HI properties of local Lyα-emitting galaxies

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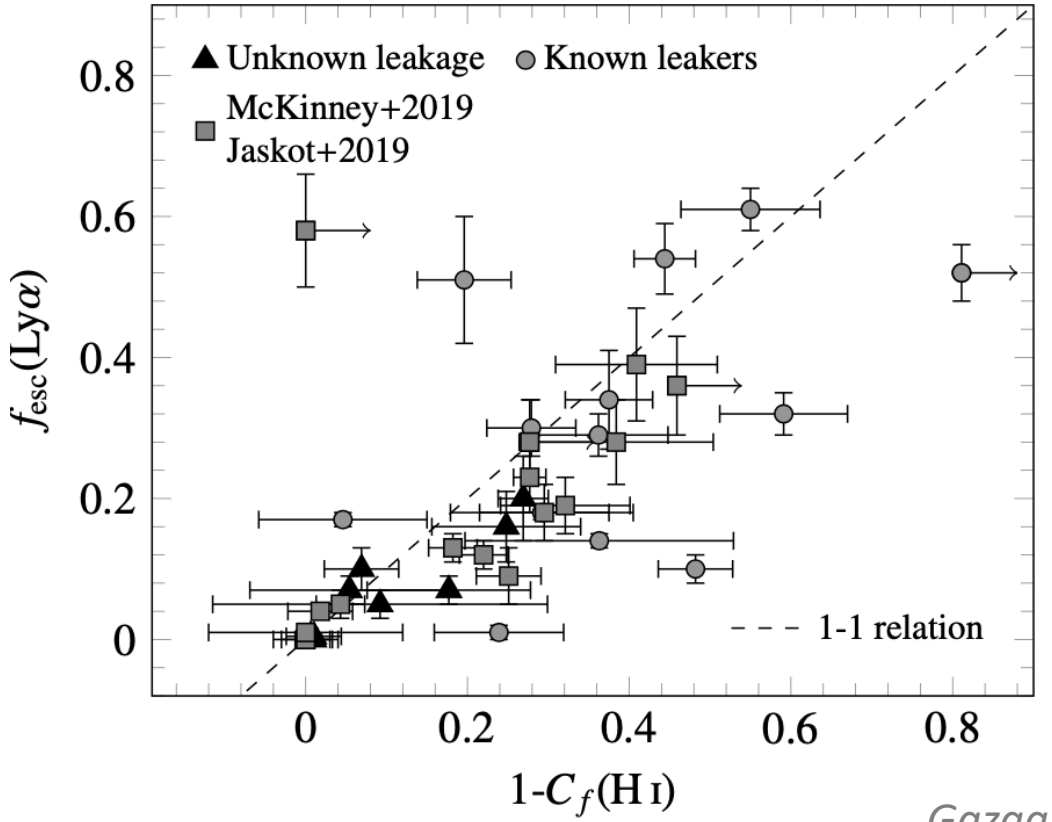
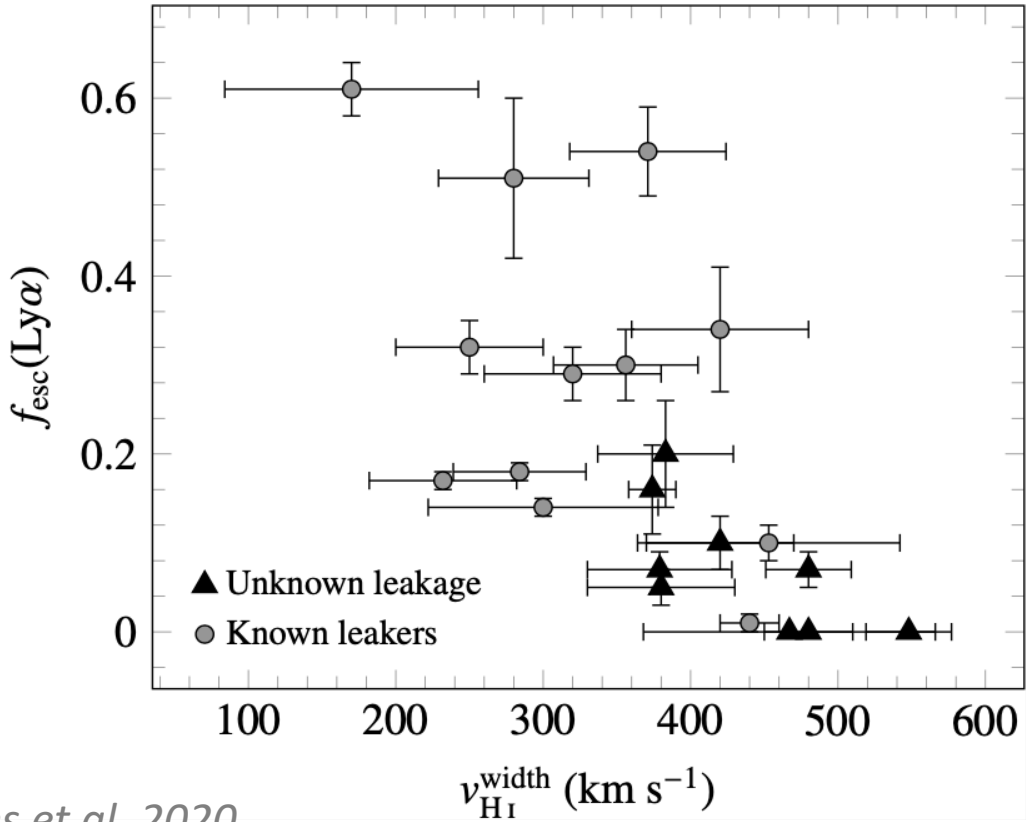
Introduction

HI in the ISM: regulates Lyman radiation escape out of galaxies



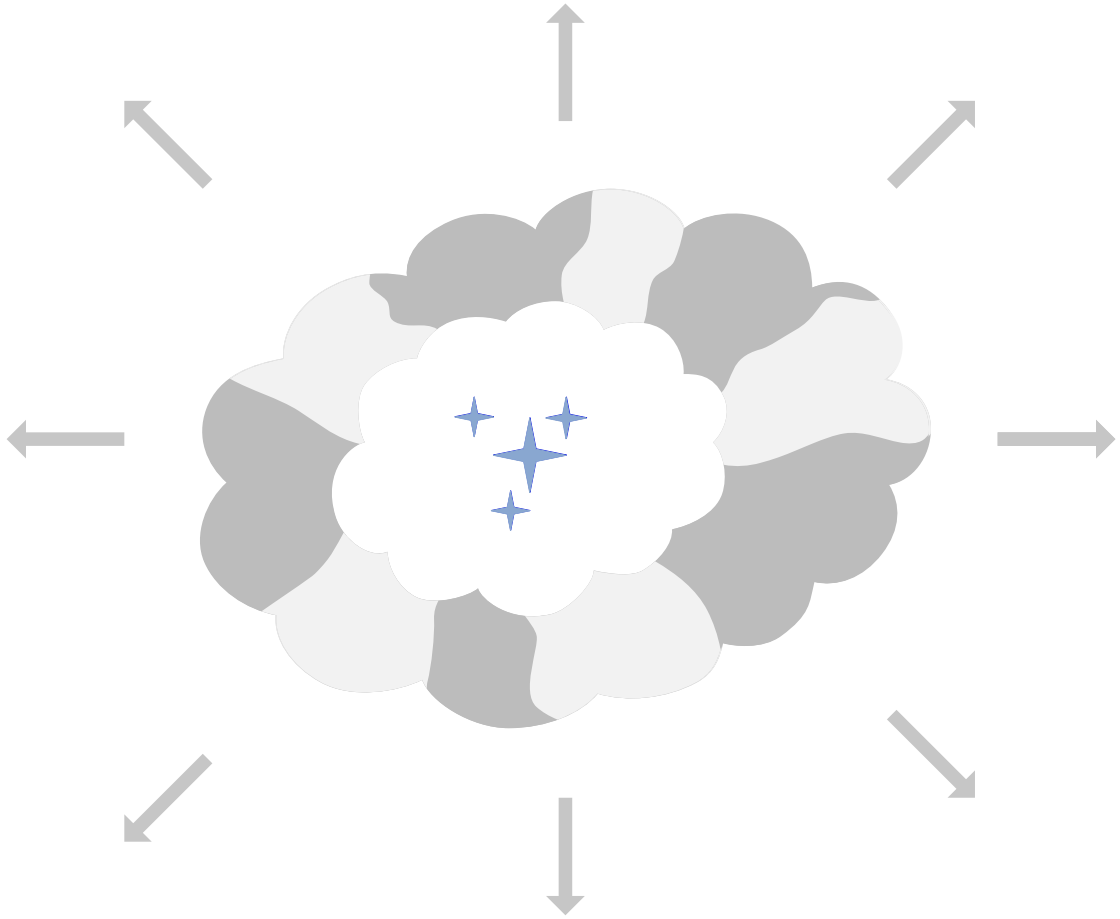


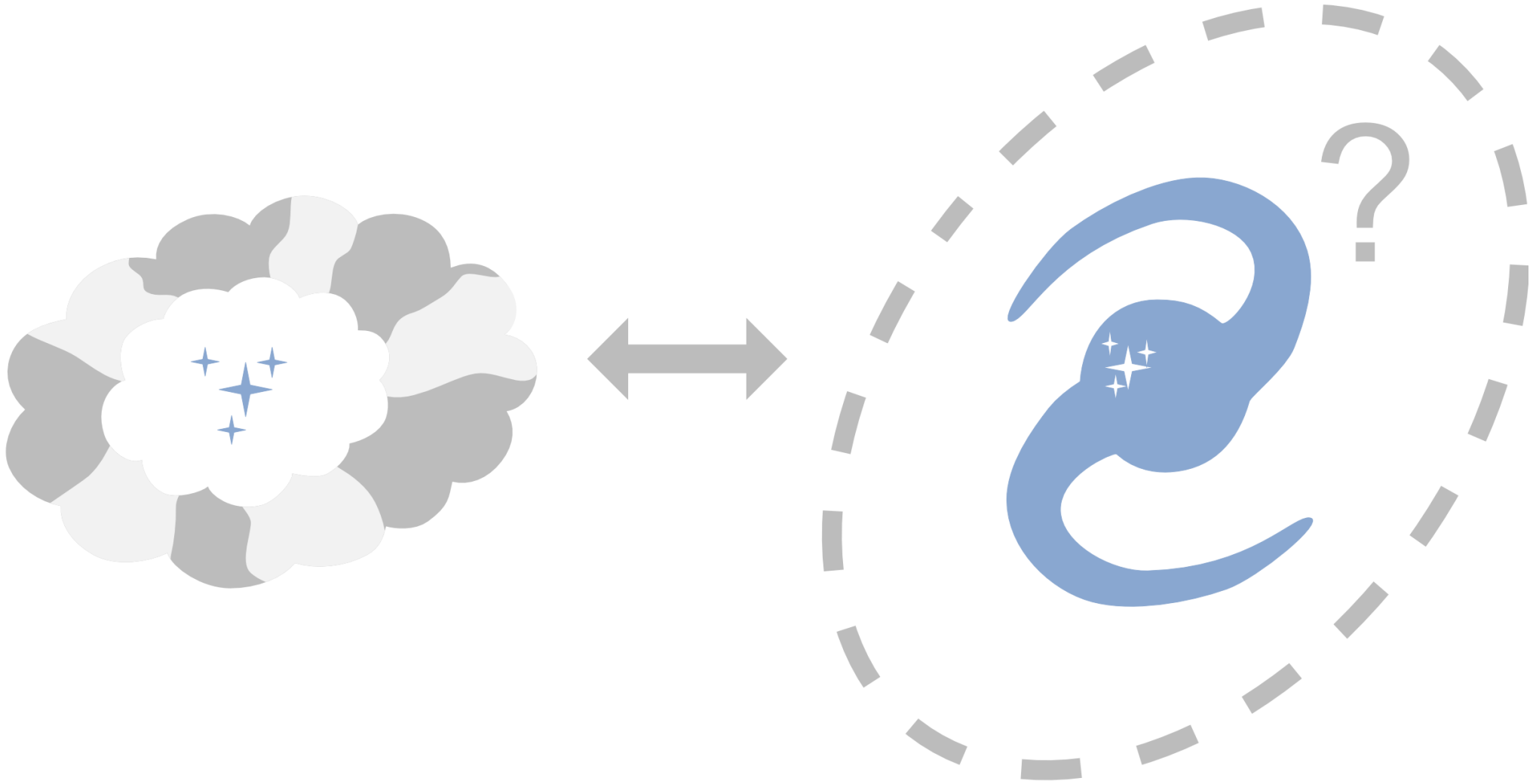
Gazagnes et al. 2020

Also see Shapley et al. 2003, Rivera-Thorsen et al. 2015, Henry et al. 2015, Gazagnes et al. 2018, Saldana-Lopez et al. 2022, and many other…

Introduction

Observations **around star-forming regions:** porous, out/inflowing neutral ISM facilitates Lyα escape



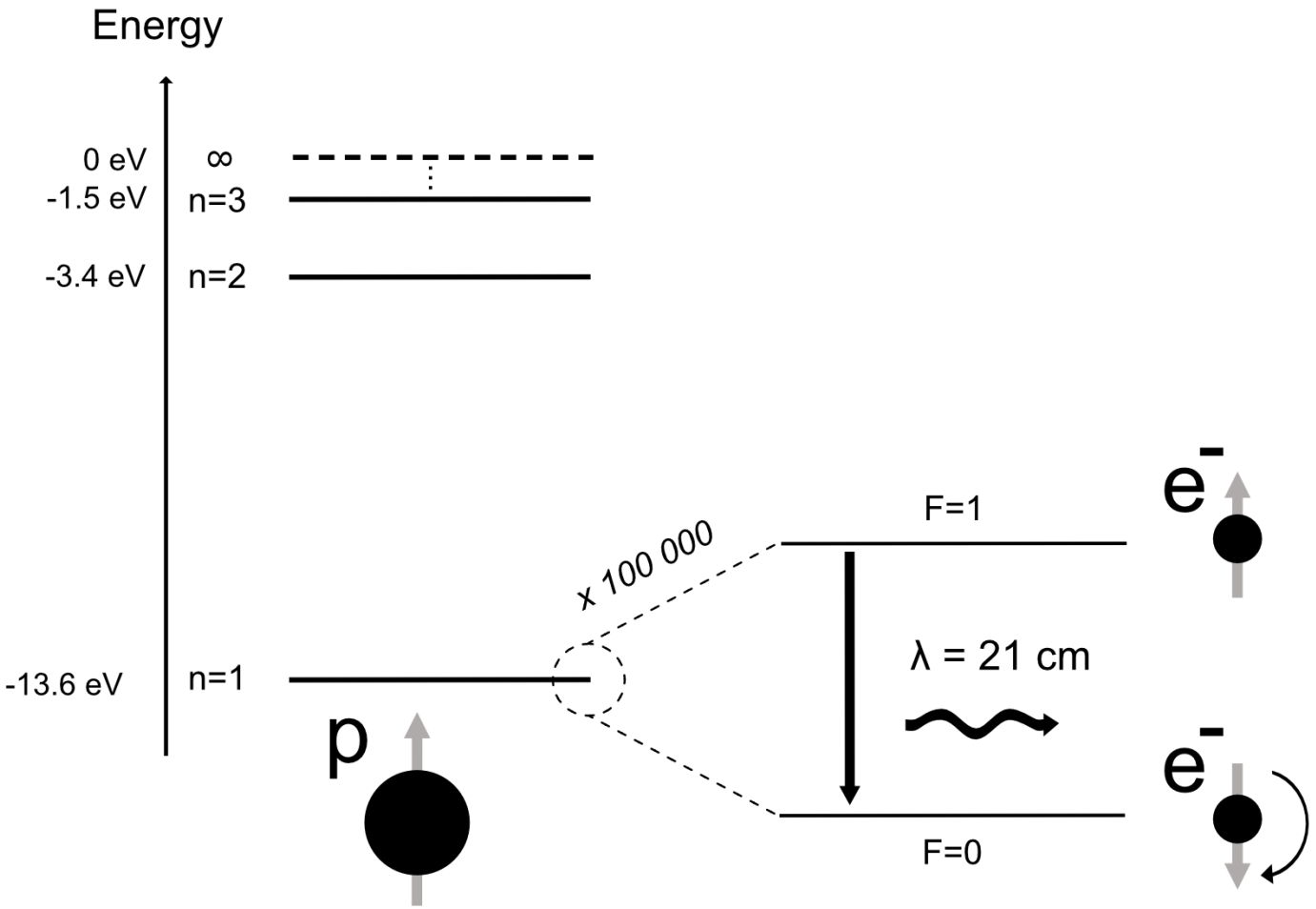


→ How do local conditions connect with the global HI properties of galaxies?

THE 21CM LINE

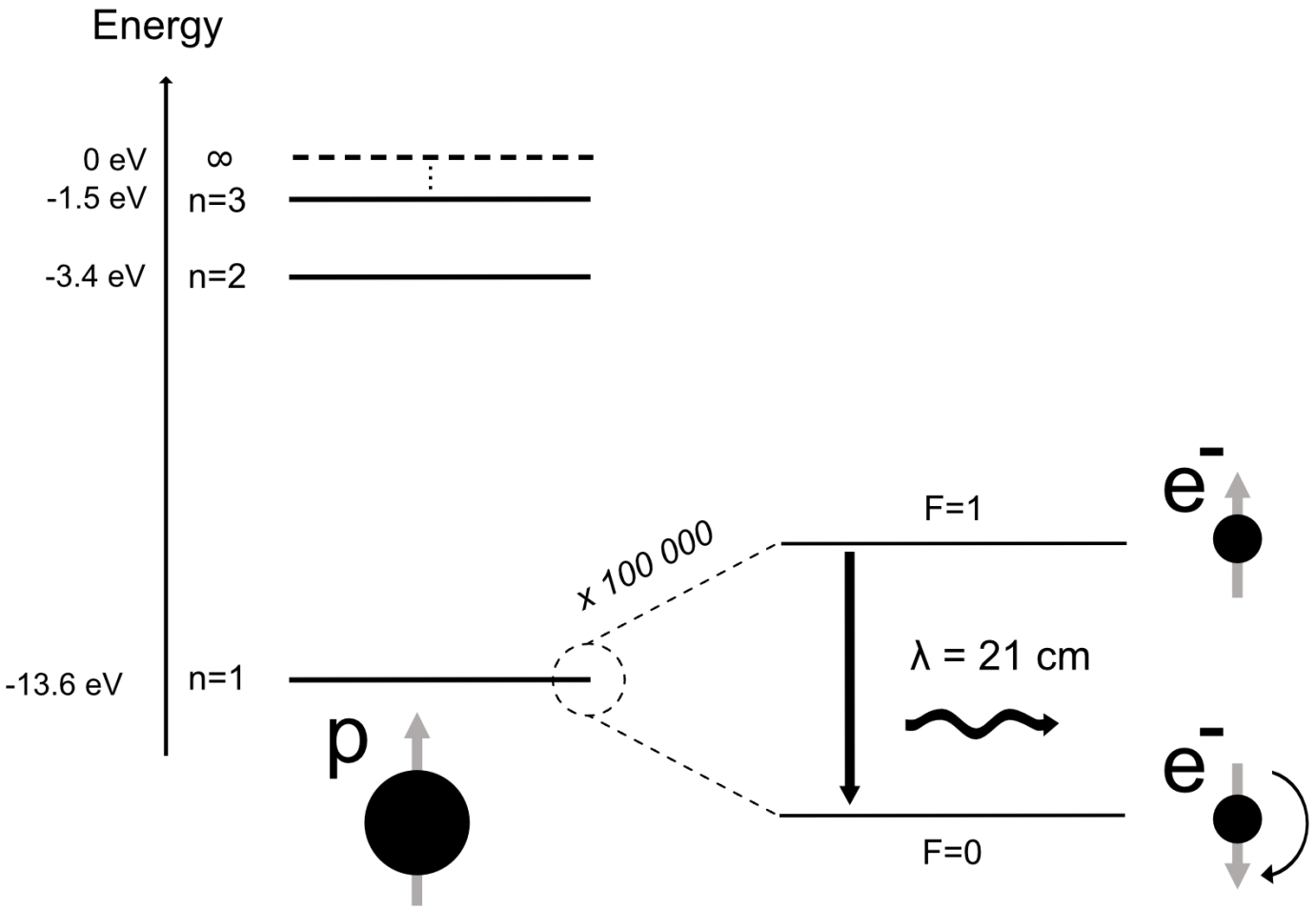
Part 1: HI properties

21cm HI observations



+ Direct tracer
+ Gas content + kinematics

21cm HI observations

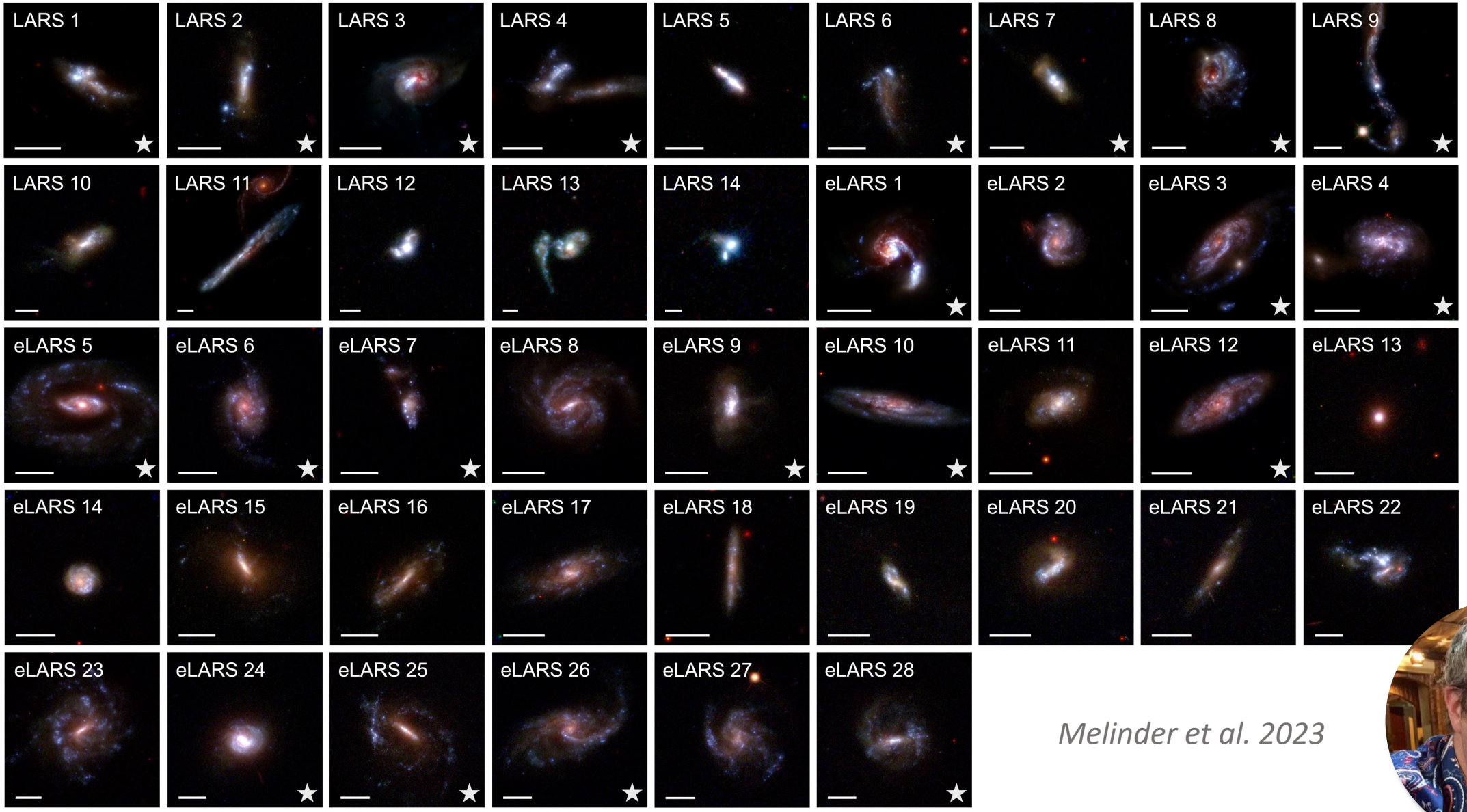


+ Direct tracer
+ Gas content + kinematics

- Poor resolution
- Low redshift only*

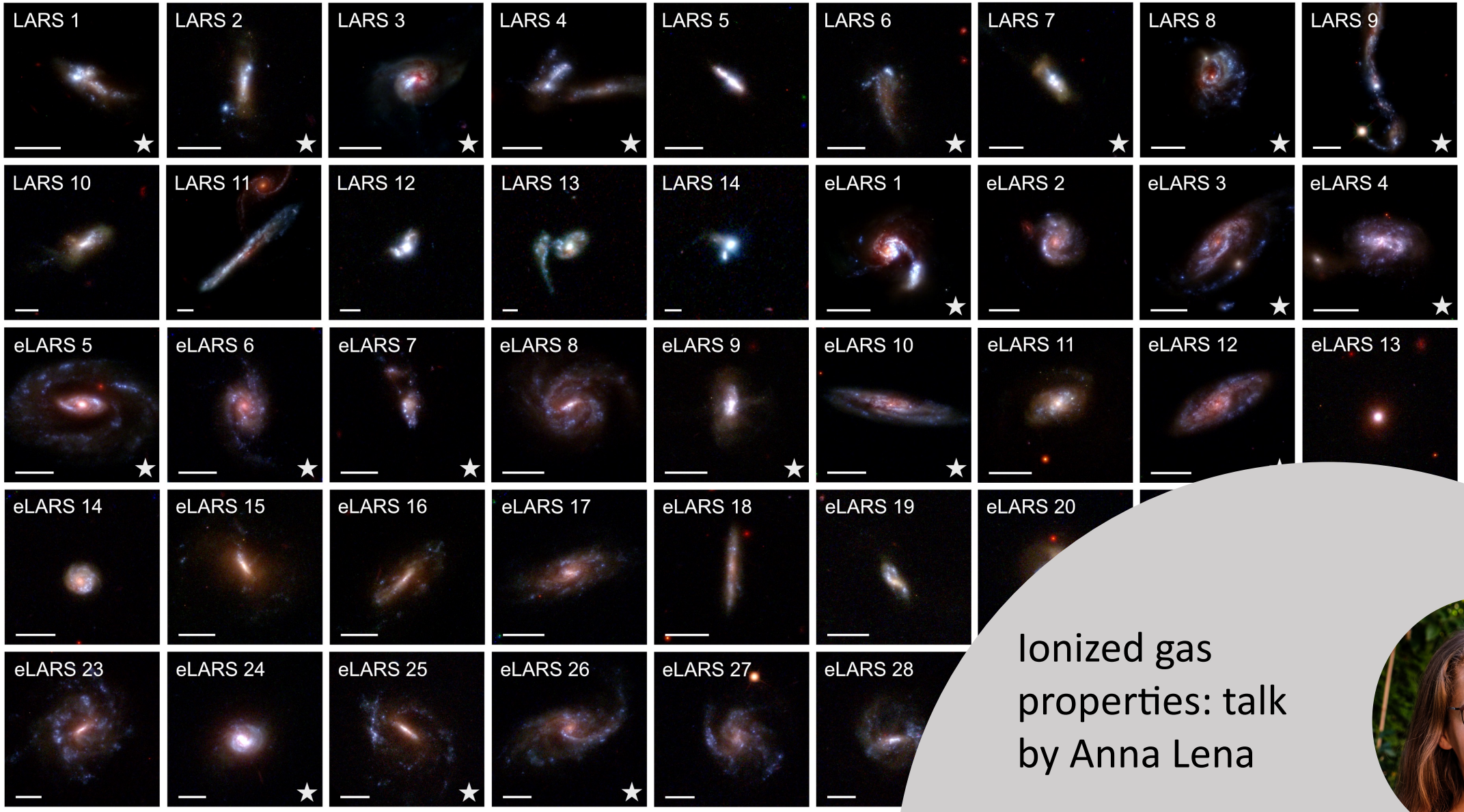
* Where low redshift means z<0.05

The Lyman Alpha Reference sample



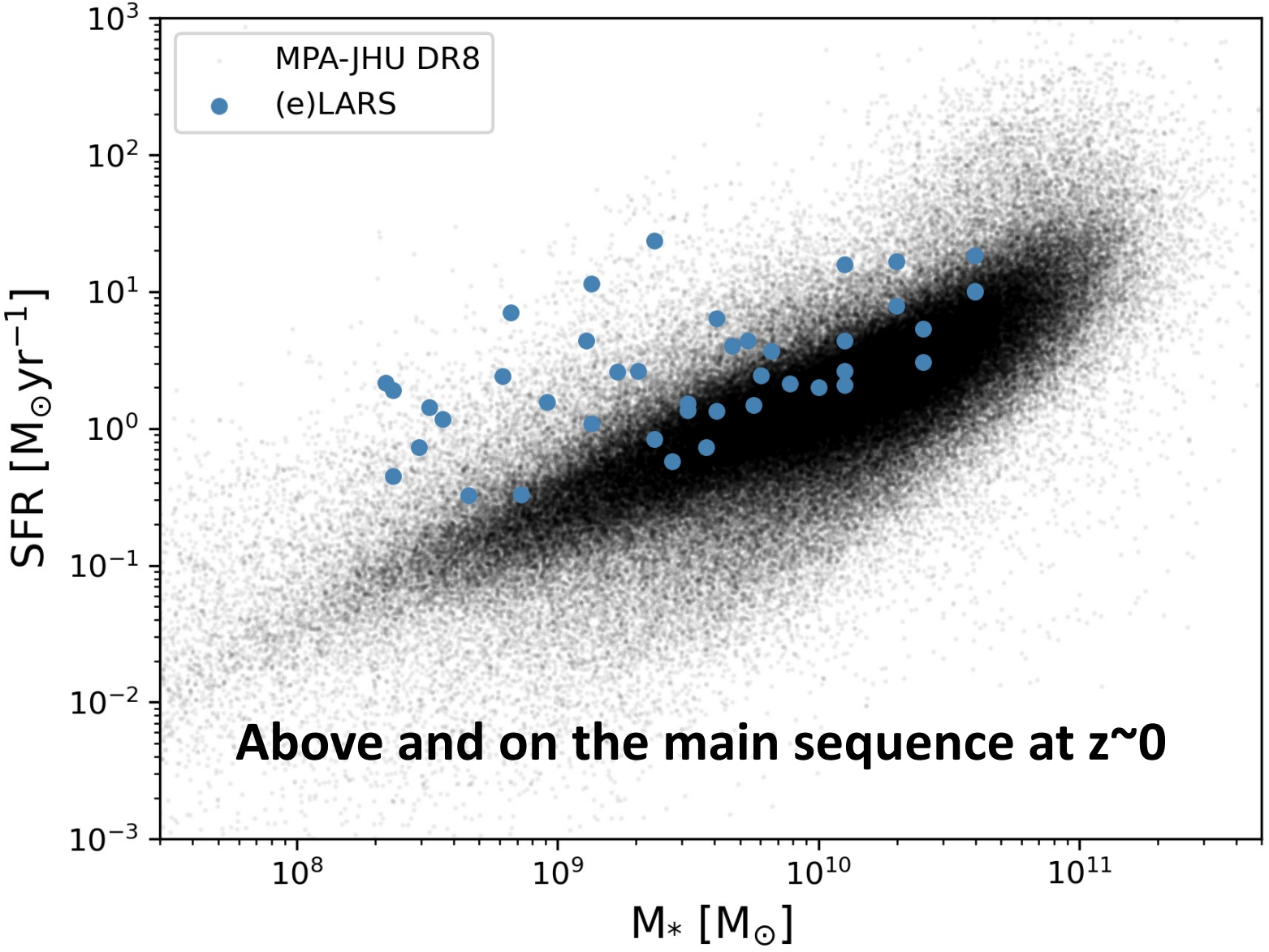
Melinder et al. 2023

The Lyman Alpha Reference sample



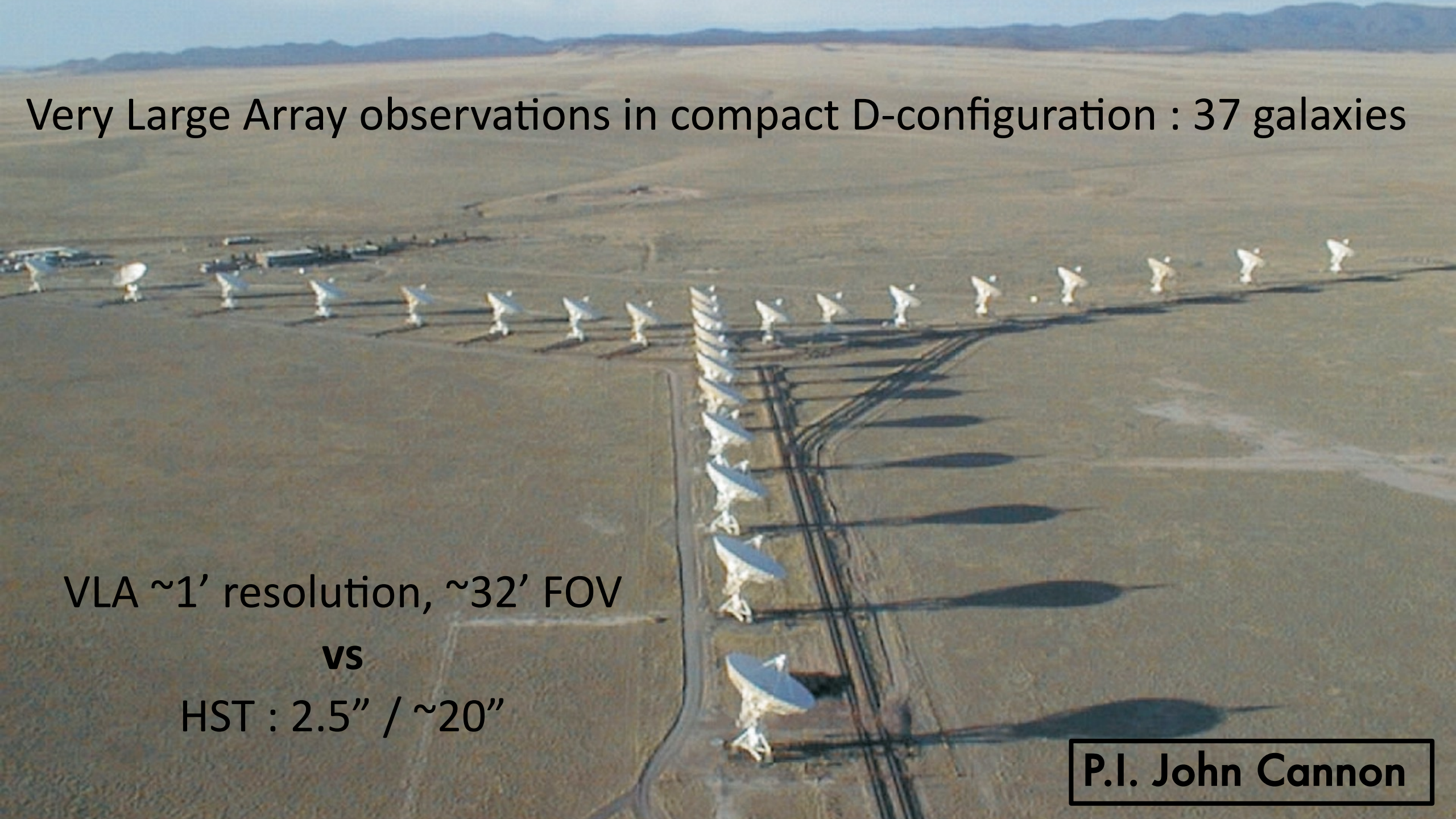
Ionized gas properties: talk by Anna Lena

The Lyman Alpha Reference sample



Main selection criteria

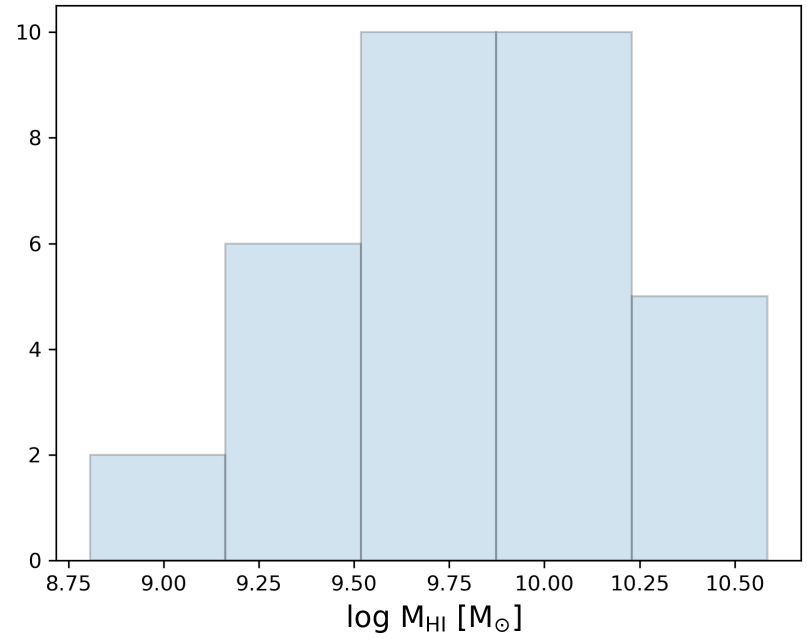
- $EW_{H\alpha} > 100$ Å (40Å)
- $z > 0.01$ (0.028)
- $z < 0.3$ (0.05)

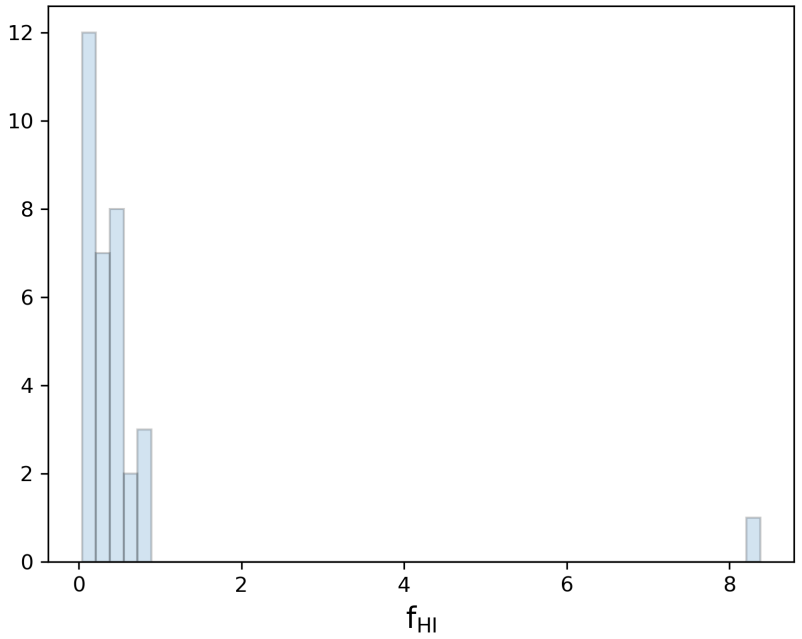

Very Large Array observations in compact D-configuration : 37 galaxies
VLA ~1’ resolution, ~32’ FOV
vs
HST : 2.5” / ~20”
P.I. John Cannon

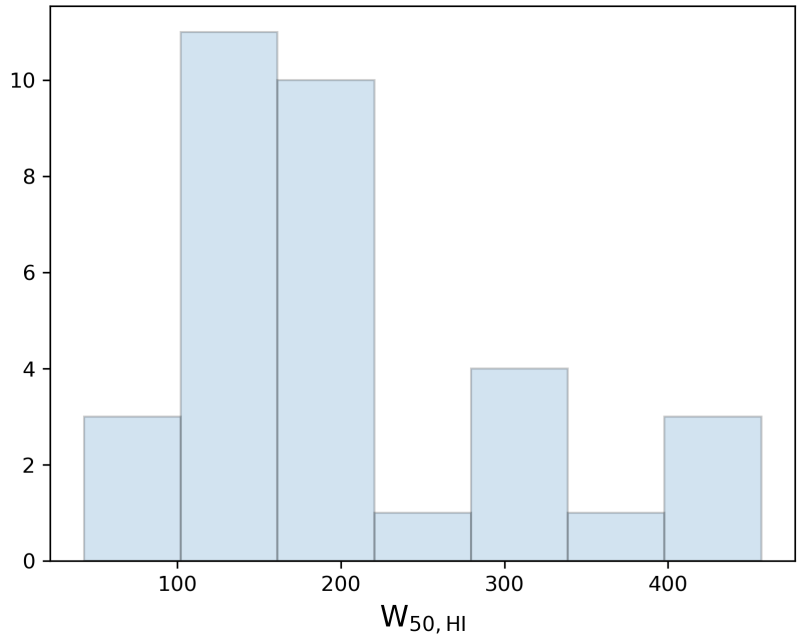
LARS – HI properties

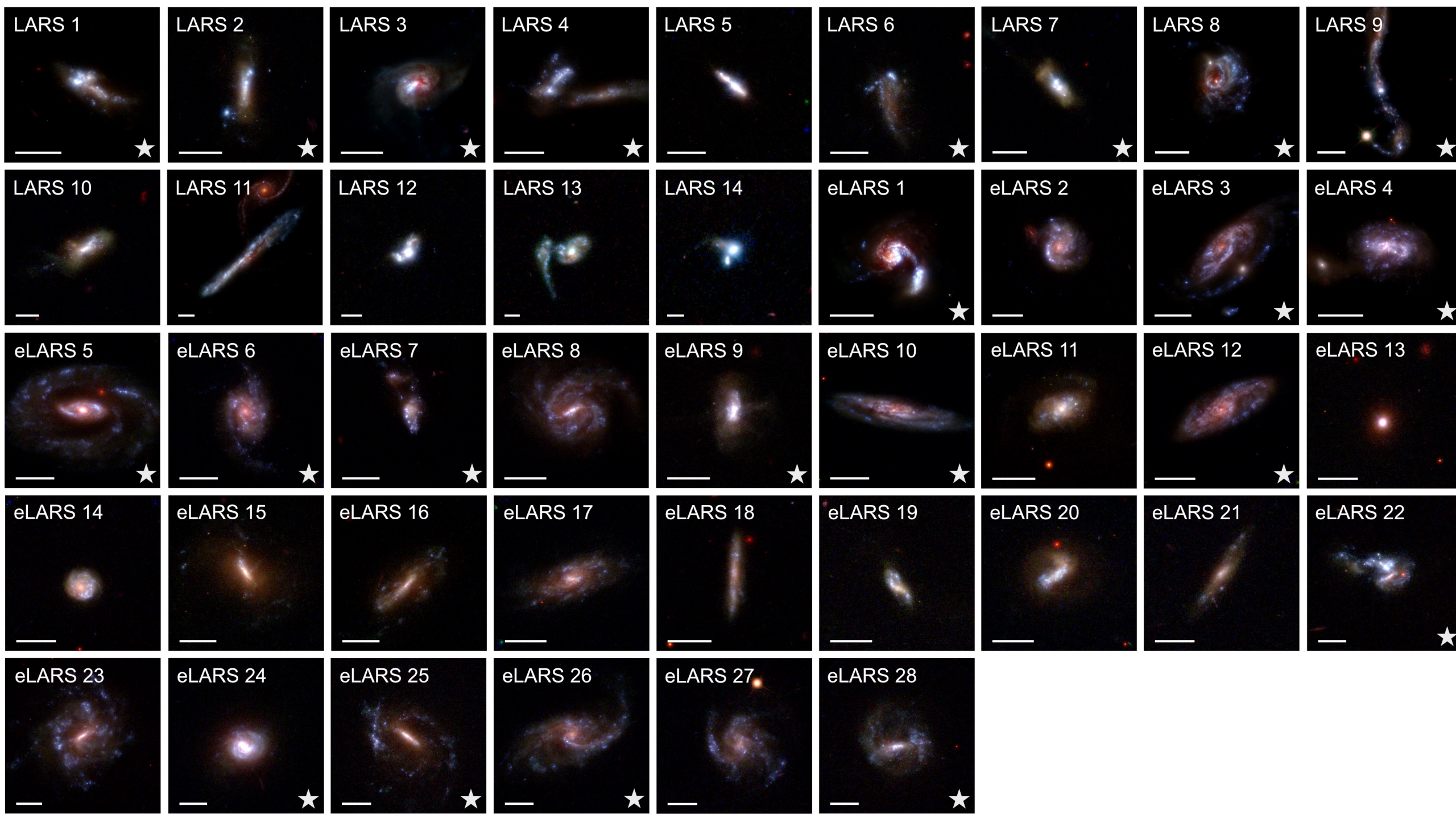
33/37 galaxies detected in 21cm with VLA D-configuration

- $M_{HI}: 6\times10^{8} - 3\times10^{10} M_{\odot}$ $\quad \overline{M_{HI}} = 5\times10^{9} M_{\odot}$
- $f_{HI}: 0.04 - 8.3$ $\quad \overline{f_{HI}} = 0.3$
- $W_{50,HI}: 43 - 454\ km.s^{-1}$ $\quad \overline{W_{50,HI}} = 169\ km.s^{-1}$








LARS 1
LARS 2
LARS 3
LARS 4
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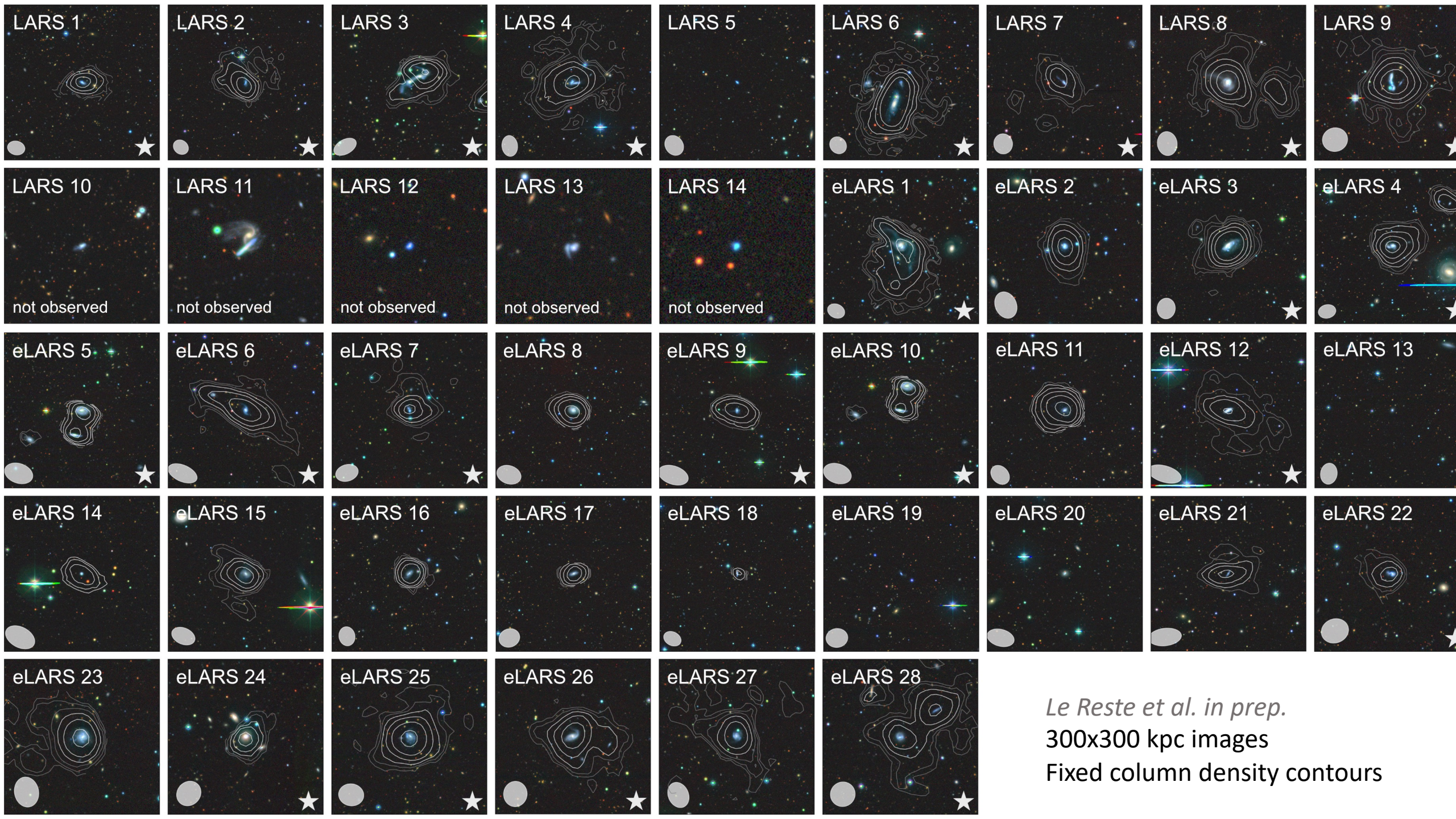
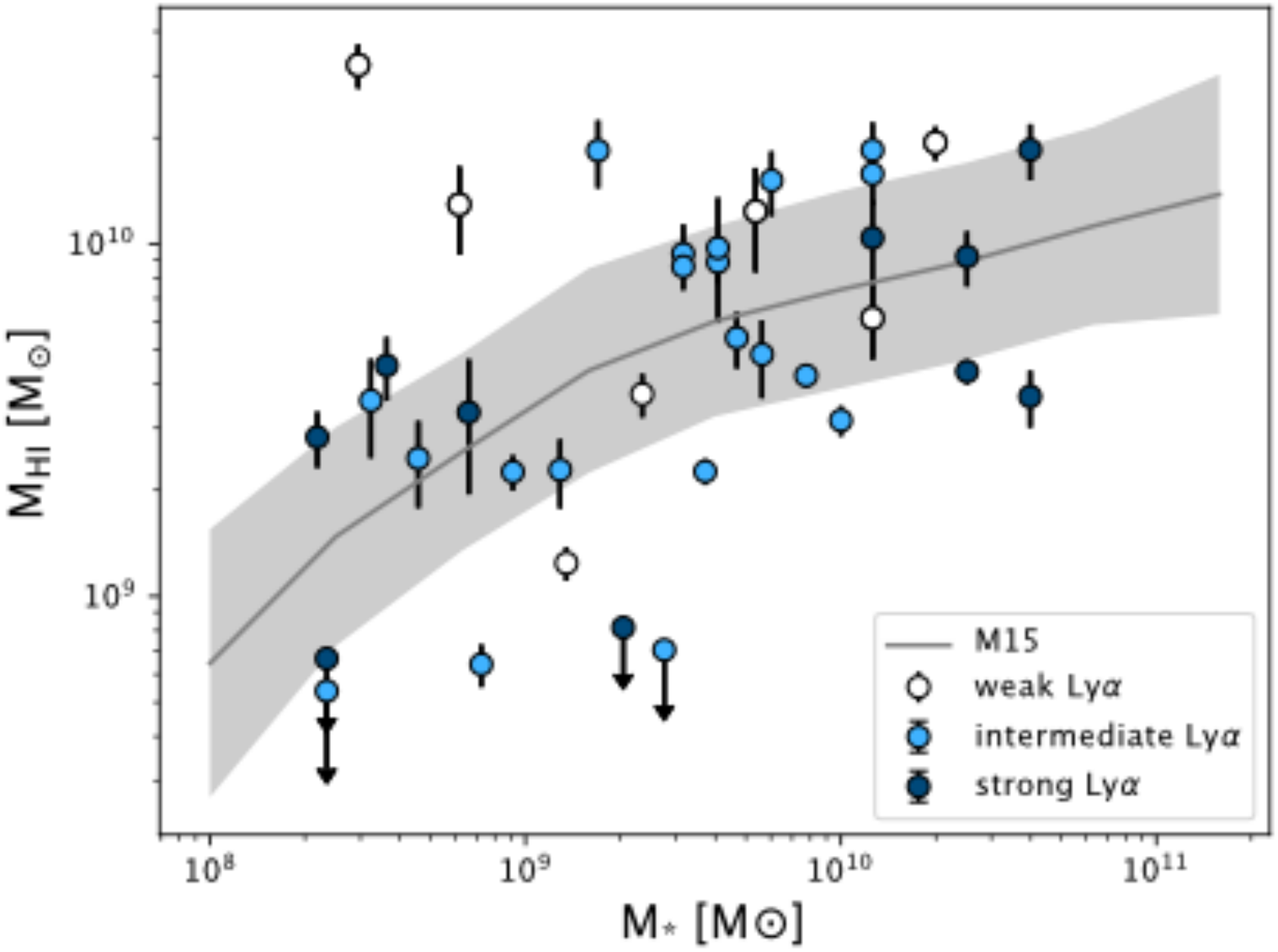


Le Reste et al. in prep.

300x300 kpc images

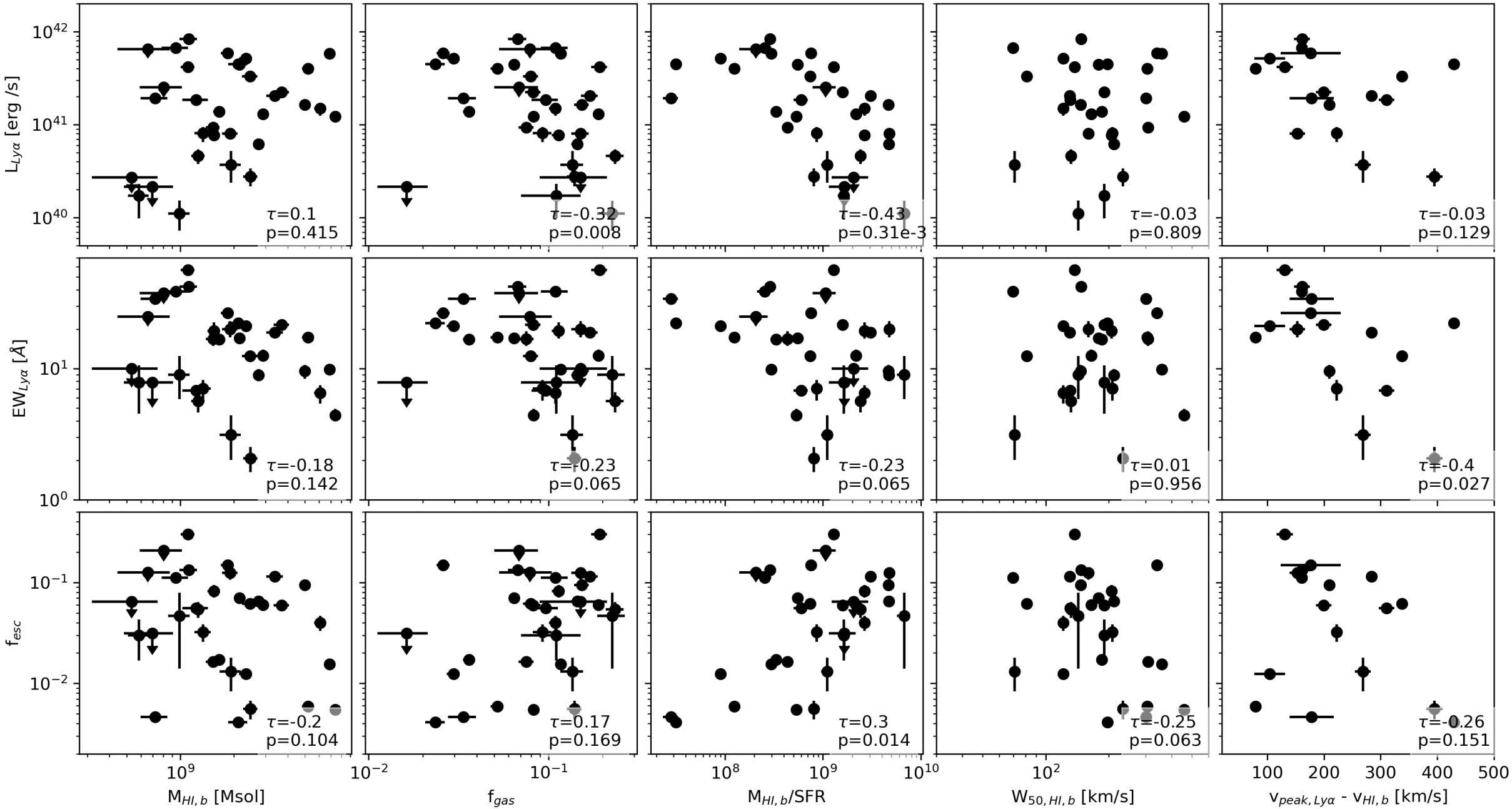
Fixed column density contours

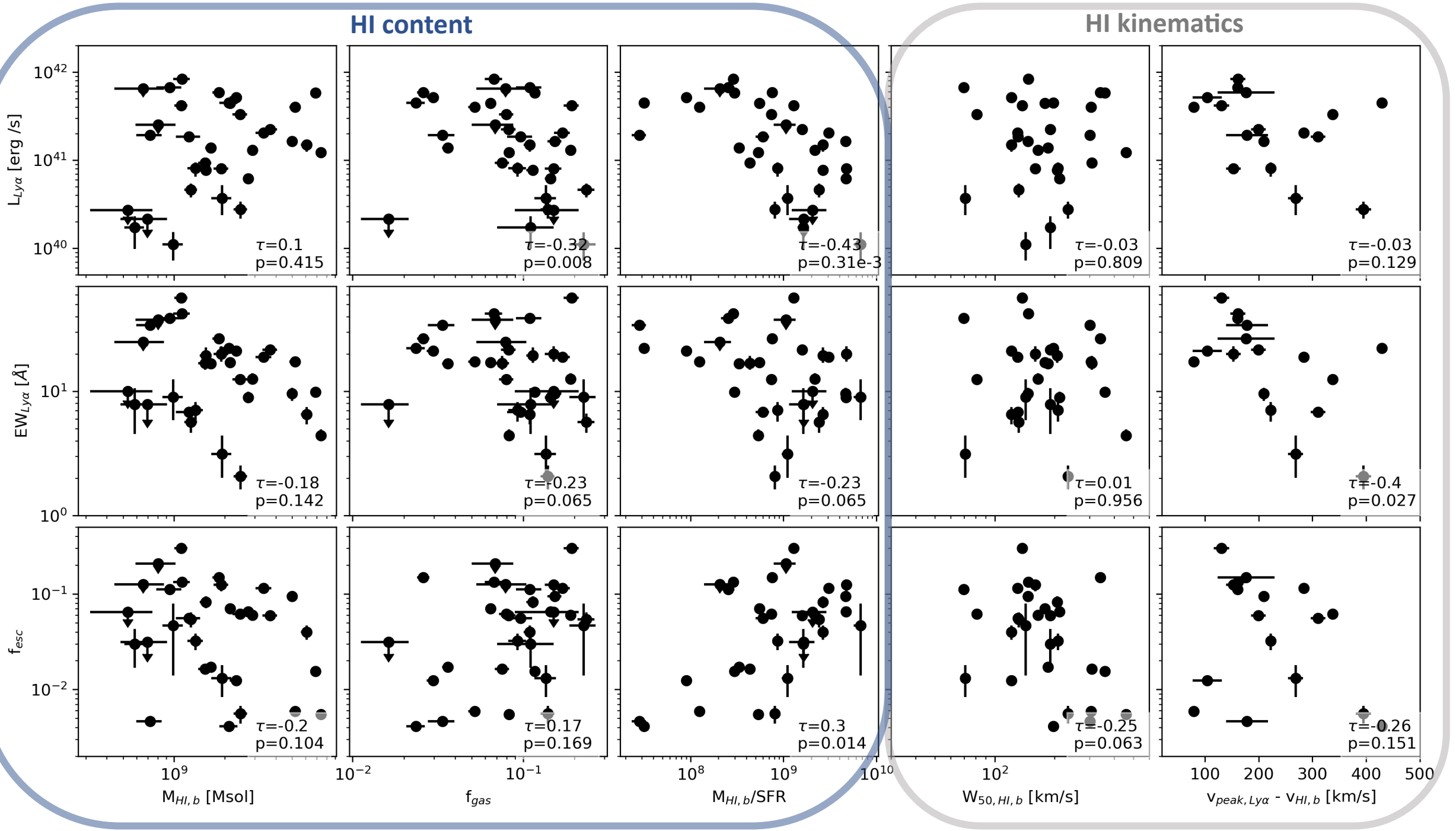
21cm properties of Lyα-emitting galaxies



HI properties **consistent with z=0** optically-selected galaxies

Weak Lyα: $EW_{Ly\alpha} < 5$ Å
Intermediate Lyα: $EW_{Ly\alpha} = 5 - 20$ Å
Strong Lyα: $EW_{Ly\alpha} > 20$ Å


$L_{Ly\alpha}$ [erg /s]
10^{42}
10^{41}
10^{40}
τ=0.1
p=0.415
τ=-0.32
p=0.008
τ=-0.43
p=0.31e-3
τ=-0.03
p=0.809
τ=-0.03
p=0.129
$EW_{Ly\alpha}$ [Å]
10^{1}
10^{0}
τ=-0.18
p=0.142
τ=-0.23
p=0.065
τ=-0.23
p=0.065
τ=0.01
p=0.956
τ=-0.4
p=0.027
f_{esc}
10^{-1}
10^{-2}
τ=-0.2
p=0.104
τ=0.17
p=0.169
τ=0.3
p=0.014
τ=-0.25
p=0.063
τ=-0.26
p=0.151
10^{9}
$M_{HI,b}$ [Msol]
10^{-2}
10^{-1}
f_{gas}
10^{8}
10^{9}
10^{10}
$M_{HI,b}$/SFR
10^{2}
$W_{50,HI,b}$ [km/s]
100
200
300
400
500
$v_{peak,Ly\alpha}$ - $v_{HI,b}$ [km/s]


HI content
HI kinematics
$L_{Ly\alpha}$ [erg /s]
$EW_{Ly\alpha}$ [Å]
f_{esc}
$M_{HI,b}$ [Msol]
f_{gas}
$M_{HI,b}$/SFR
$W_{50,HI,b}$ [km/s]
$v_{peak,Ly\alpha}$ - $v_{HI,b}$ [km/s]
τ=0.1 p=0.415
τ=-0.32 p=0.008
τ=-0.43 p=0.31e-3
τ=-0.03 p=0.809
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τ=-0.26 p=0.151

No clear correlation of Lyα with global HI properties

No clear correlation of Lyα with global HI properties

But Lyα is a multivariate problem…
Maybe adding parameters will solve it?

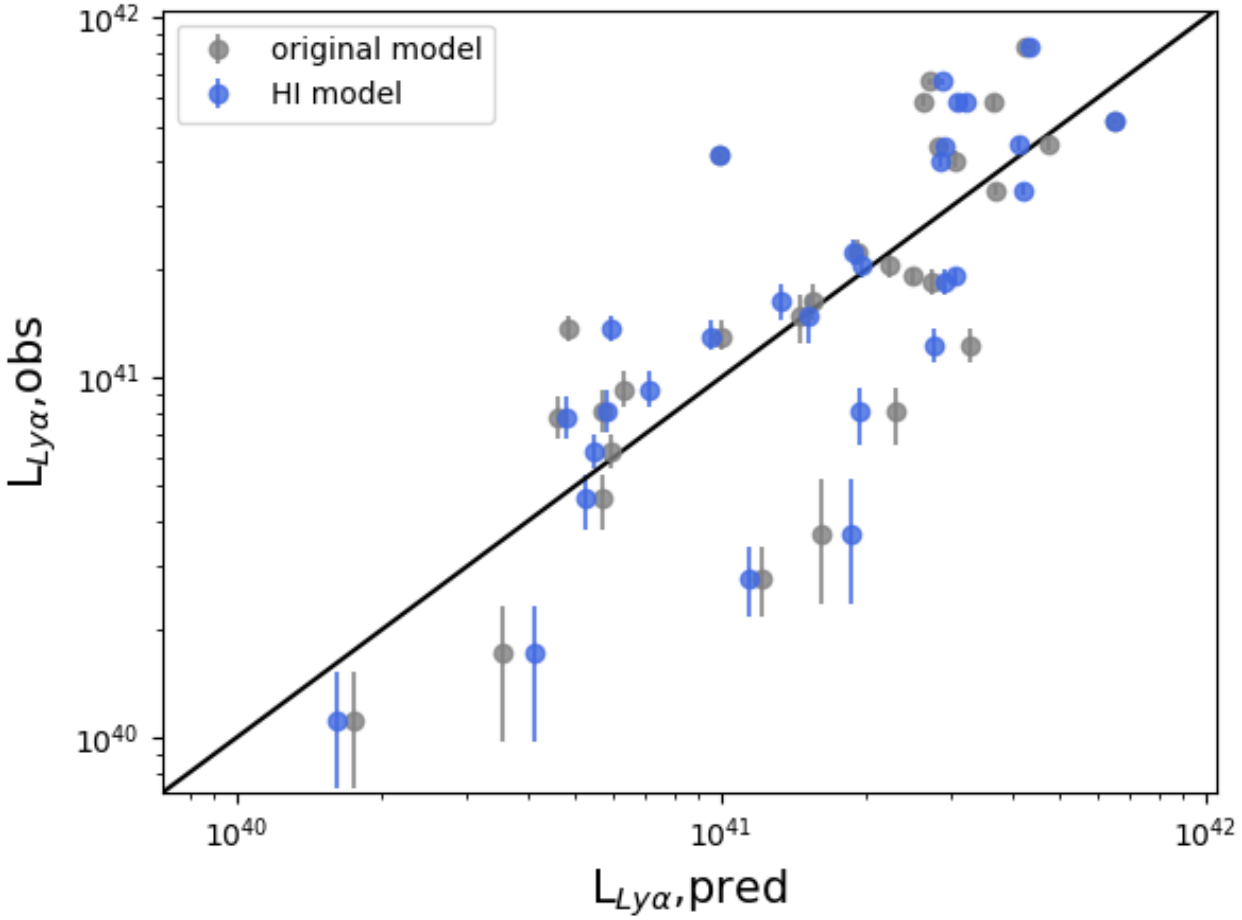
Multivariate linear regression

Model from *Runnholm et al. 2020*

Rank	original model Forward/Backward
1	SFR
2	E(B-V)
3	F_{cov}
4	UV size
5	O32
6	12+log(O/H)
7	w_{90}
8	M_*
9	v_{95}

R^2=0.604

Multivariate linear regression

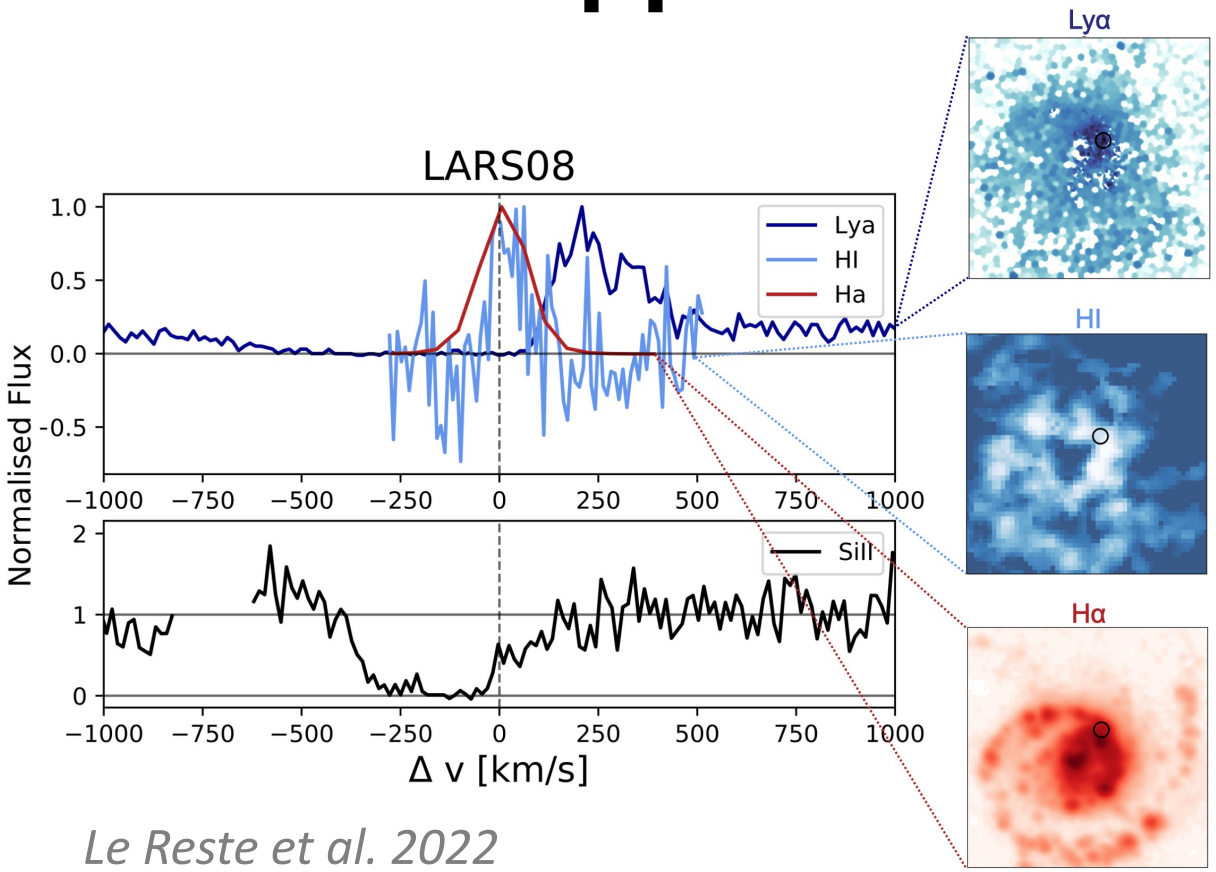


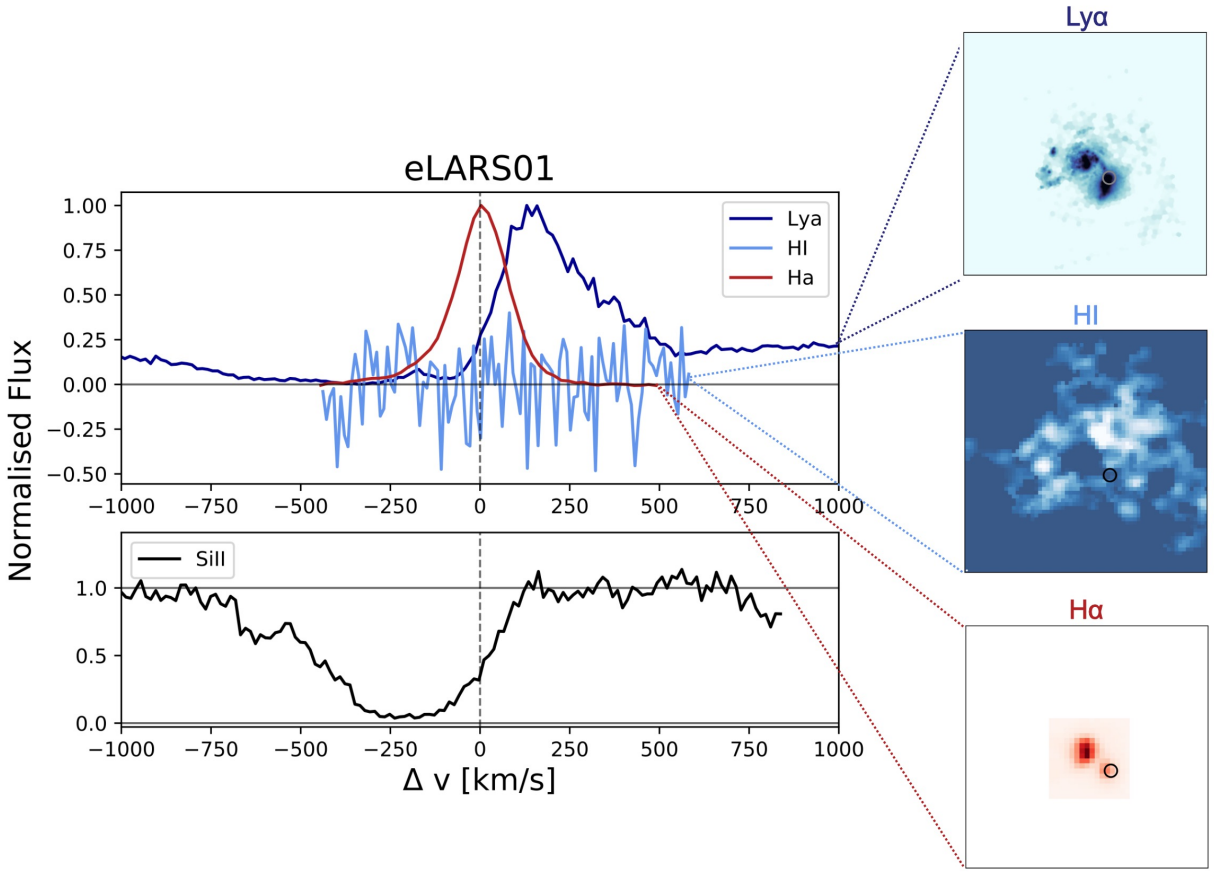
Swapping galaxy for **global HI properties does not improve the R^2 much**

Rank	original model Forward/Backward	HI model Forward/Backward
1	SFR	SFR
2	E(B-V)	E(B-V)
3	F_{cov}	F_{cov}
4	UV size	$M_{HI,b}$
5	O32	O32
6	12+log(O/H)	12+log(O/H)
7	w_{90}	UV size
8	M_*	$W50_{HI,b}$
9	v_{95}	w_{90}
	R^2=0.604	R^2=0.607

Does HI regulate Lyα on small scales?

What happens on small scales?





Le Reste et al. 2022

Lyα line profile: depends on HI properties

Faint Lyα emission traces the structure of Hα and 21cm emission

→ Bimodal emission modality in the centre vs halo?

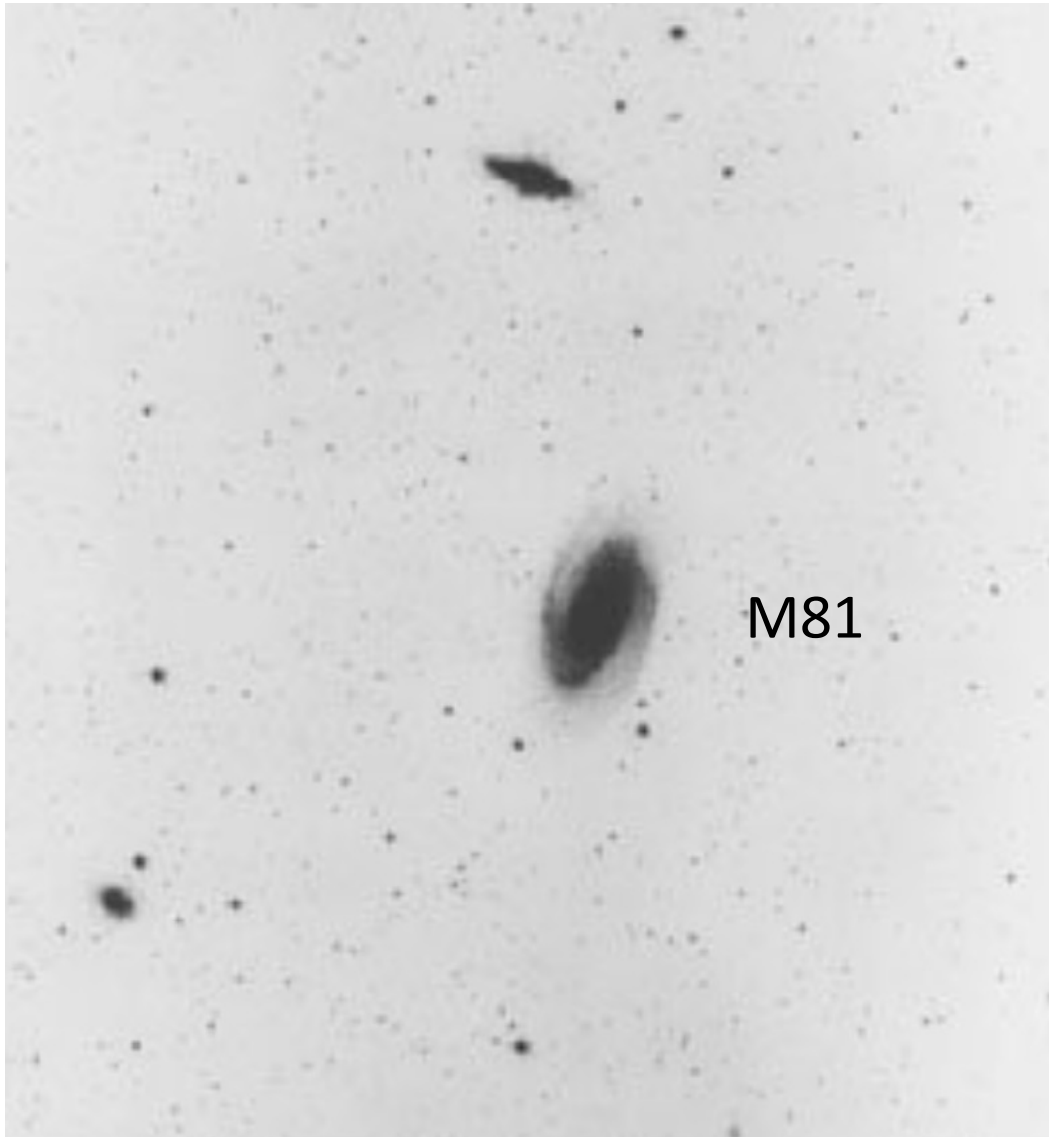
What happens on small scales?

Also *Le Reste et al. 2022:*

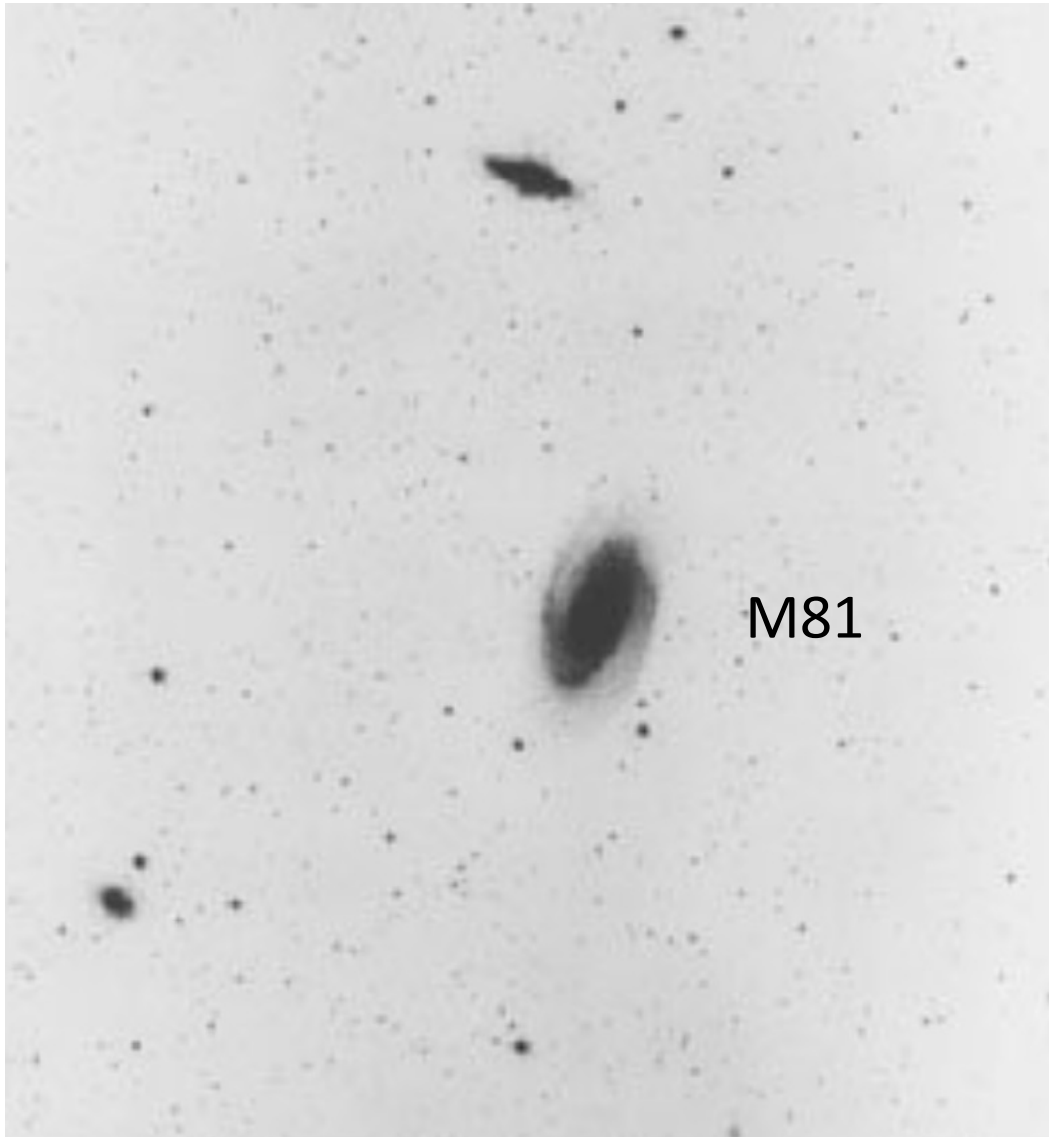
"[The 21cm distribution of the galaxies] indicates that mergers might play a decisive role in fragmenting the neutral ISM and in creating the conditions that facilitate Lyα escape."


THE 21CM LINE
Part 2: Galaxy interactions

Identifying mergers with the 21cm line



Identifying mergers with the 21cm line



De Blok et al. 2018

Identifying interacting galaxies in the LARS

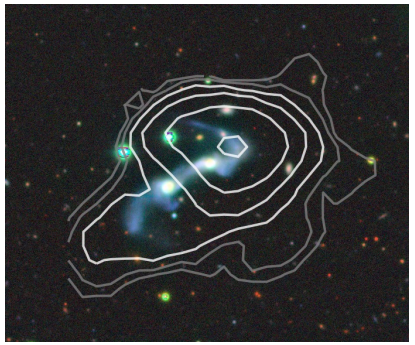
Merger morphology in optical or 21cm

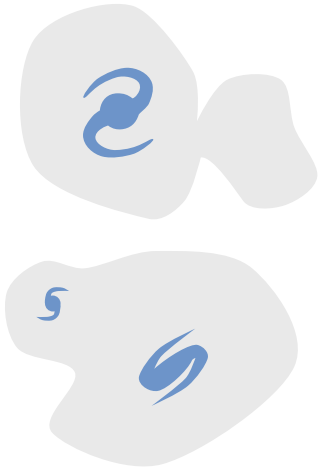
Offset neutral gas envelope including companion object

Regular morphology but galaxy in known group

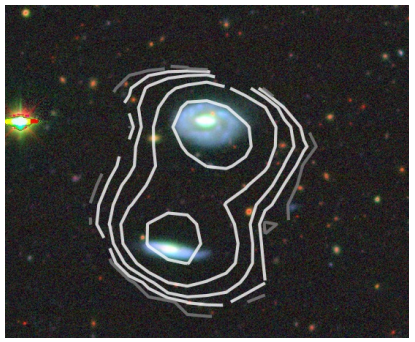
Identifying interacting galaxies in the LARS

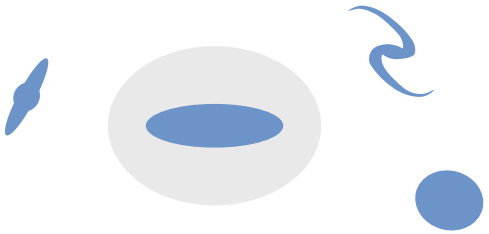
Merger morphology in optical or 21cm





Offset neutral gas envelope including companion object



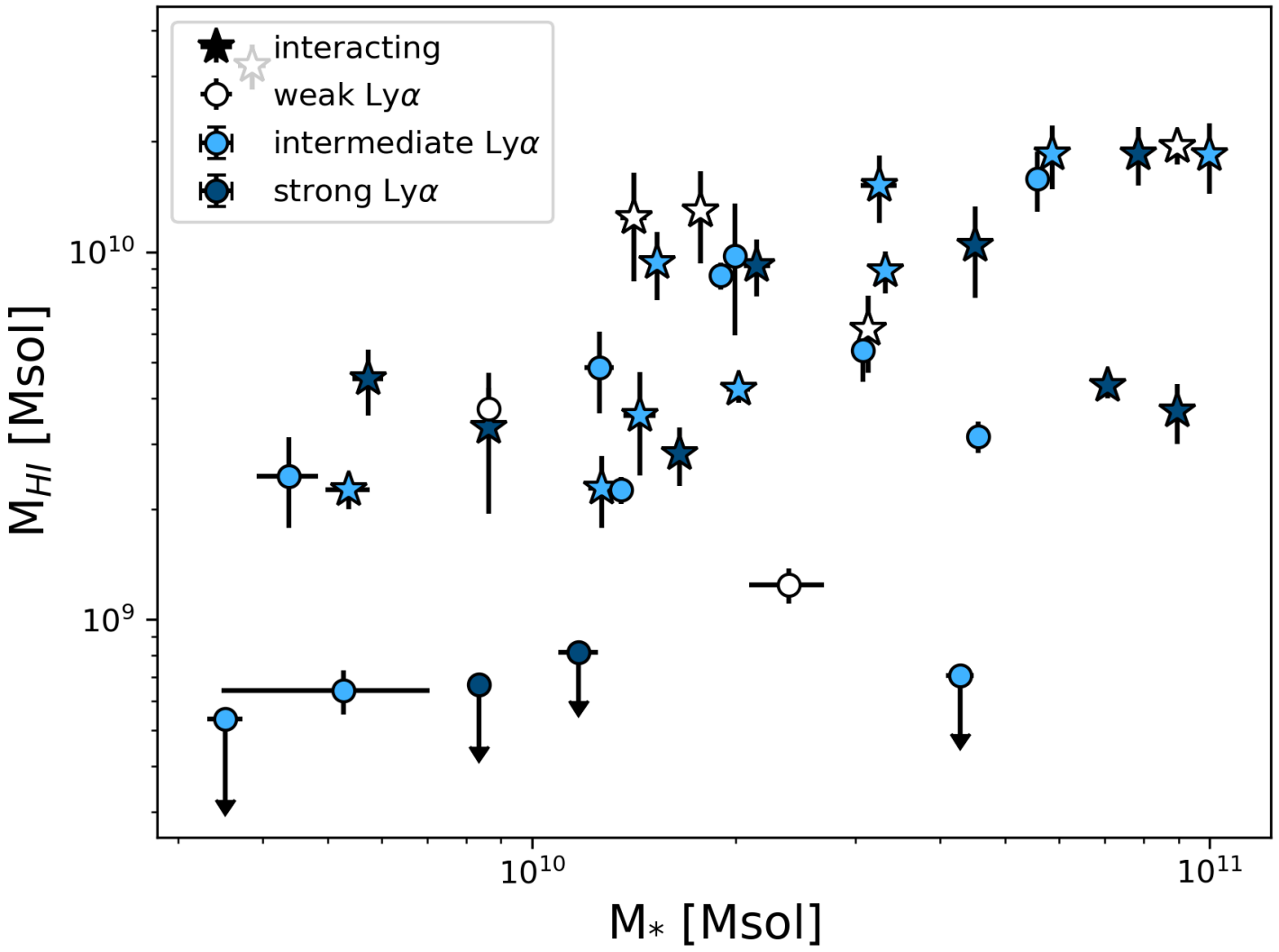


Regular morphology but galaxy in known group

Interacting galaxies in the LARS

Galaxies undergoing gravitational interaction with companion: **at least 60% of the sample** observed in 21cm.

Interacting galaxies in the LARS



Higher fraction of interacting galaxies at high M_* and high M_{HI}

Interacting galaxies in the LARS

Lyα class	interacting
weak emitter	71%
intermediate emitter	45%
strong emitter	85%

High fraction of interacting galaxies for **both the weak and strong emitters**

Anisotropic gas distribution resulting from mergers might play a role

Mergers and Lyα radiation escape

Cooke+2010

“ This [...] suggests a picture in which a measurable fraction of the Lyα emission of LBGs, and potentially LAEs, is generated via interaction mechanisms such as triggered star formation and the dispersal of obscuring gas and dust ”

Mergers and Lyα radiation escape

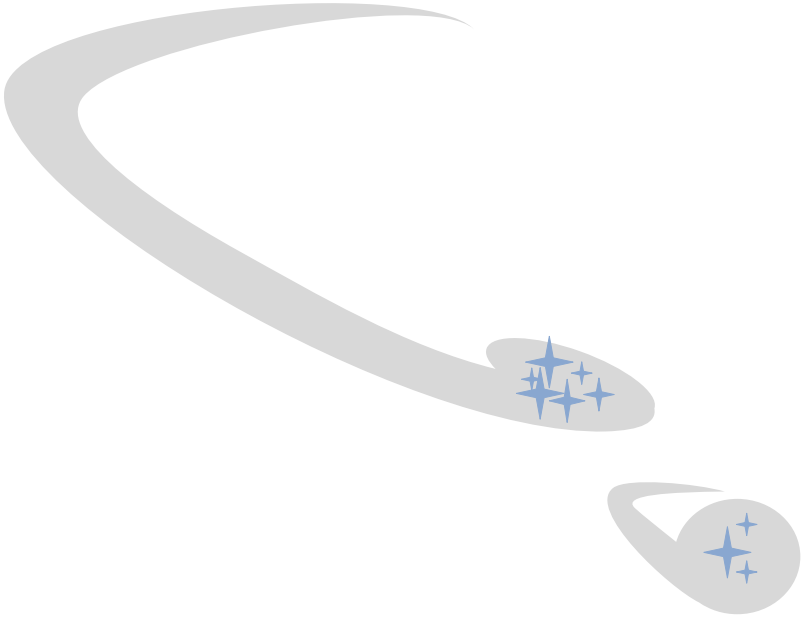
Cooke+2010

“ This [...] suggests a picture in which a measurable fraction of the Lyα emission of LBGs, and potentially LAEs, is generated via interaction mechanisms such as triggered star formation and the dispersal of obscuring gas and dust ”

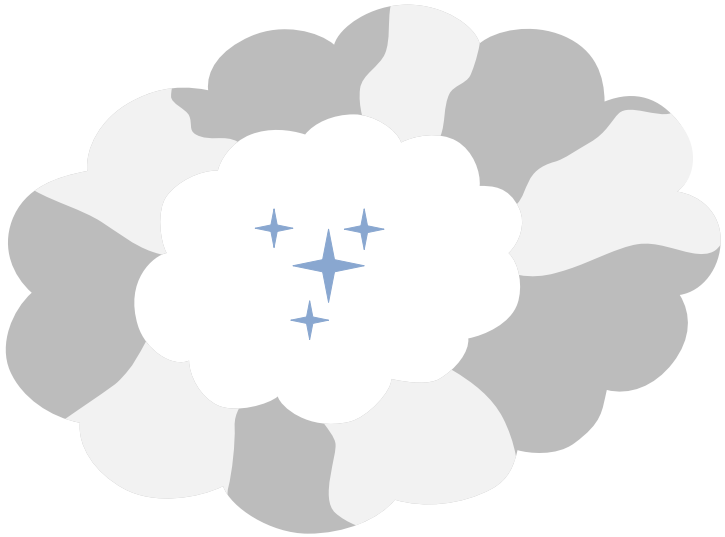
Results not confirmed in subsequent studies (e.g. *Hagen+2016*)

⚠️ Pair count: not always able to identify interaction, especially at high-z

Mergers and Lyman radiation escape



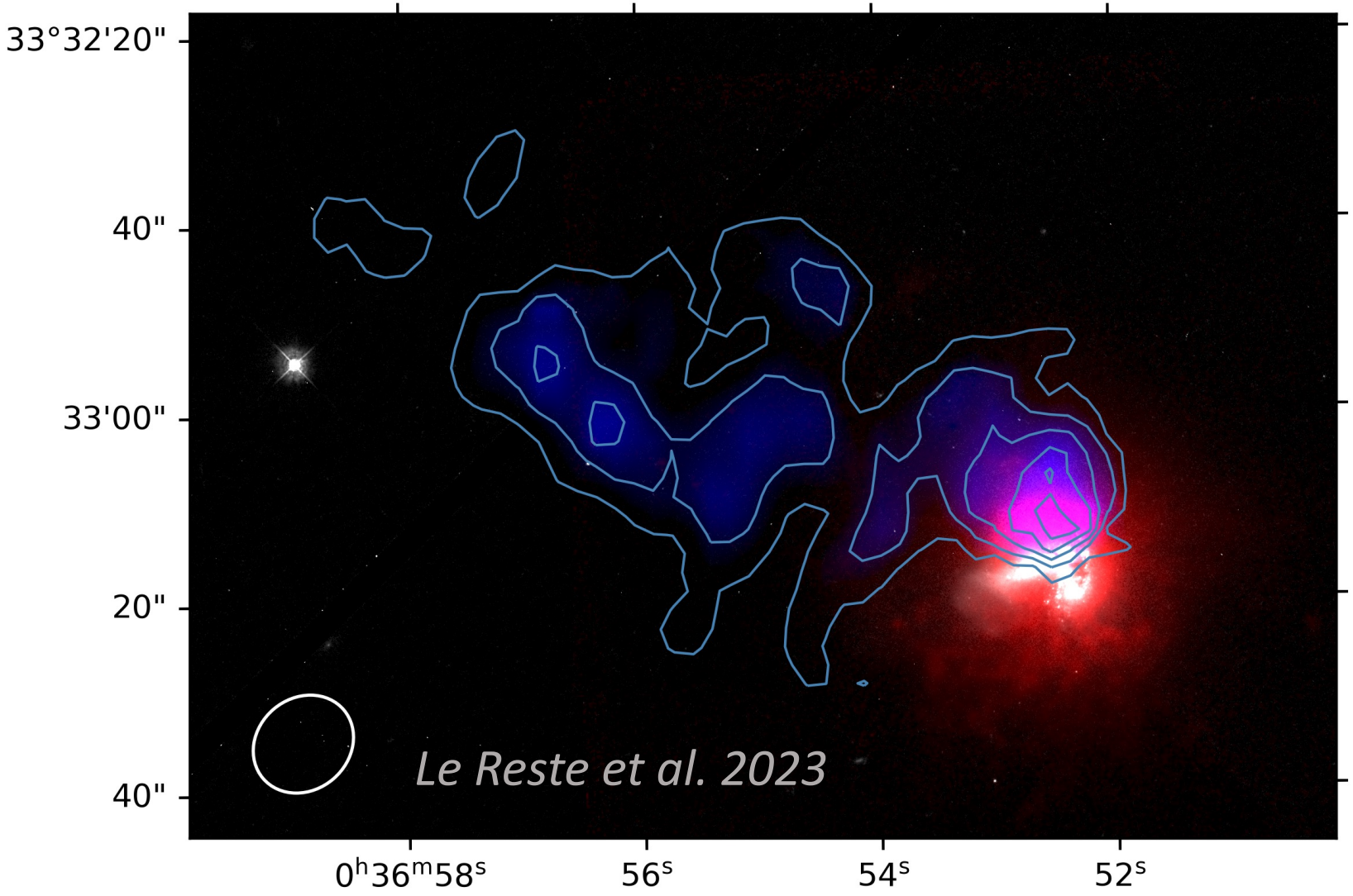
1) Cause several starburst episodes:
→ Ly* production



2) Starburst generates large-scale ionized channels + outflows

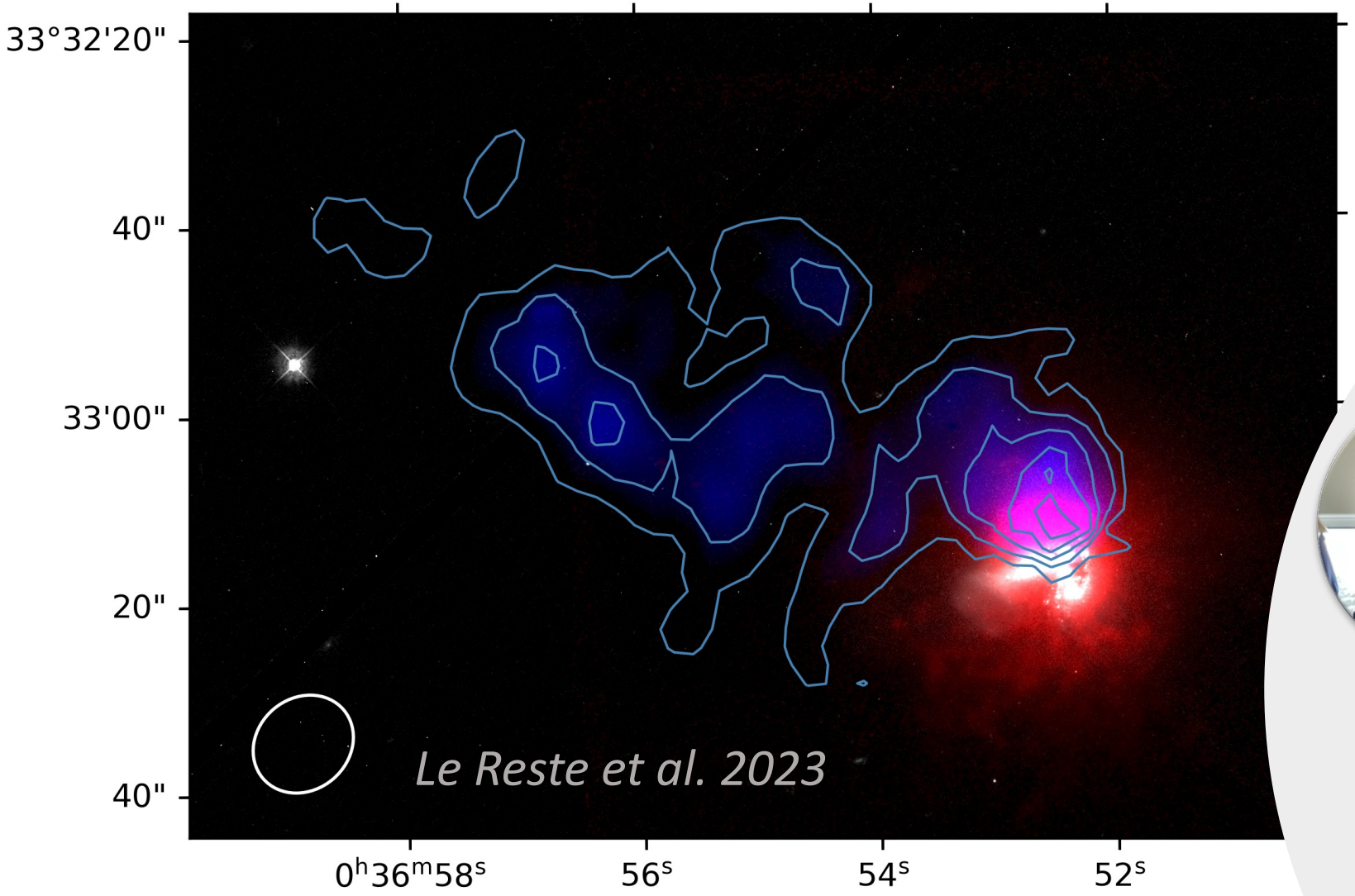
3) Large scale displacement of HI
→ anisotropic escape to IGM

Mergers and Lyman continuum escape

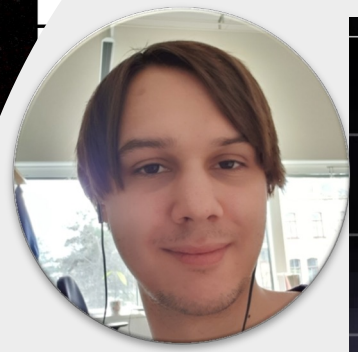


Up to 82% of the HI mass is offset from the LyC producing regions

Mergers and Lyman continuum escape



Don’t miss Timmy’s talk this afternoon!



Conclusions

HI properties of Lyα-emitters

- Lyα-emitting galaxies have global HI properties similar to bulk of z~0 galaxies
- Global HI properties do not impact the Lyα EW, fesc or luminosity much

Gravitational interaction

- **At least 60%** of LARS galaxies are interacting gravitationally with a companion
- 70% of weak emitters/absorbers **AND** 80 % of high Lyα emitters are interacting – due to anisotropy in merger interactions
- Higher fraction of mergers at high stellar masses: interaction required so sufficiently perturb the ISM?

Open questions

→ **Correlation between Lyα properties and 21cm on kpc scale?**

→ **Effect of environment on Lyα emission?**

→ **Which mergers are Ly-emitters ? What characteristic timescales?**

Ευχαριστώ !