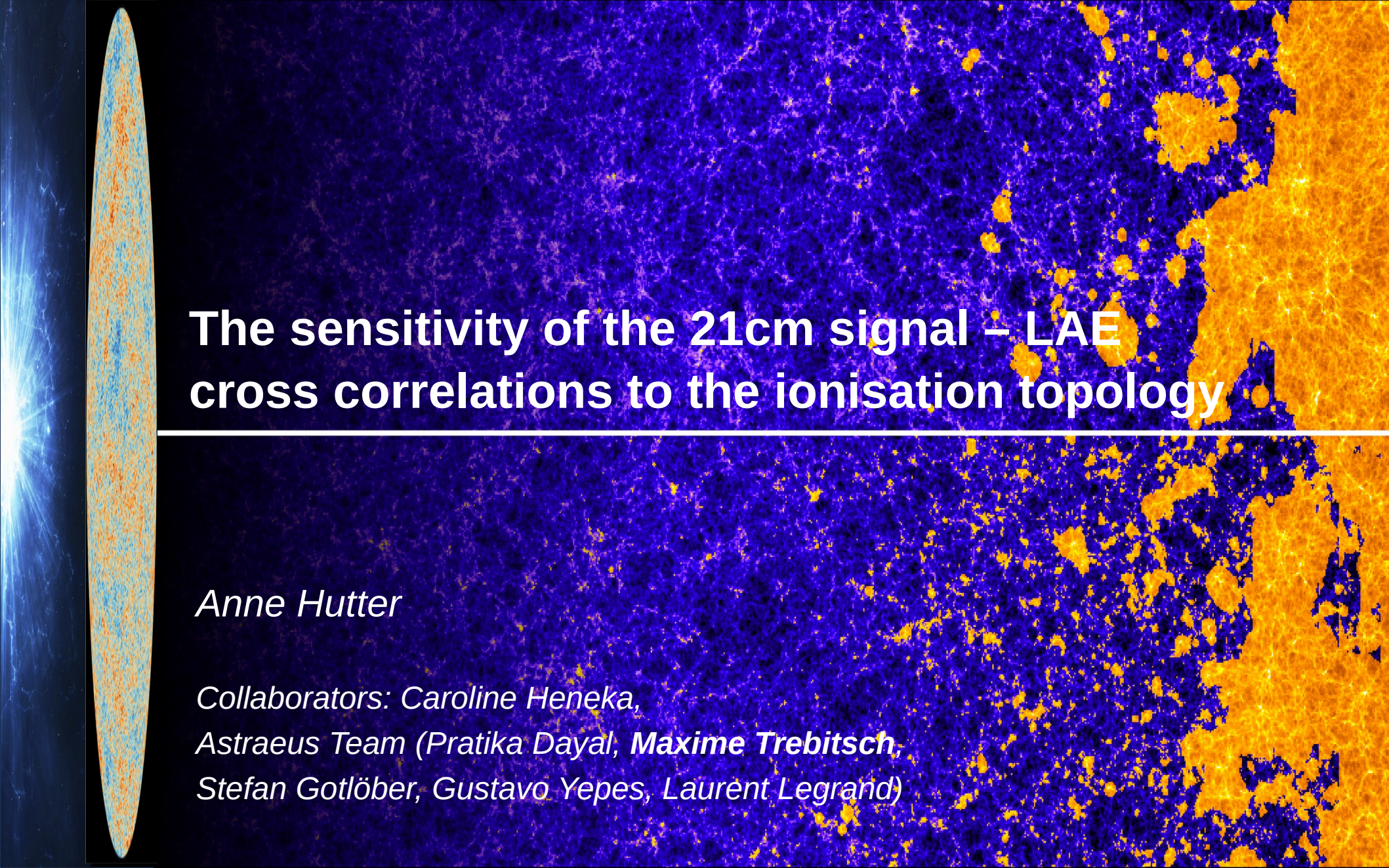
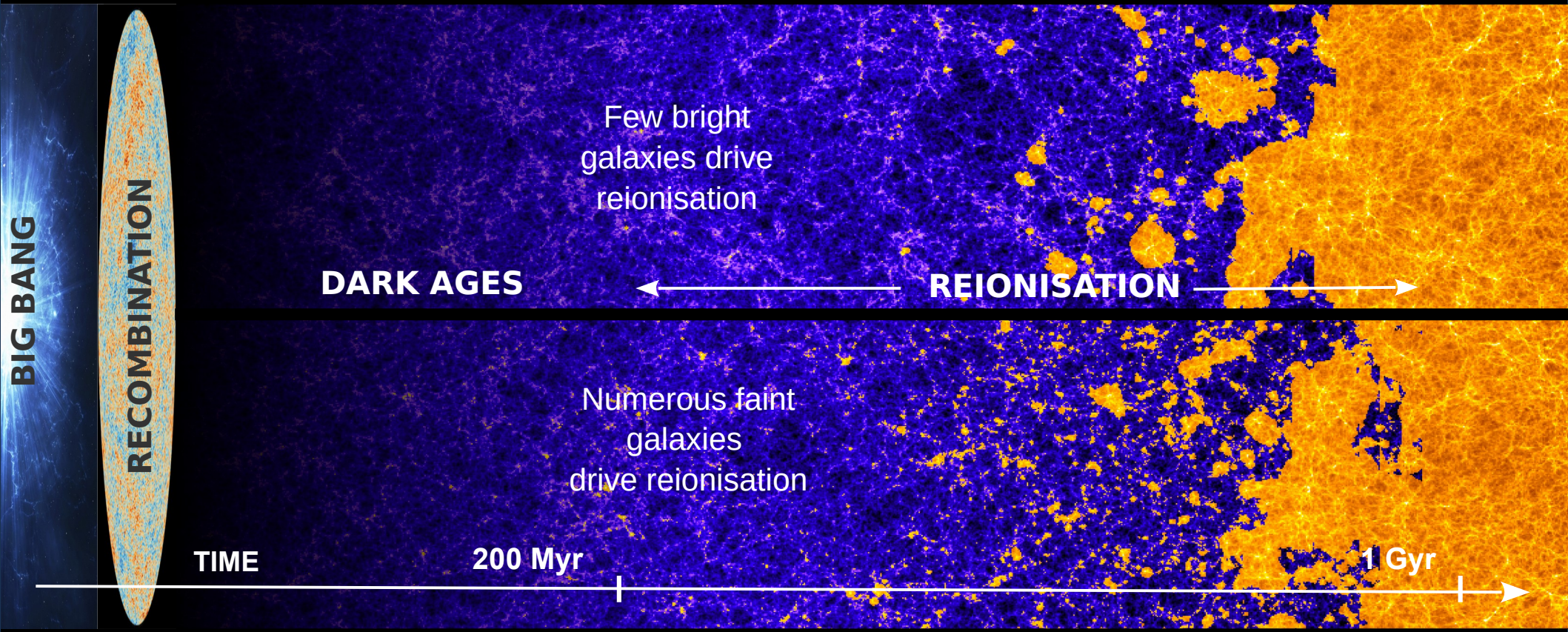


The sensitivity of the 21cm signal – LAE cross correlations to the ionisation topology

Anne Hutter

Collaborators: Caroline Heneka,
*Astraeus Team (Pratika Dayal, **Maxime Trebitsch**,*
Stefan Gotlöber, Gustavo Yepes, Laurent Legrand)

Was reionisation driven by the numerous faint or the few bright galaxies?



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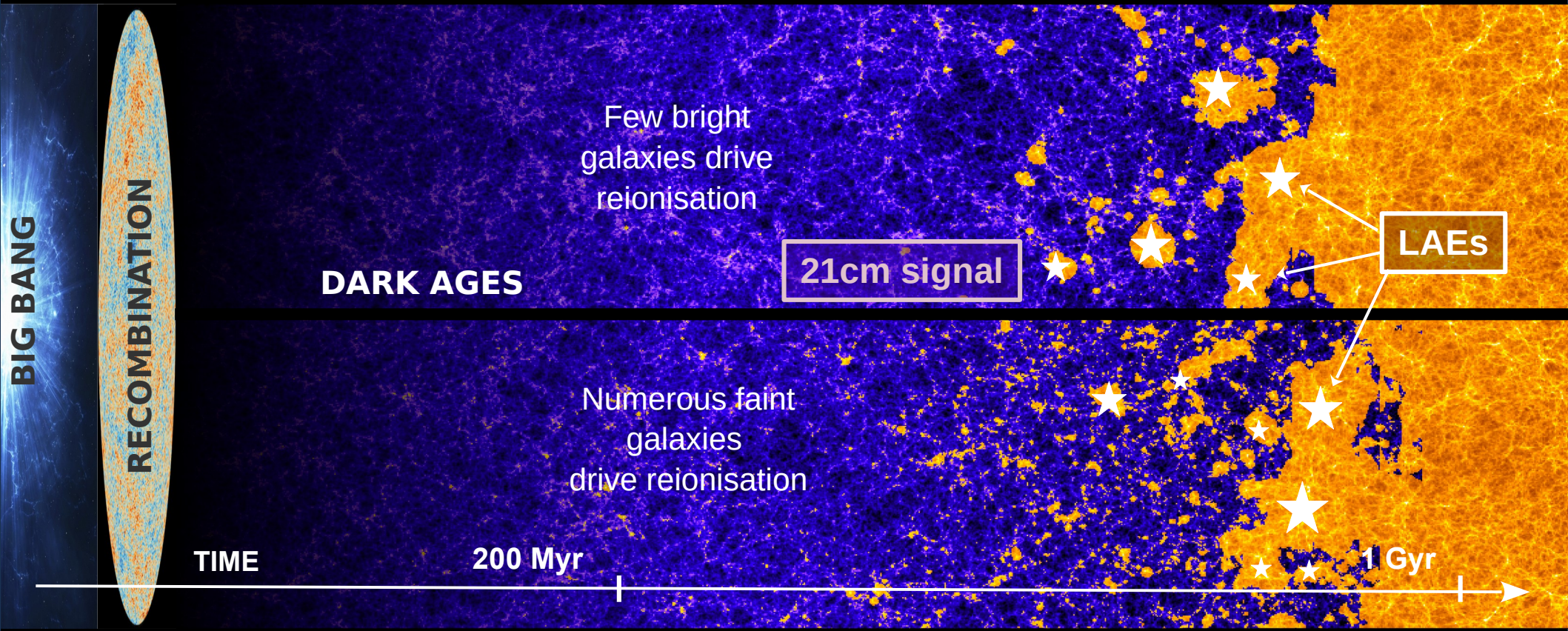
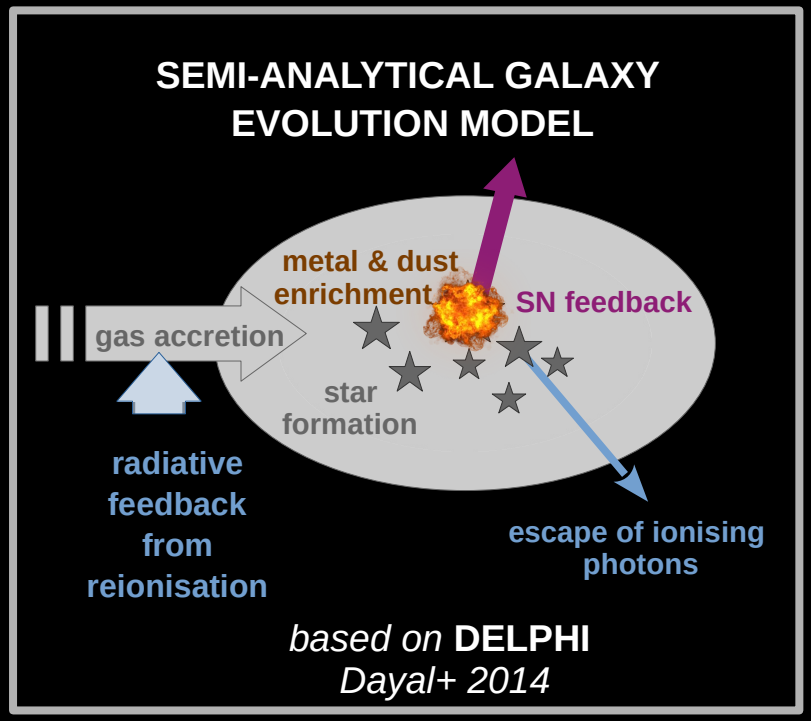
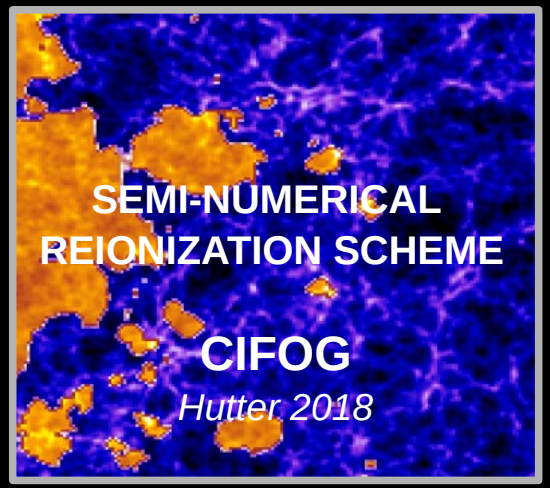


Astraeus framework: simulating the evolution of galaxies and the IGM





ionising emissivity distribution

COUPLING

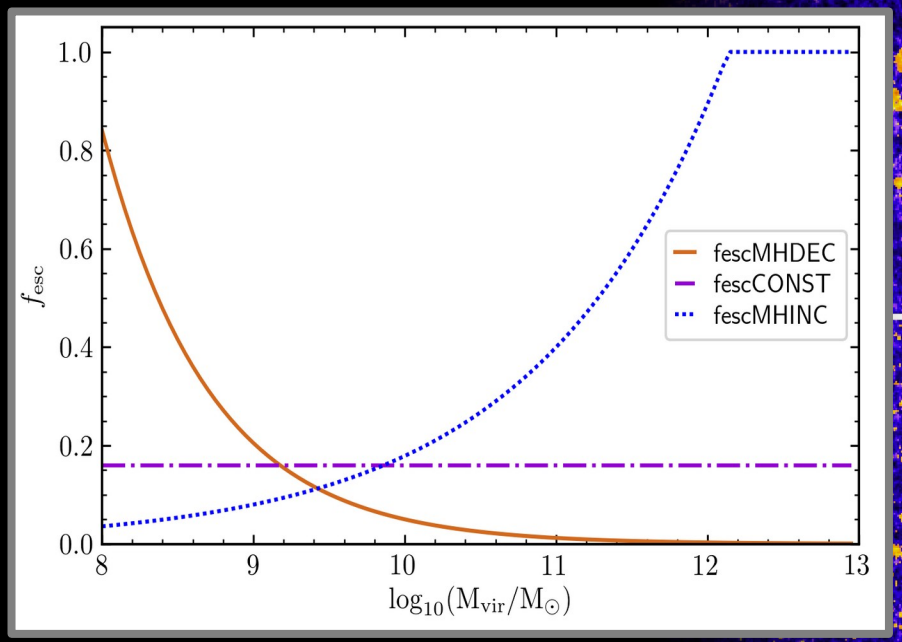
feedback from reionisation

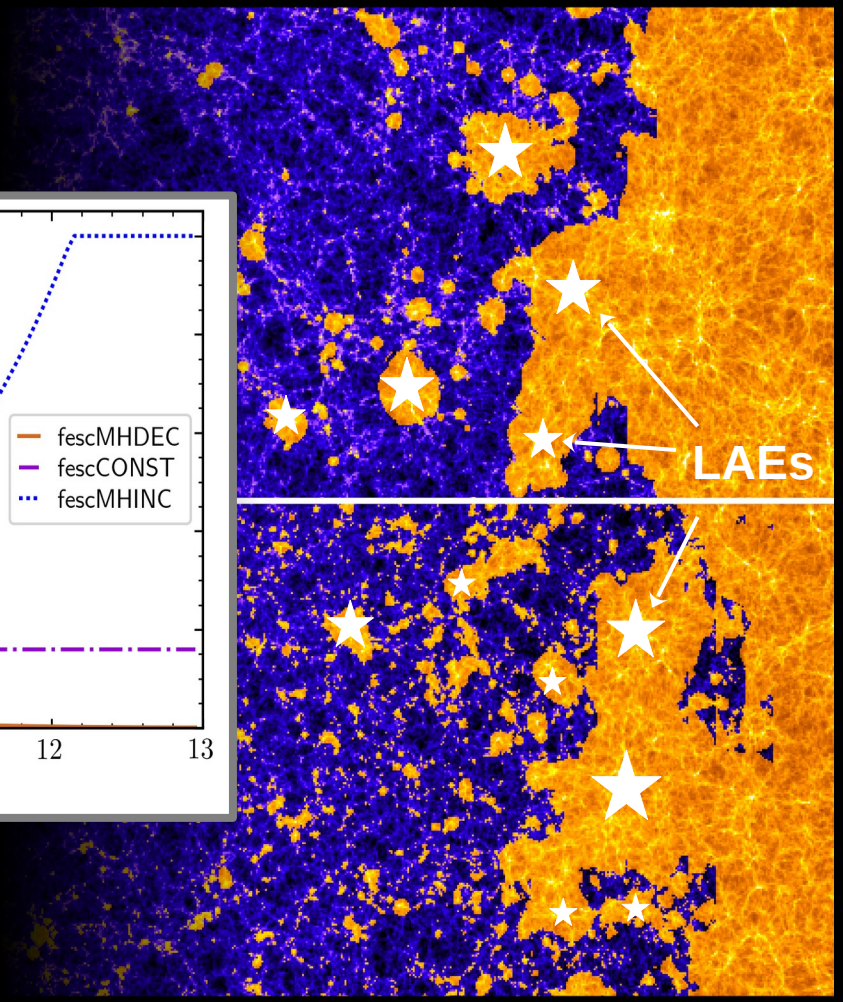
Hutter+ 2021a, 2022, Ucci+2023

Is the visibility of Lyman-α emitters sensitive to ionisation topology?

f_{esc} increases with halo mass MHINC

f_{esc} decreases with halo mass MHINC





Is the visibility of Lyman-α emitters sensitive to ionisation topology?

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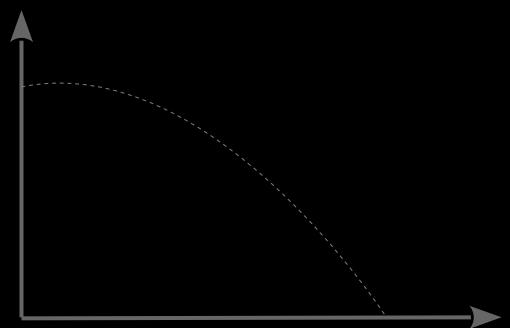
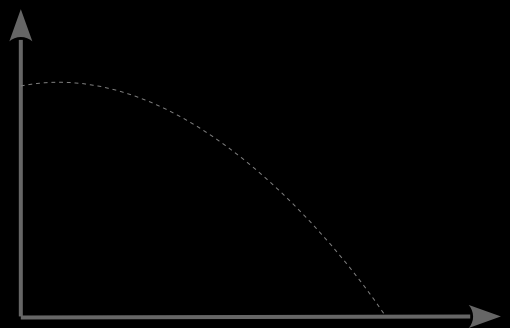


L_α

Lyα luminosity function



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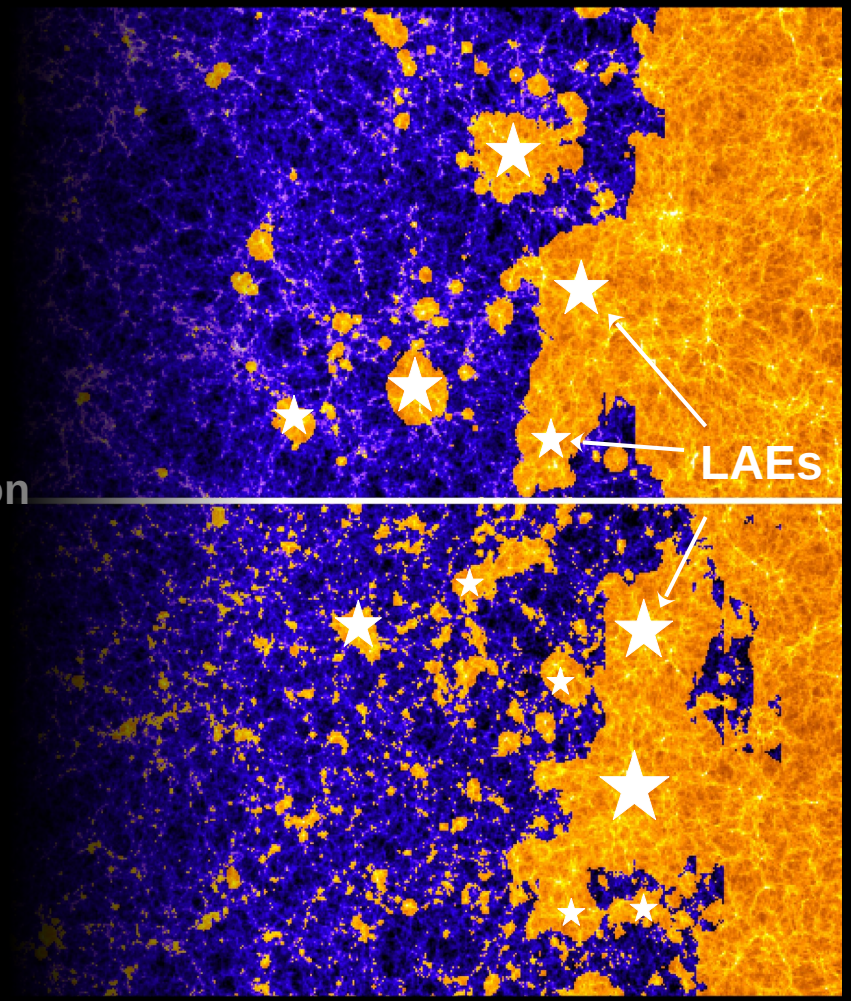

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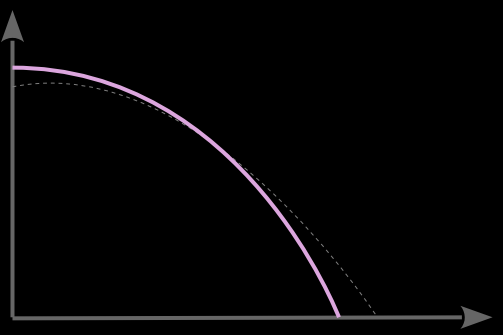
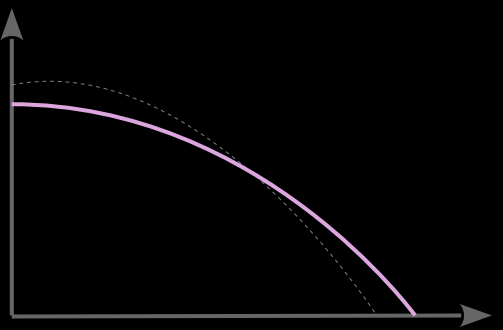


$L_\alpha \propto (1 - f_{esc})$

intrinsic Lyα production

Lyα luminosity function



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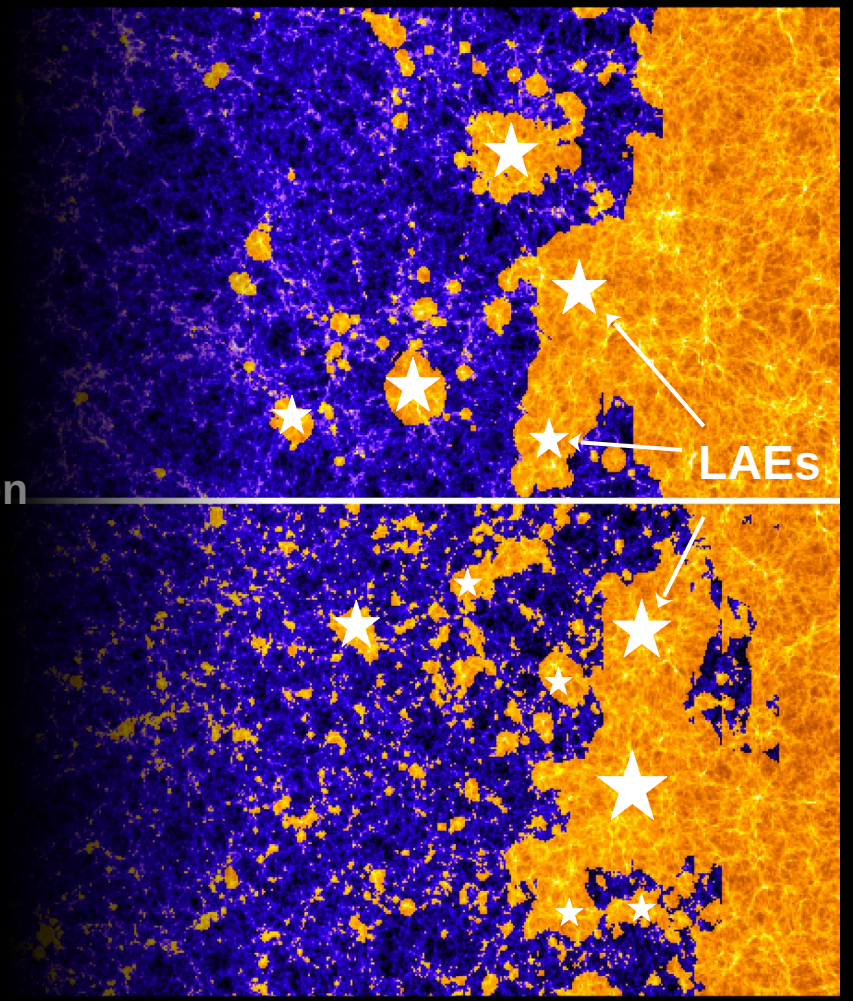

Is the visibility of Lyman-α emitters sensitive to ionisation topology?

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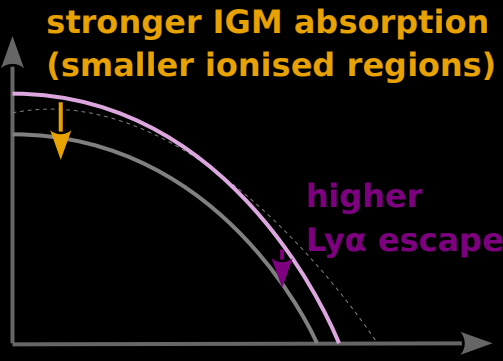


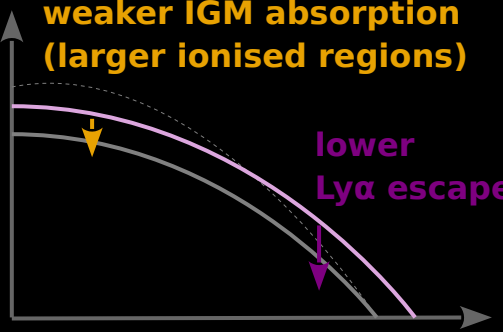
Lyα escape fraction

$$L_\alpha \propto (1 - f_{esc})\ f_\alpha\ T_\alpha$$

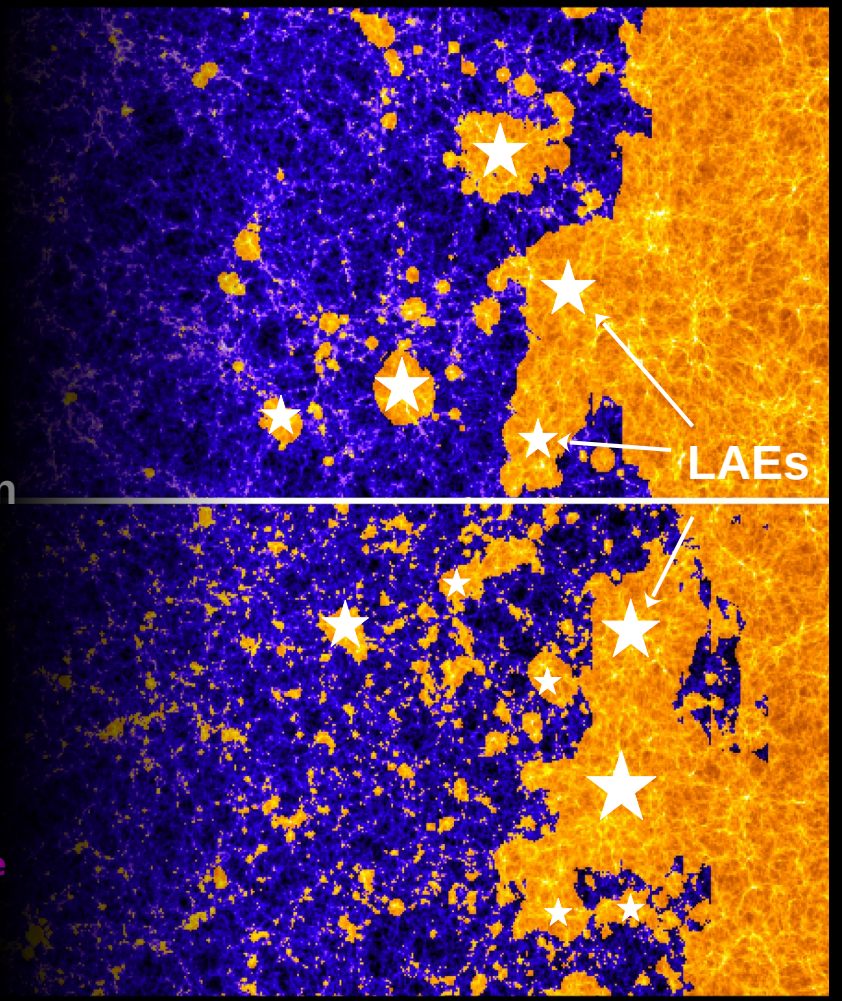
intrinsic Lyα production

Lyα IGM transmission

Lyα luminosity function



f_{esc} decreases with halo mass MHINC

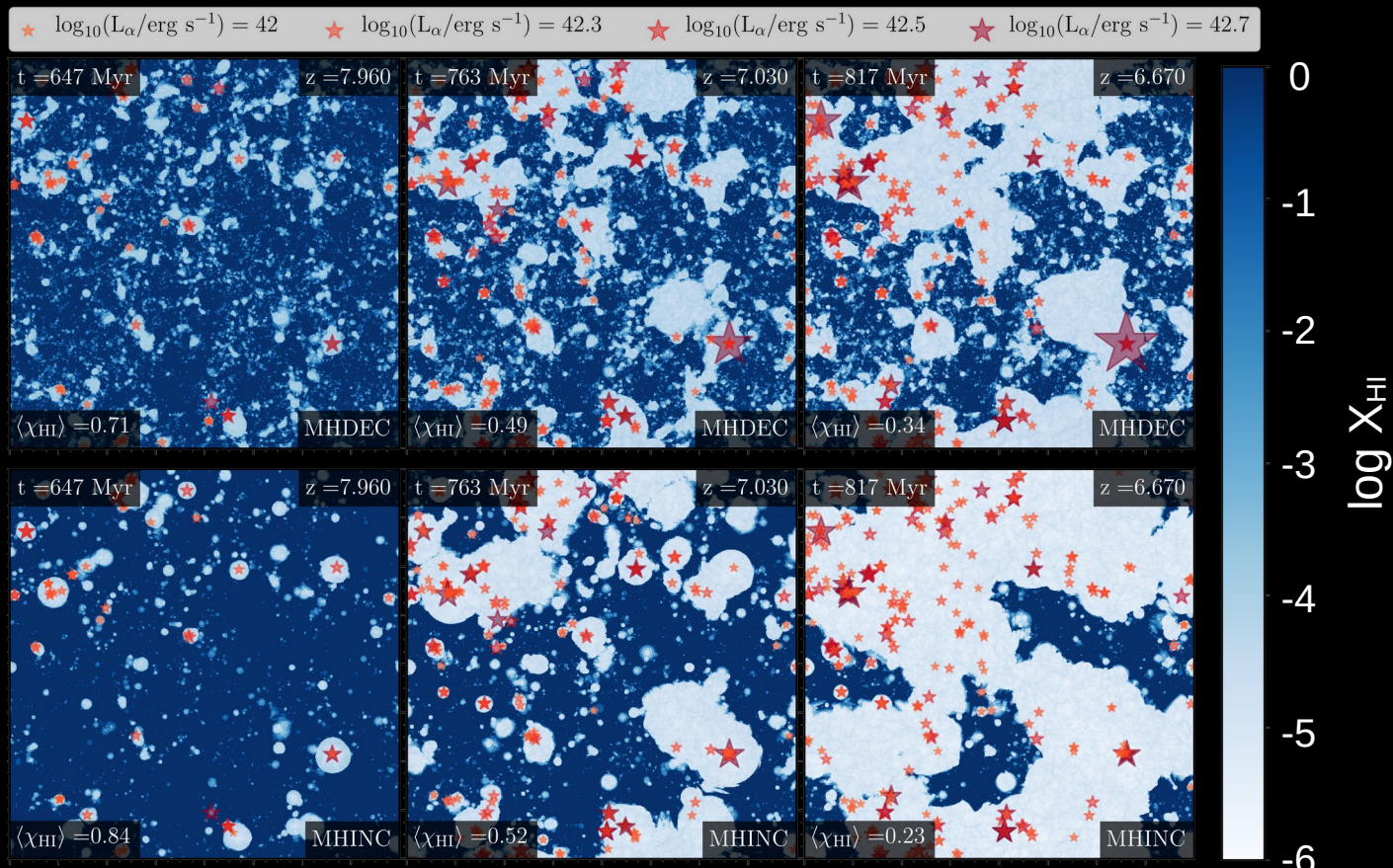


Is the visibility of Lyman-α emitters sensitive to ionisation topology?

f_{esc} decreases with halo mass
MHDEC

Astraeus simulations

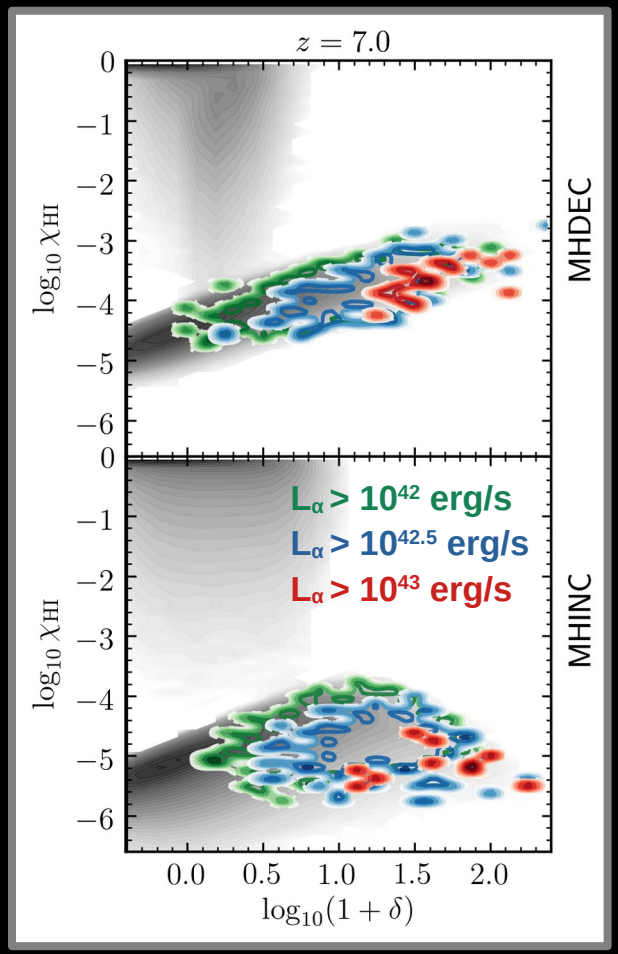
f_{esc} increases with halo mass
MHINC



Hutter+ 2022

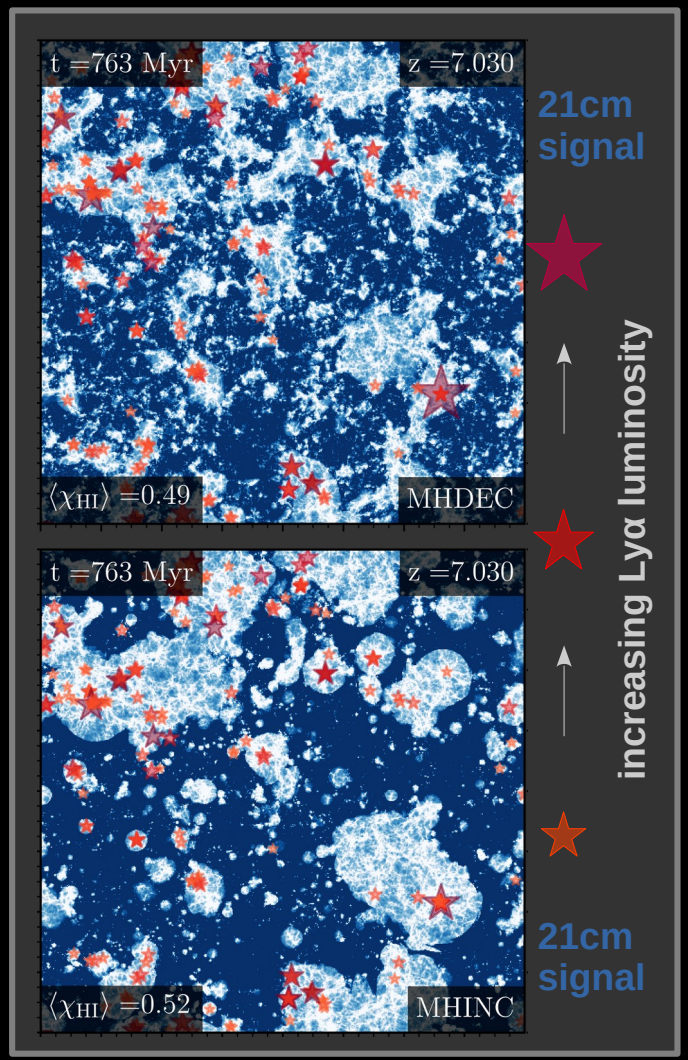
As LAEs ($L_\alpha > 10^{42}$ erg/s) are the most massive galaxies, their spatial distribution depends mostly on the global ionisation state of the IGM.

Where are Lyman-α emitters located in the IGM?



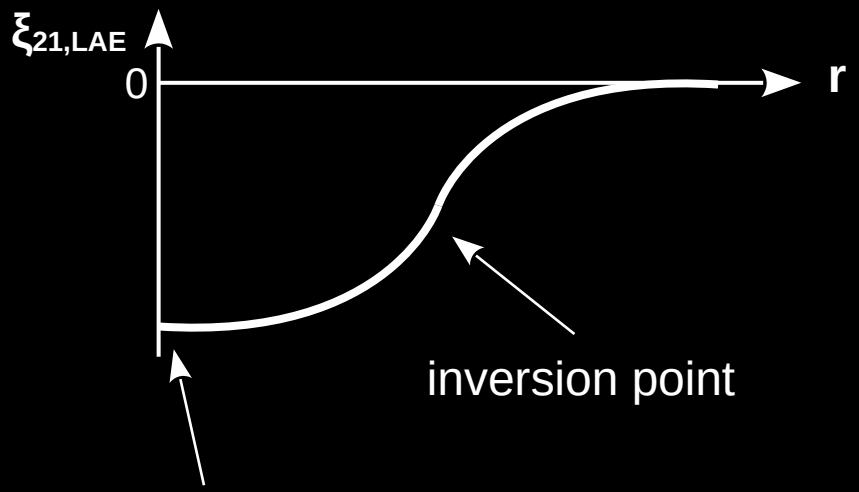
LAEs are located in the most ionised overdense regions

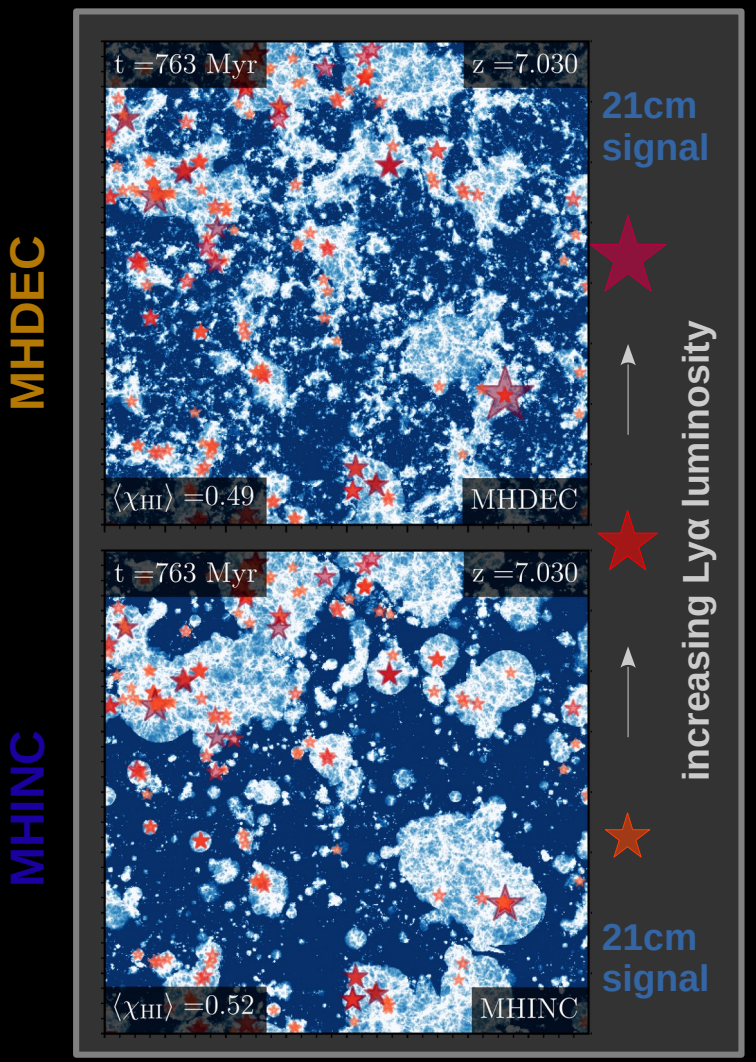
no 21cm signal



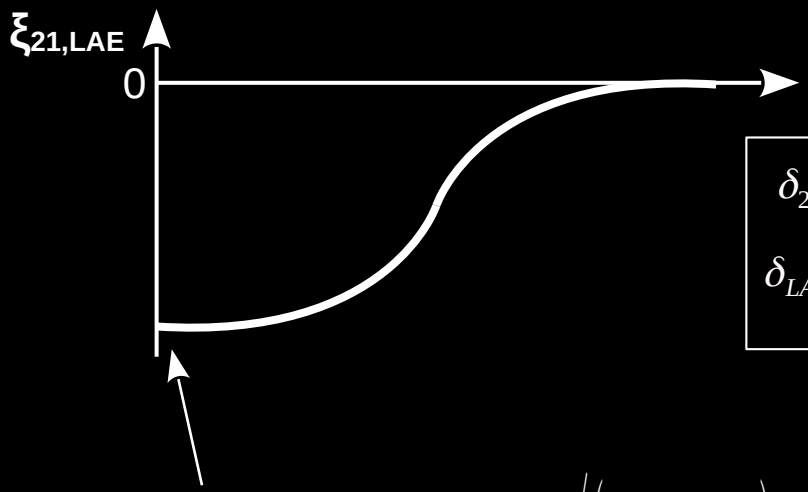
Hutter+ 2022

21cm – LAE cross correlation function: characteristics





21cm – LAE cross correlation functions: small-scale amplitude



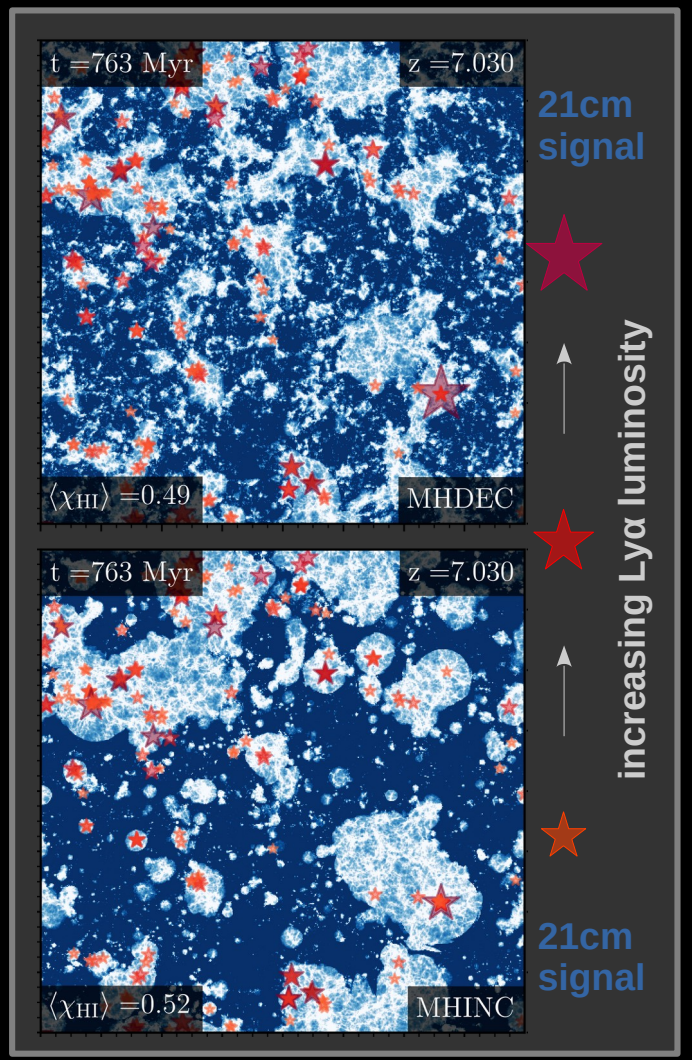
$$\delta_{21}(x) = \delta T_b(x)/T_0$$

$$\delta_{LAE}(x) = \frac{n_{LAE}(x)}{\langle n_{LAE}\rangle} - 1$$

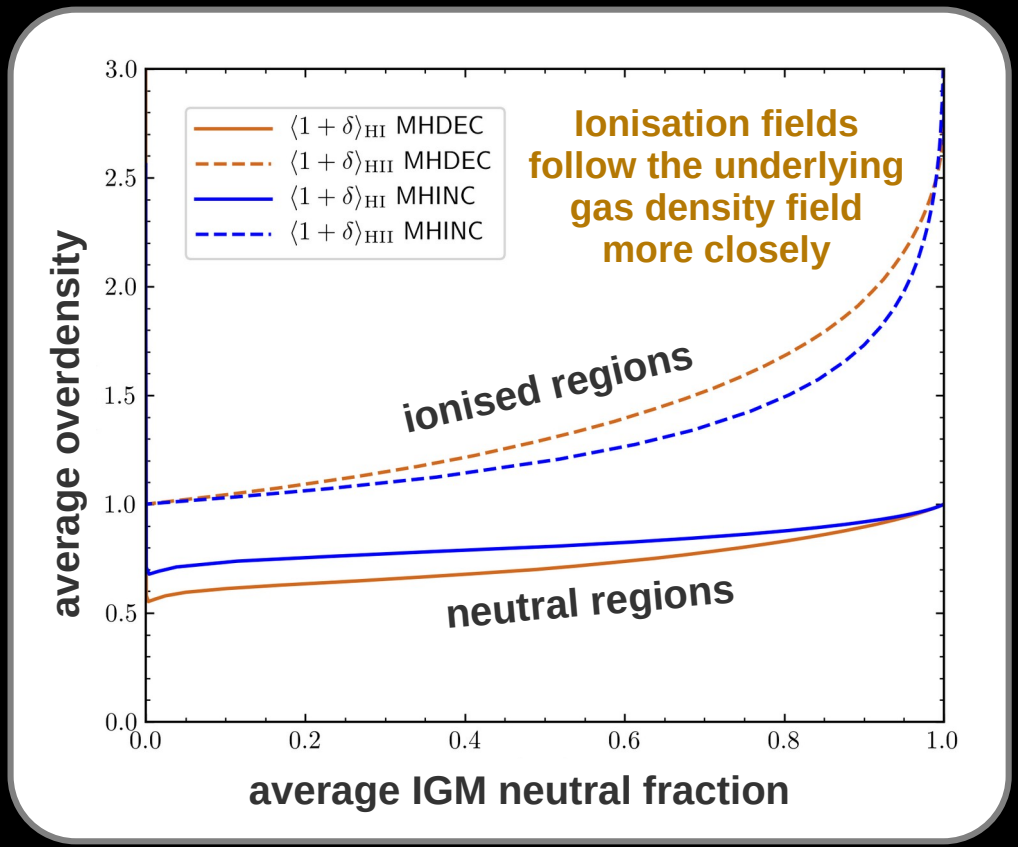
$$\xi_{21,LAE}(r\approx 0) \approx -\langle \chi_{HI}\rangle \left\langle \left(1-\frac{T_{CMB}}{T_s}\right)(1+\delta)\right\rangle_{HI}$$

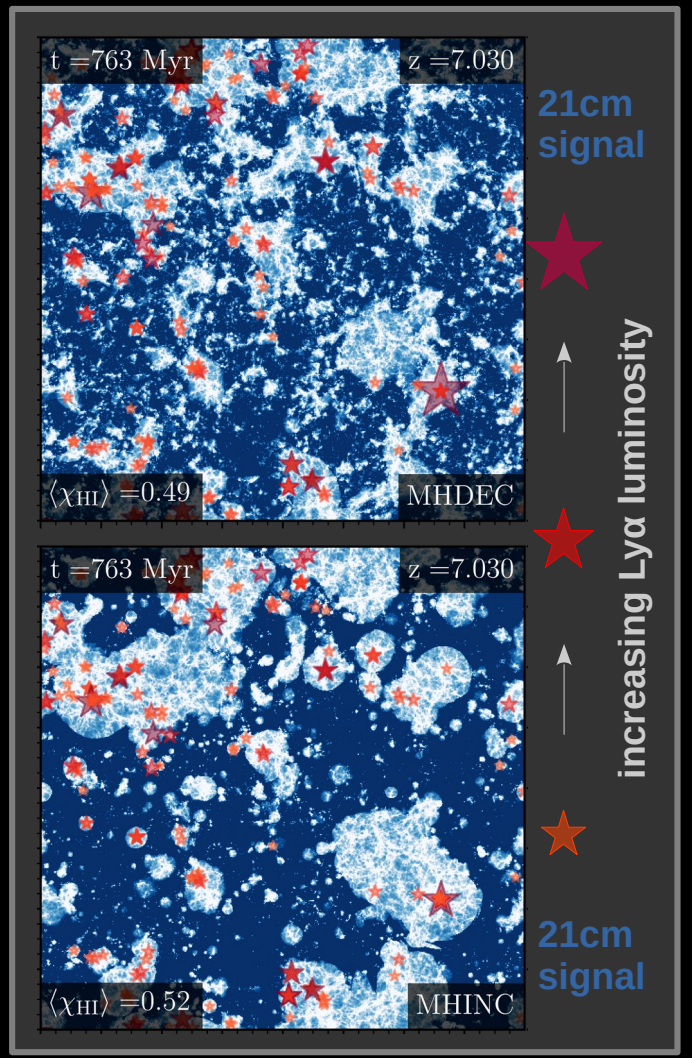
During reionisation:

$$\xi_{21,LAE}(r\approx 0) \approx -\langle \chi_{HI}\rangle \langle 1+\delta\rangle_{HI}$$



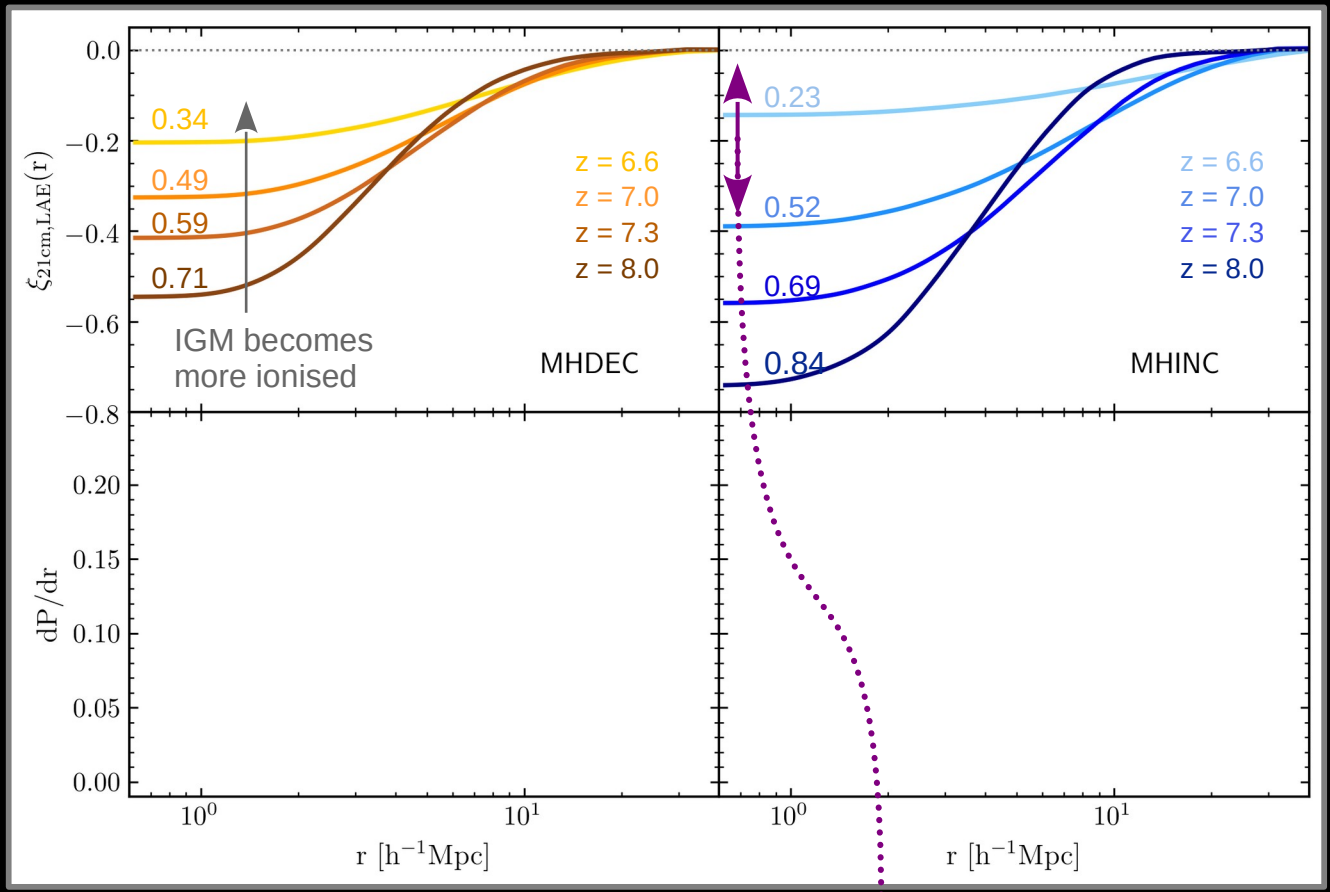
21cm – LAE cross correlation function: small-scale amplitude traces ionisation topology!





21cm – LAE cross correlations are sensitive to ionisation topology!

21cm-LAE cross correlation function

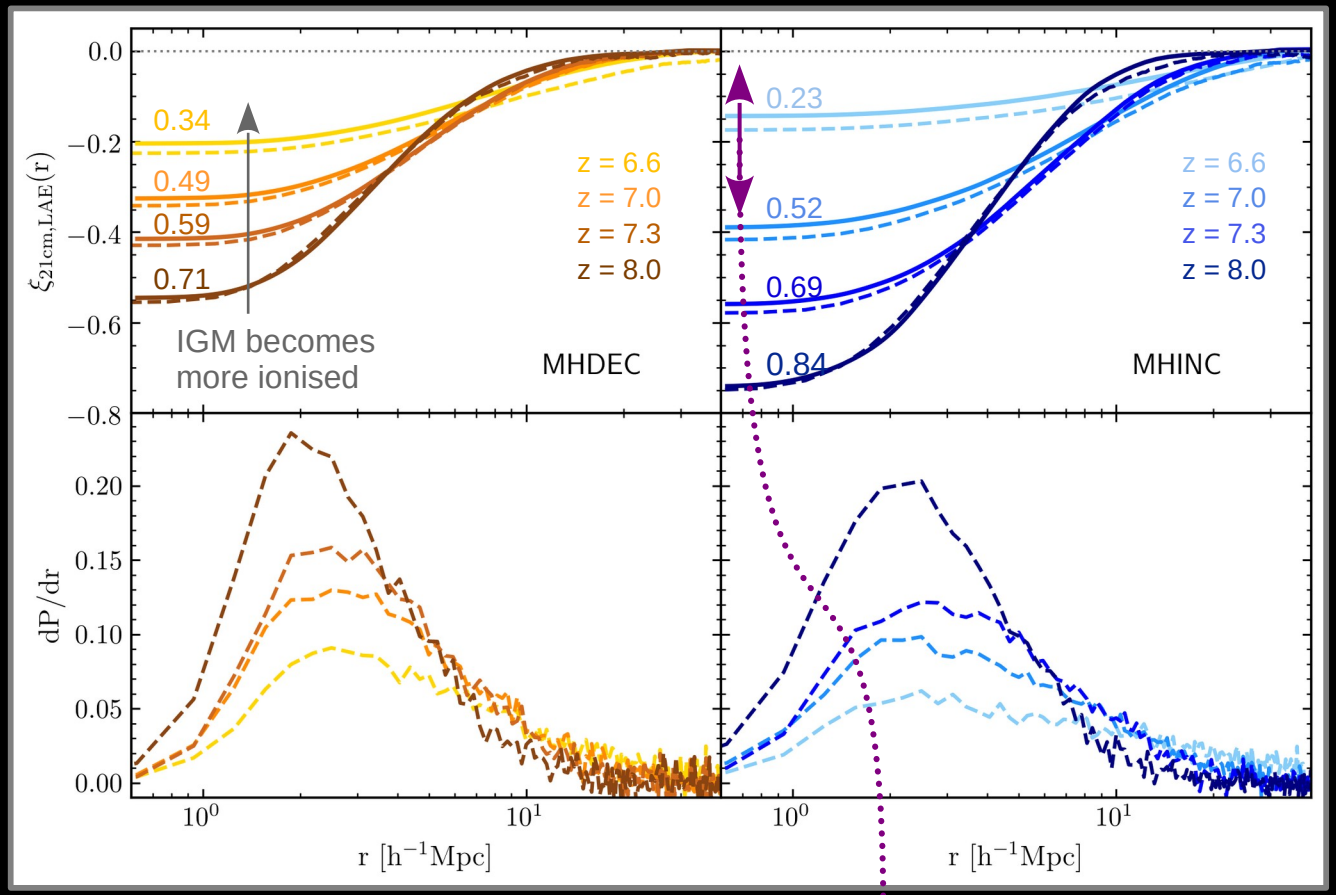


Analytical limit: $\xi_{21,LAE}(r \approx 0) \approx -\langle \chi_{HI} \rangle \langle 1+\delta \rangle_{HI}$

21cm – LAE cross correlations are sensitive to ionisation topology!

21cm-LAE cross correlation function

size distribution of ionised regions around LAEs



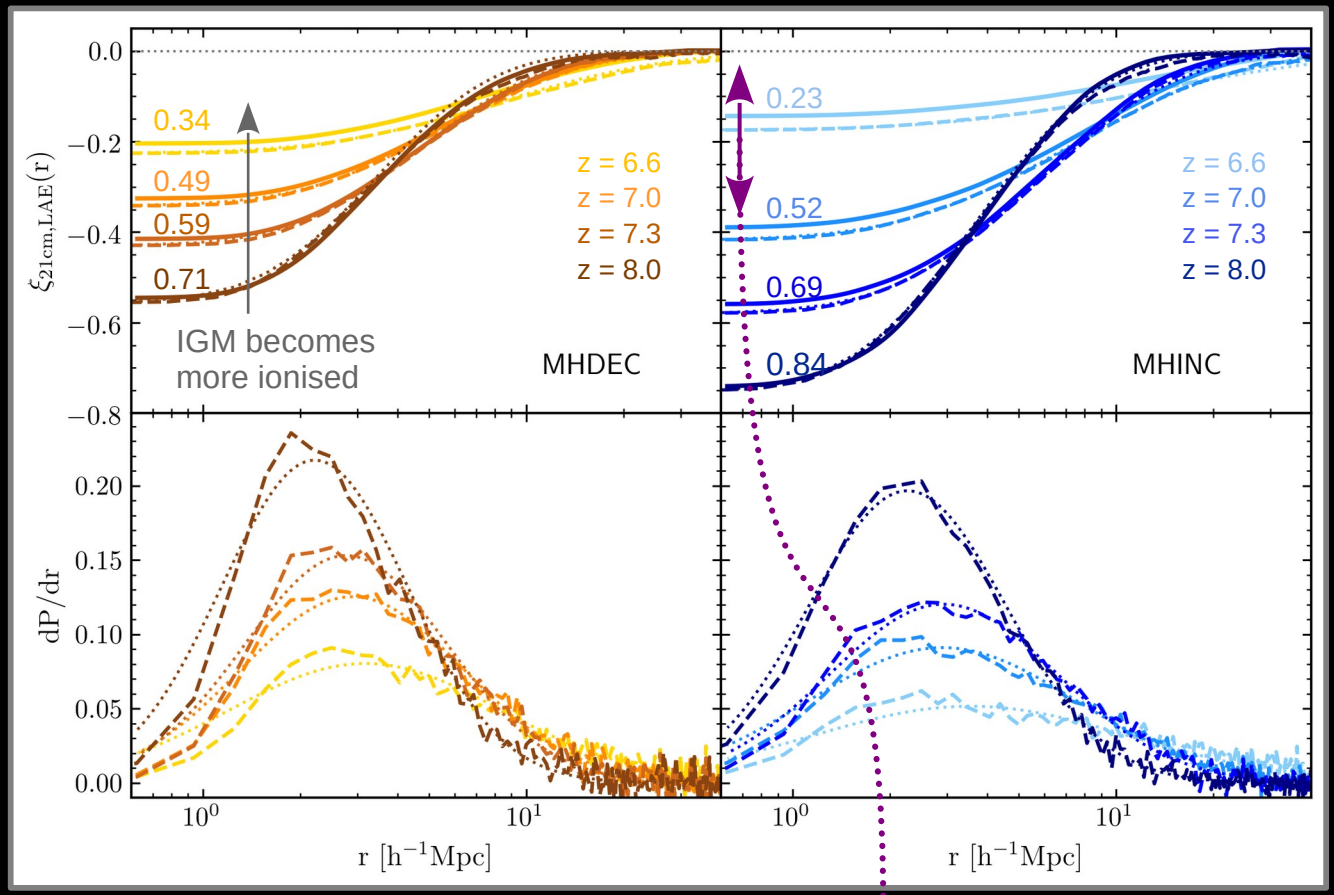
Cumulative distribution function of size of ionised regions around LAEs

Analytical fitting function: $\xi_{21,LAE}(r) \approx -\langle \chi_{HI} \rangle \langle 1+\delta \rangle_{HI} \left[1 - \langle \chi_{HI} \rangle CDF(r) \right]$

21cm – LAE cross correlations are sensitive to ionisation topology!

21cm-LAE cross correlation function

size distribution of ionised regions around LAEs



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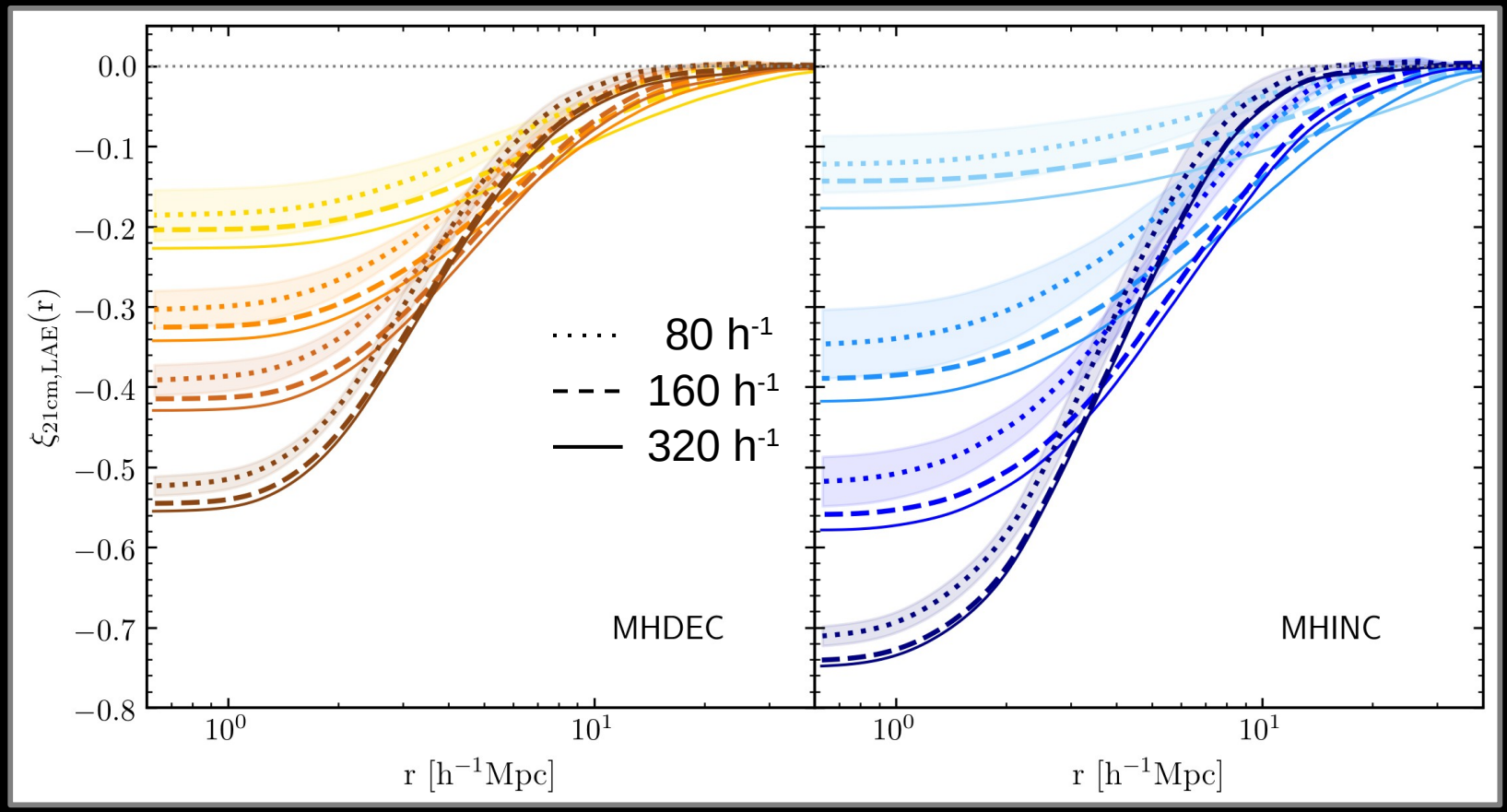
Too small boxes underestimate 21cm – LAE cross correlation amplitudes due to missing large-scale power



Simulation volumes of more than ~(250 cMpc)^3 needed.

Conclusions

LAEs ($L_\alpha > 10^{42}$ erg/s) are the most massive galaxies.

- They are located in the most ionised overdense regions.
- Spatial distribution is mostly sensitive to the the global ionisation state of the IGM.

21cm-LAE cross correlation function amplitude is sensitive to:

- ionisation history
- ionisation topology
- IGM heating

$$\xi_{21,LAE}(r) \approx -\langle \chi_{HI} \rangle \langle 1+\delta \rangle_{HI} \left[1 - \langle \xi_{HI} \rangle CDF(r) \right]$$

$$\xi_{21,LAE}(r \approx 0) \approx -\langle \chi_{HI} \rangle \left\langle \left(1 - \frac{T_{CMB}}{T_s} \right) (1+\delta) \right\rangle_{HI}$$

Is the visibility of Lyman-α emitters sensitive to ionisation topology?