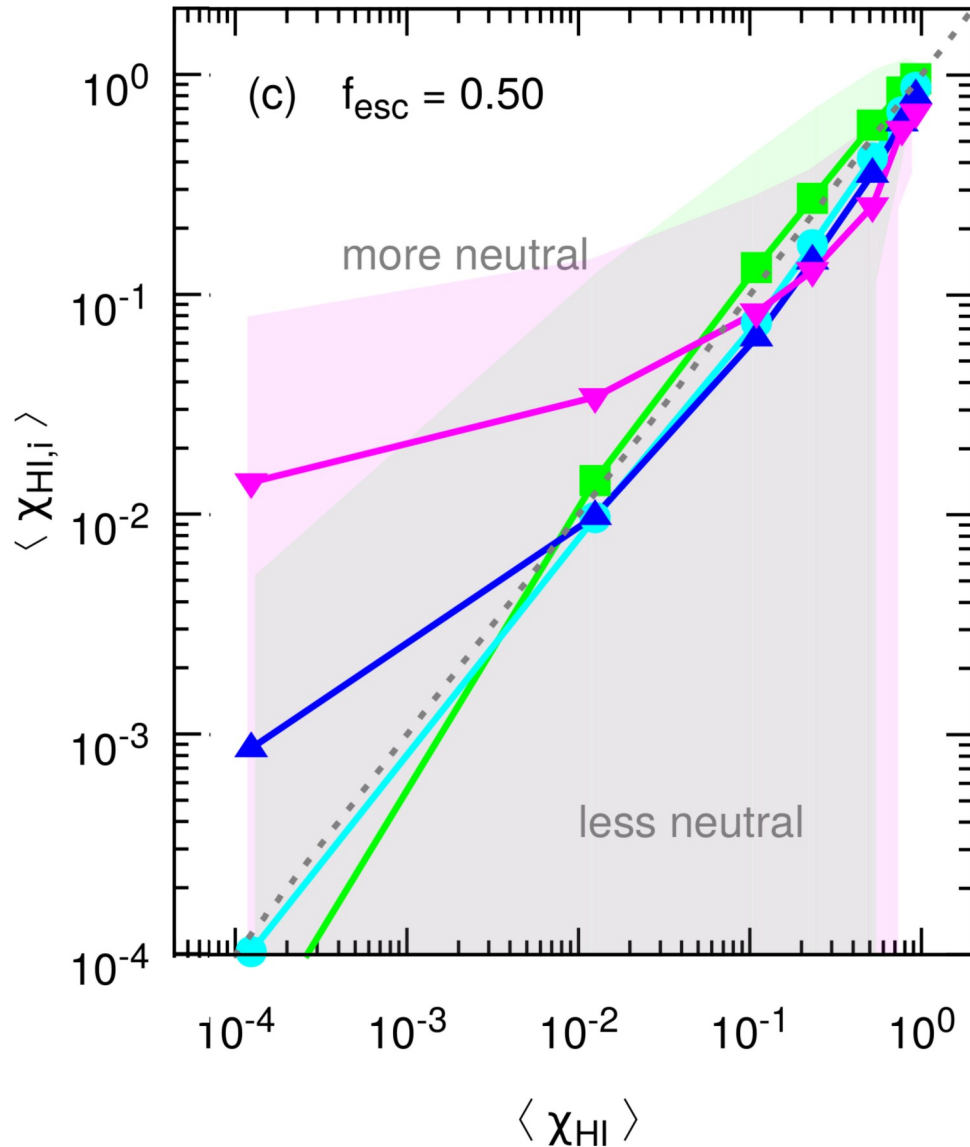
$f_{\text{esc}} = 0.25$

$f_{\text{esc}} = 0.50$

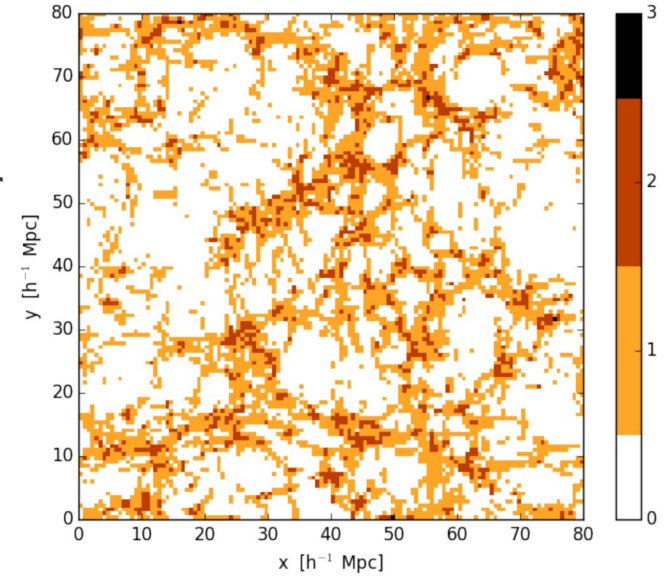


Simulated 21cm-LAE cross correlation function depend on galactic properties.

Topology of reionization



Tidal field tensor
 \downarrow *Nuza+ 2014*
 Cosmic web

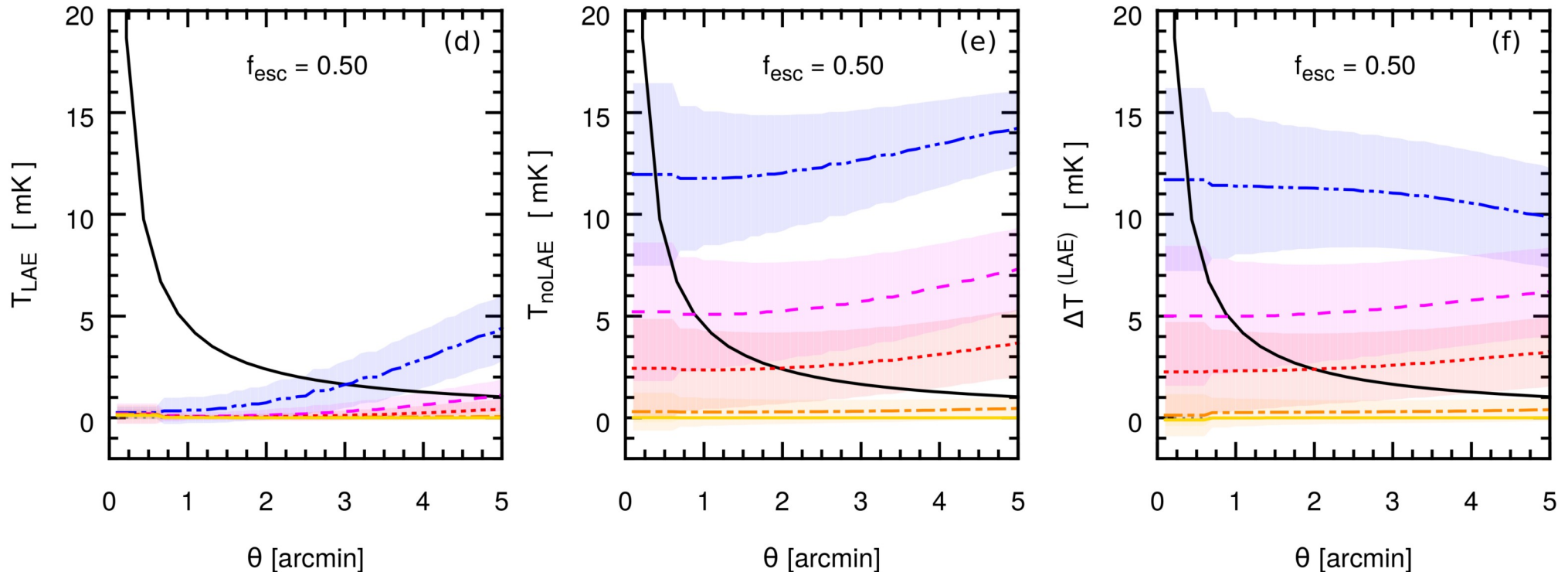


Ionization history in the cosmic web:

- knots
- filaments
- sheets
- voids

reionization proceeds inside-out

Measuring topology using 21cm correlations with overdensities and voids



overdense regions are ionized before underdense regions

→ mean 21cm signal in *overdense regions* is lower than in *underdense regions*

Conclusions – 21cm cross correlation with LAEs

LOCATION OF LAEs IN IGM

- *LAEs* lie in the most *overdense and ionized regions*, where the 21cm signal is strongly suppressed.

GALACTIC PROPERTIES

- *21cm-LAE cross correlations* are sensitive to galactic properties, e.g. the escape fraction of ionizing photons

TOPOLOGY OF REIONIZATION

- With the 21cm signal being significantly lower in regions containing LAEs than regions lacking LAEs, the corresponding difference in the *21cm signal in overdensities and voids* provides an “observable” for reionization topology.