Dark Cosmology Centre
Niels Bohr Institute

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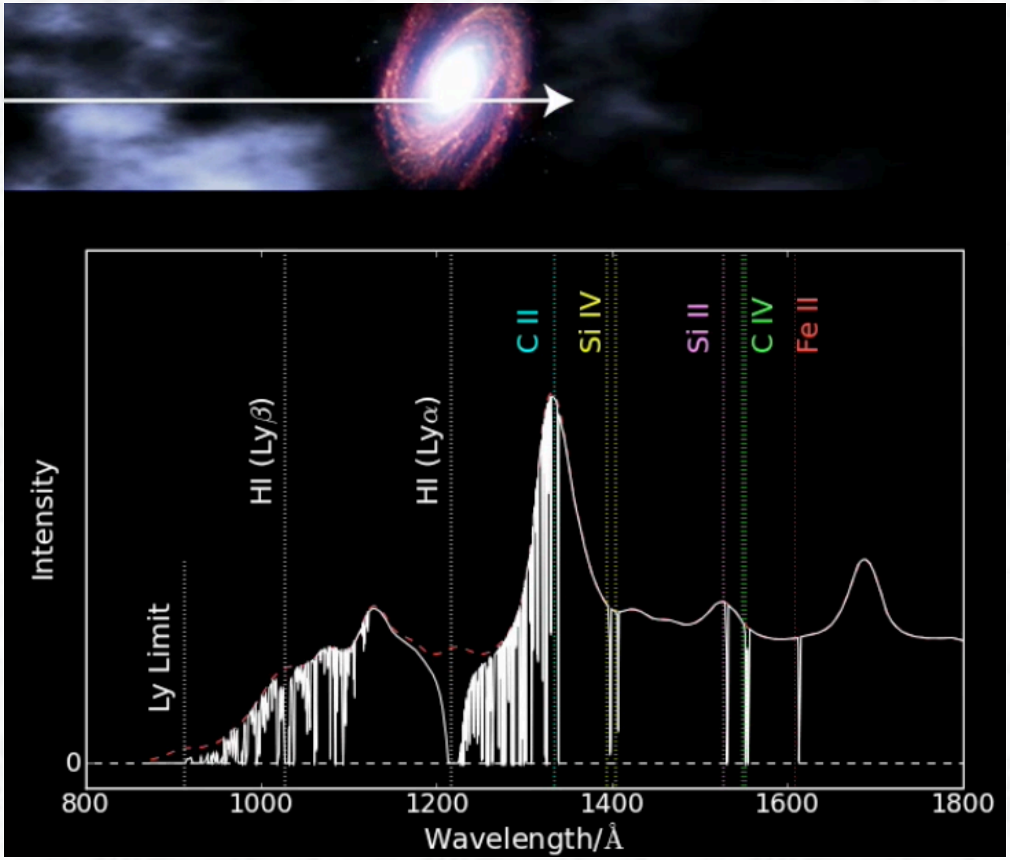
Connecting the CGM from strong absorbers with galaxy dark matter halos



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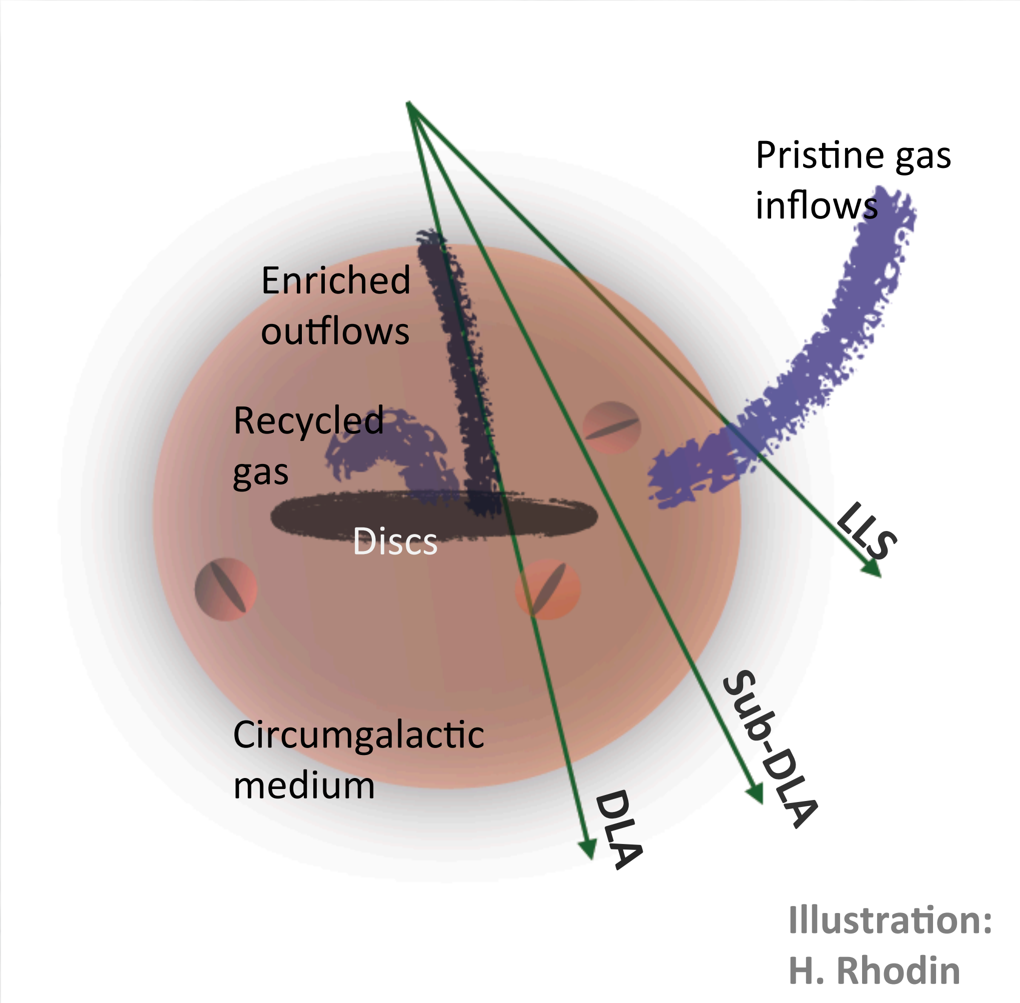
Collaborators:

Henrik Rhodin, Palle Møller, Johan Fynbo

Intergalactic interconnection conference
Marseille
July 12, 2018

Absorption line tracers



Damped Lyα systems (DLAs)

- log N(HI) > 20.3
- Cold, neutral gas
- Robust metal measures

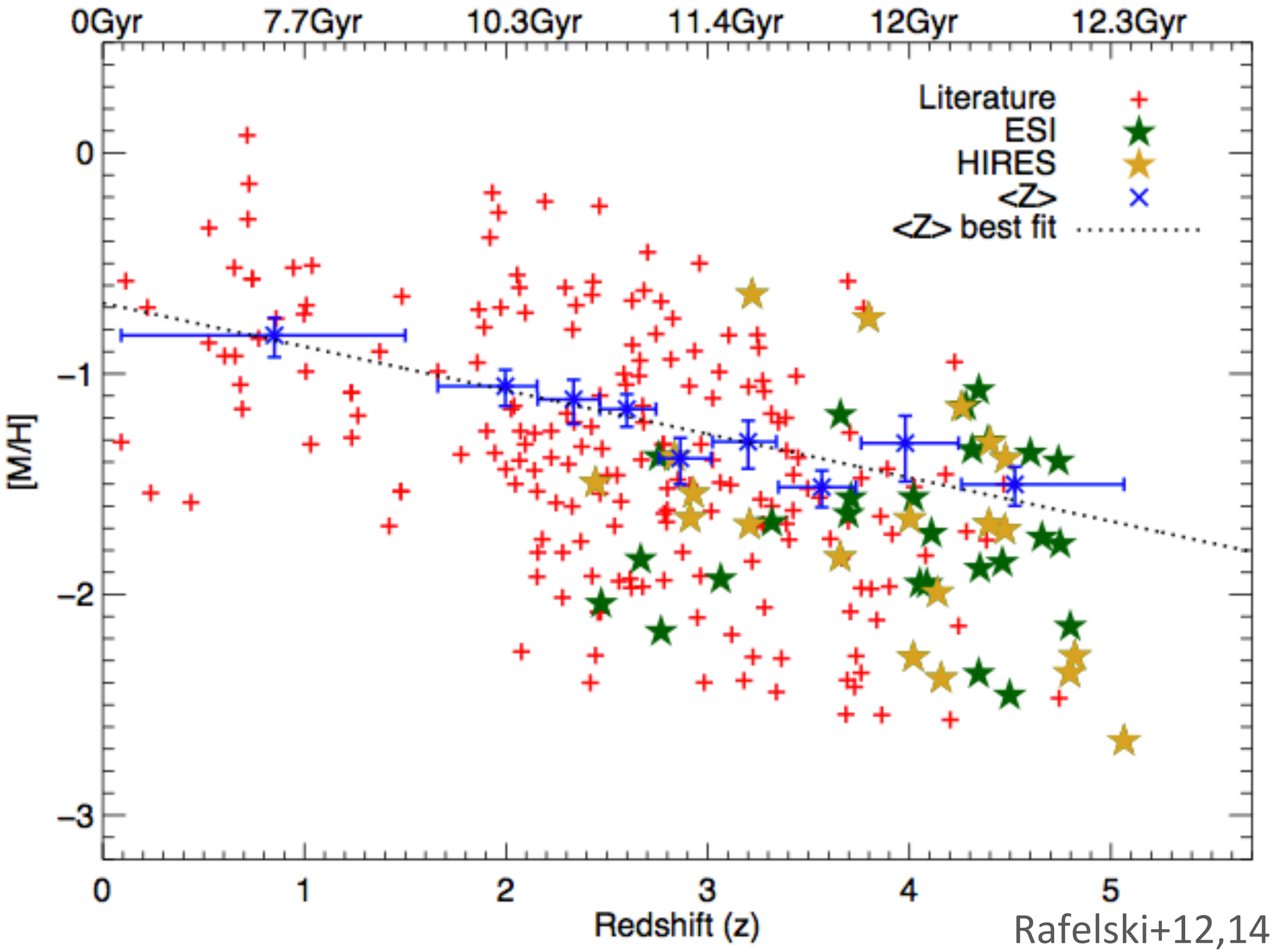
Sub-DLAs / Super - LLS

- 19.0< log N(HI) < 20.3
- Partly ionised
- More metal enriched
  (e.g. Kulkarni+2007)

Lyman limit systems (LLSs)

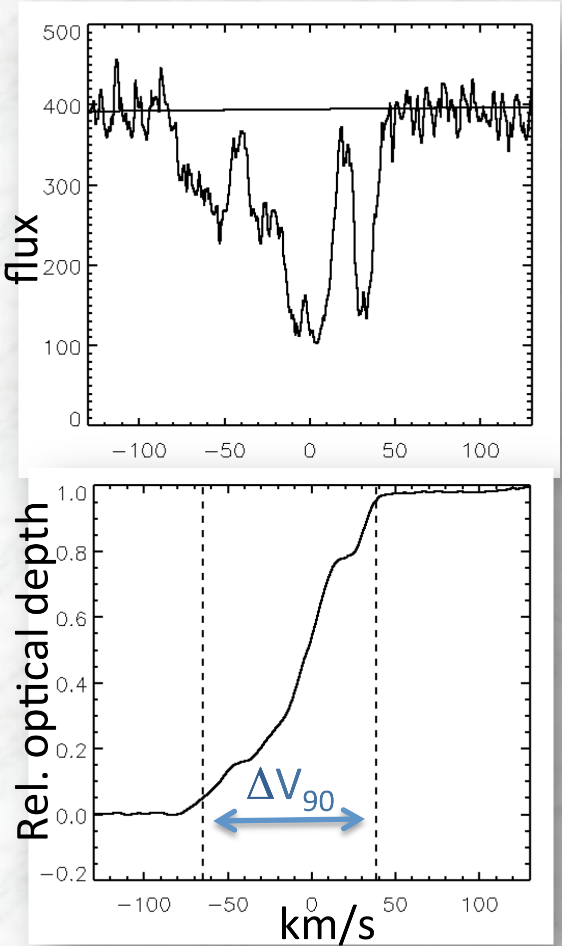
- 17 < log N(HI) < 19.0
- Ionized
- Trace overdensities
- Low metallicities
  (Becker+12; Fumagalli+11)

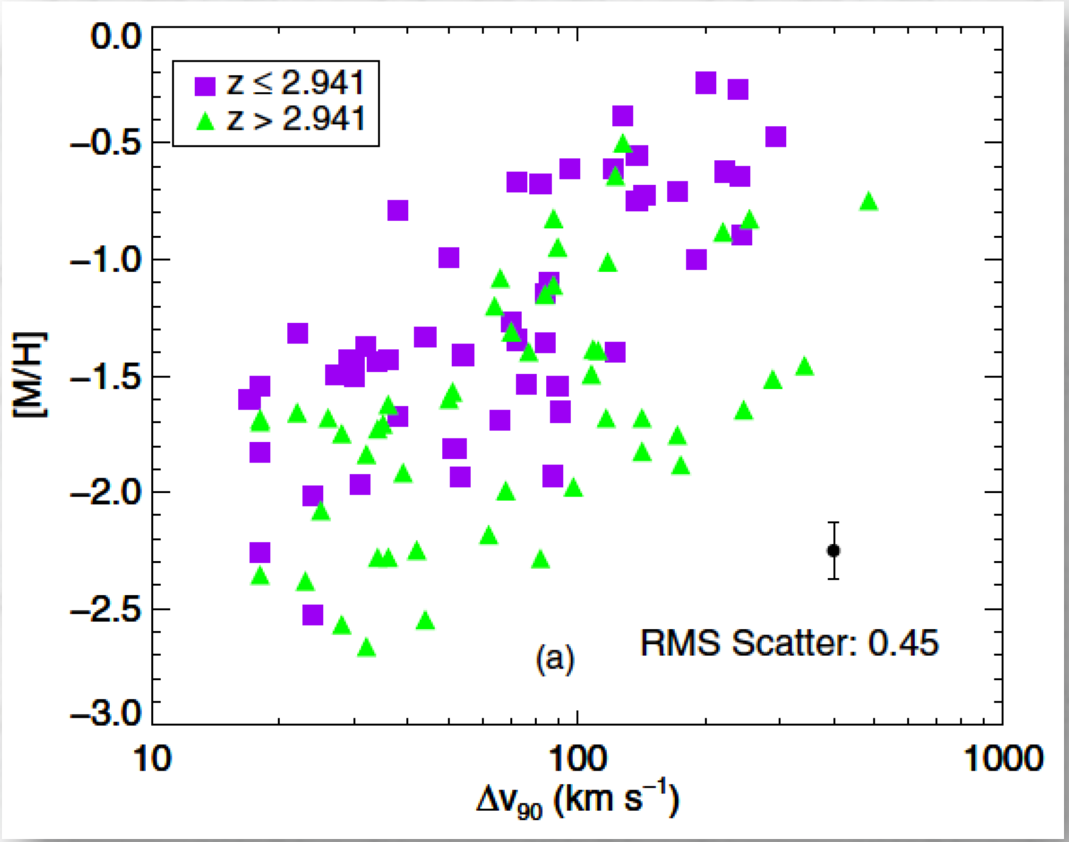
Absorption line – metallicities



Rafelski+12,14

Metal absorption line widths ΔV_{90}





- Evolves with z
- DLA- mass metallicity relation

Prochaska & Wolfe 97; Ledoux+06; Prochaska+08; Møller+13, Neeleman+13; Som+15

Probing the CGM with quasar absorbers

Observations of dependence with radius :

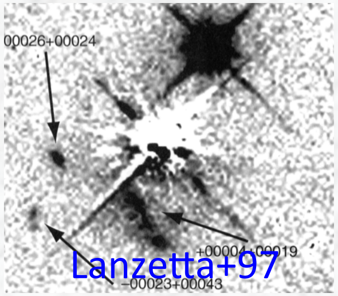
- Gas covering fractions
- Cloud sizes
- Column densities
- Equivalent widths
- Metallicities
- Velocity offsets

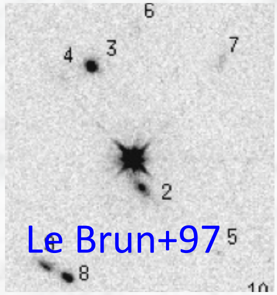
Host mass dependence?

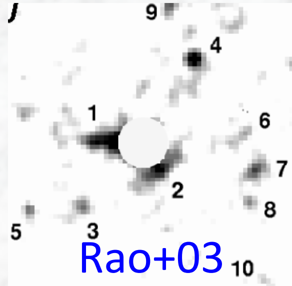
Velocity dispersion (ΔV_{90}) as tracer ?

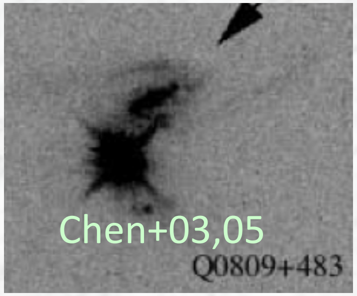
Finding the absorbers in emission

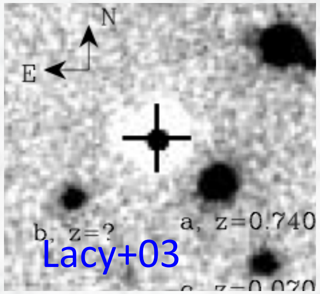
Many searches for the DLA host counterparts (non-exhaustive list.)

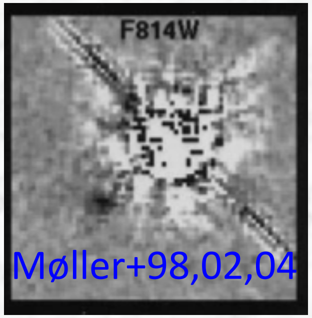


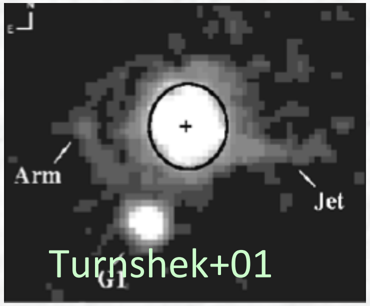


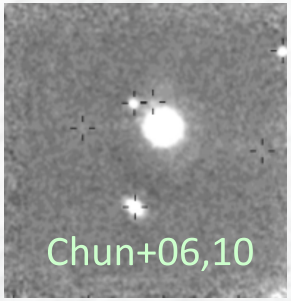


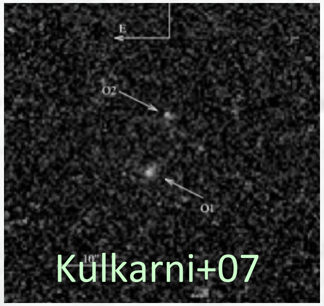


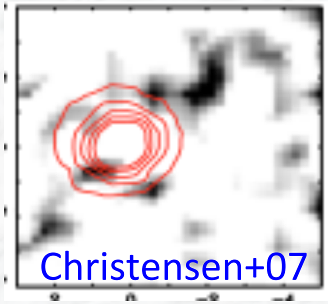


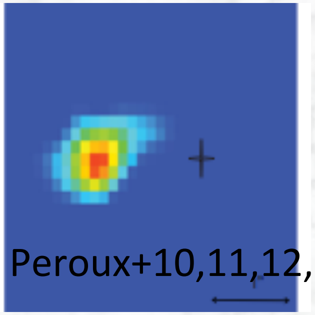


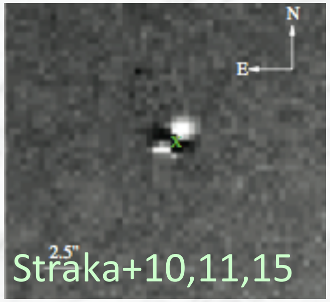


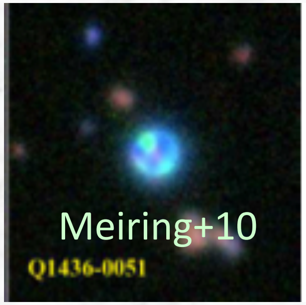


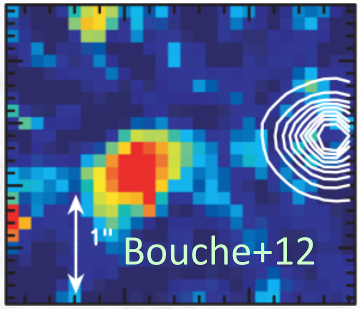


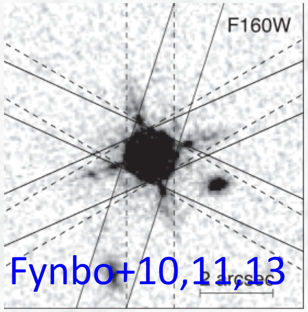




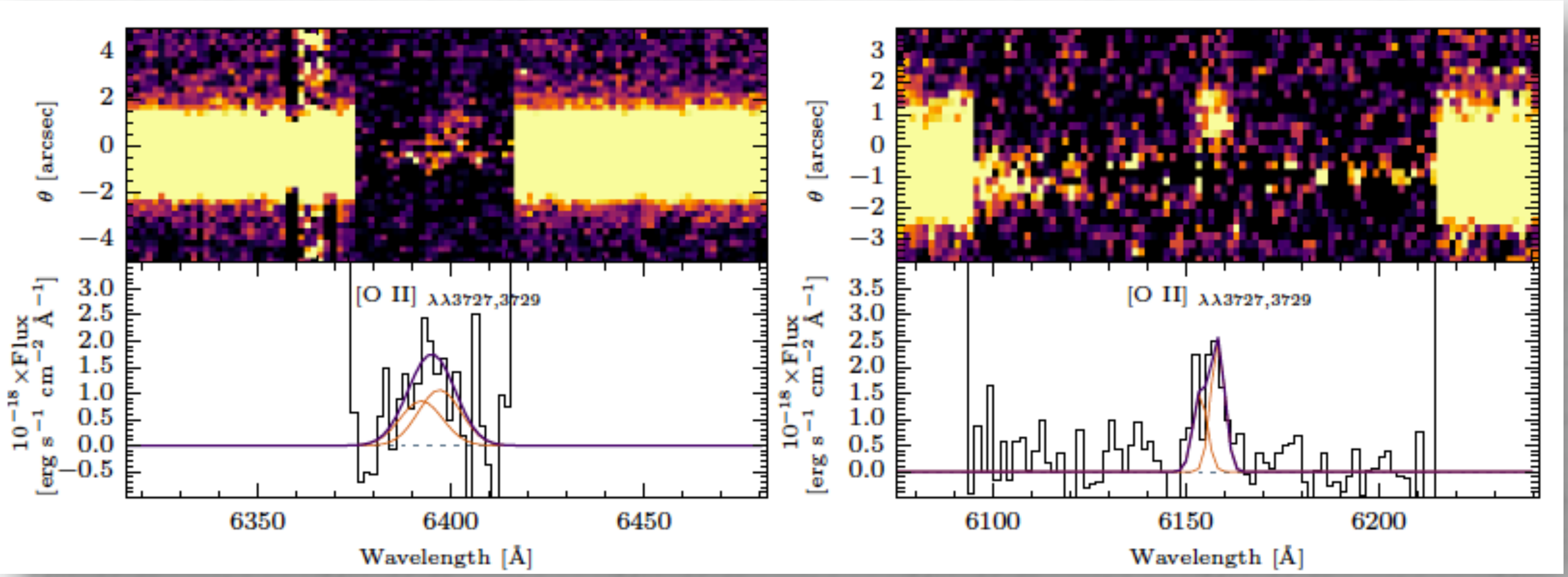








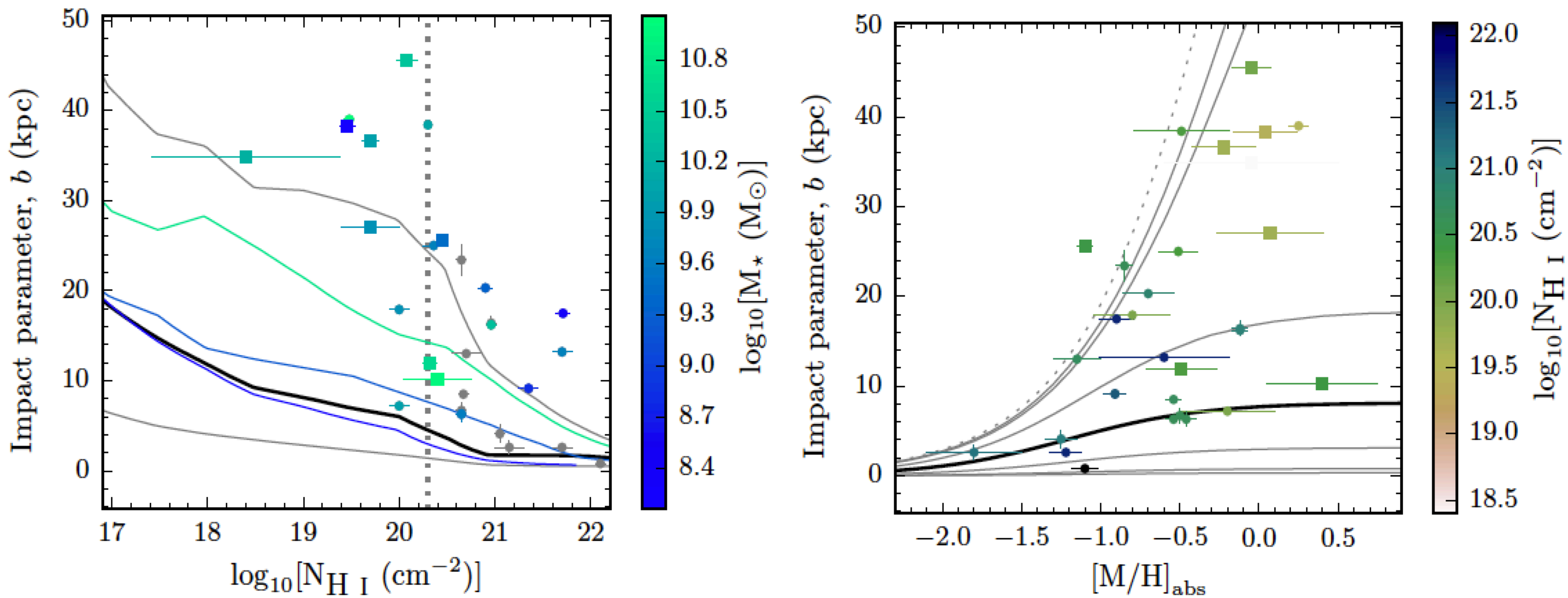
Galaxies associated with DLAs



Spectroscopic survey of DLA hosts

(Henrik Rhodin et al. 2018)

Impact parameter – disc sizes in (sub)-DLAs



Metal rich (sub) DLAs (at ~> 10% solar metallicity) at redshifts z = 0.1-3.1

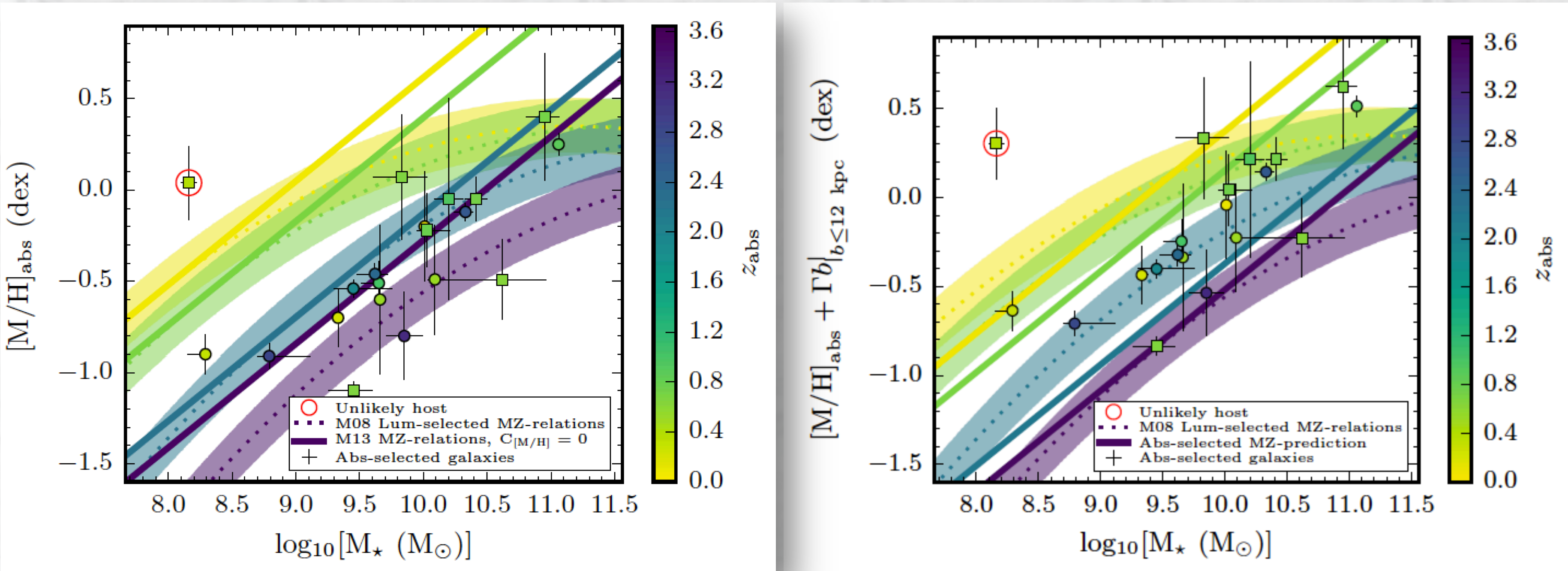
Impact parameters : 0 – 50 kpc

Stellar masses : log M* = 8 - 11

Rhodin +2018 (ArXiv/1807.01755)

(model comparisons in Krogager+17; Freudling in prep.)

Probes of galaxy stellar masses



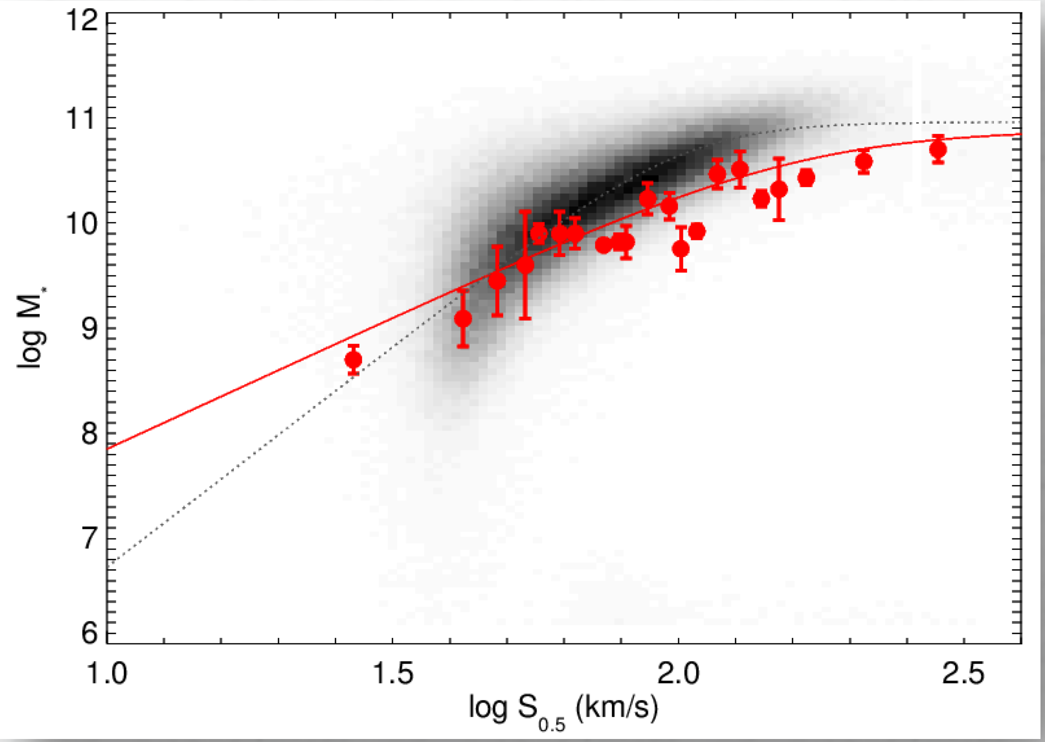
DLA system mass-Metallicity Relation

Radial metallicity gradient : -0.022 dex/kpc

Møller+13 ; Christensen +2014; Rhodin+2018 (ArXiv/1807.01755)

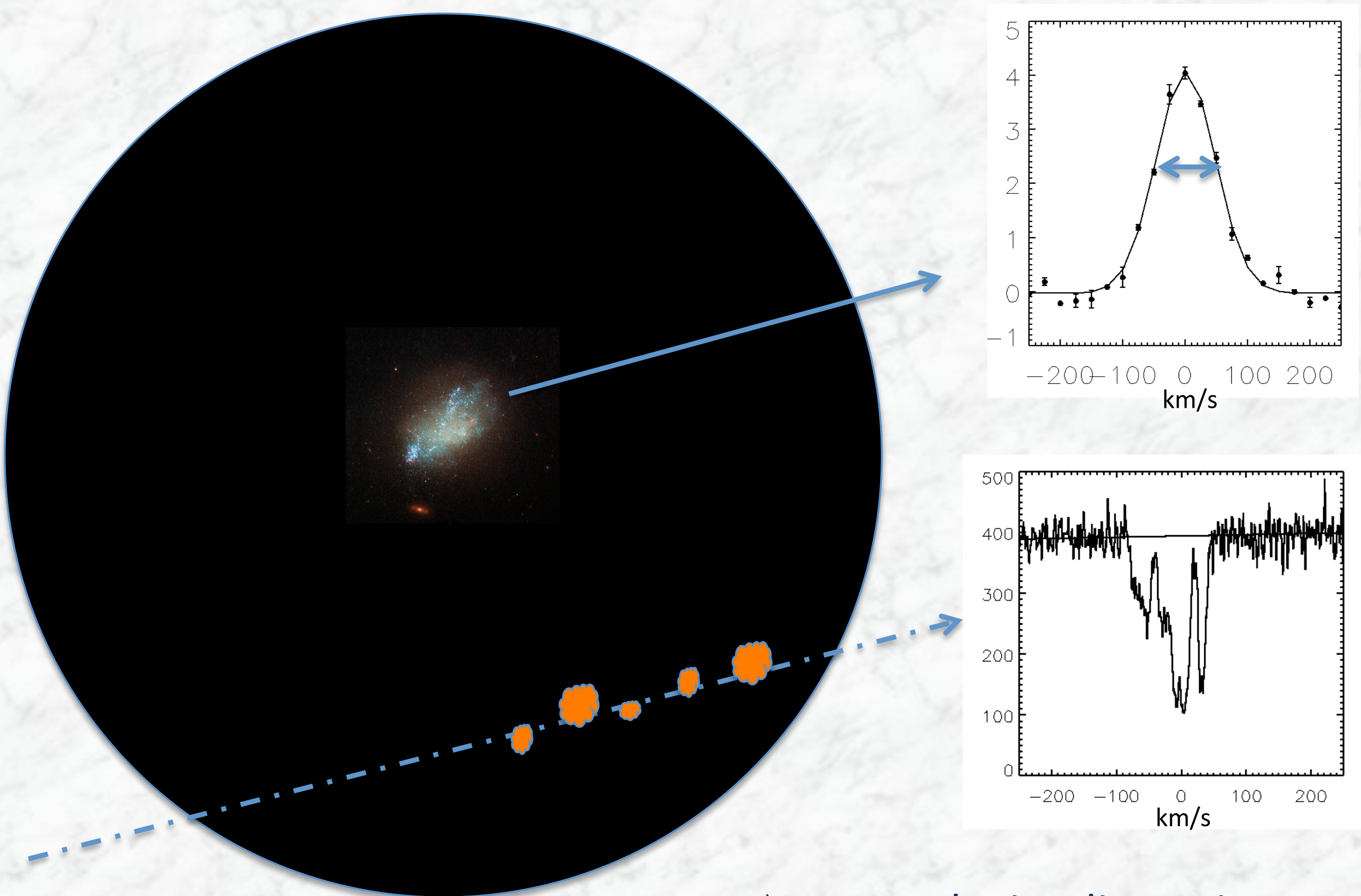
Probes of galaxy stellar masses

Stellar mass Tully-Fisher Relation



Kassin+07;
Christensen+2017
Turner+2017

Proxies of stellar masses

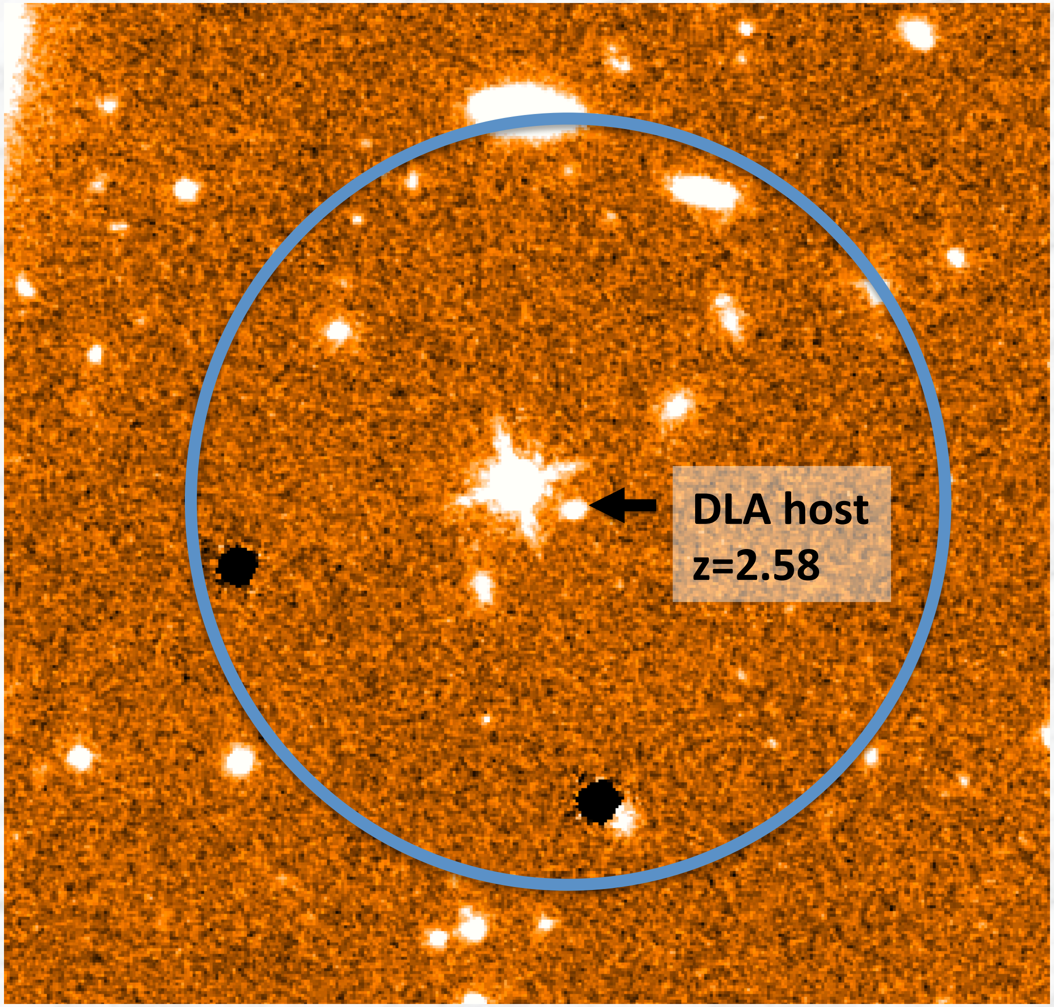


σ -> M*

ΔV_{90} -> M*

- ΔV_{90} ~ velocity dispersion
- Affected by infall, # clumps, feedback
- Influence of impact parameter, halo mass ?

DLA host galaxy



Fynbo+13

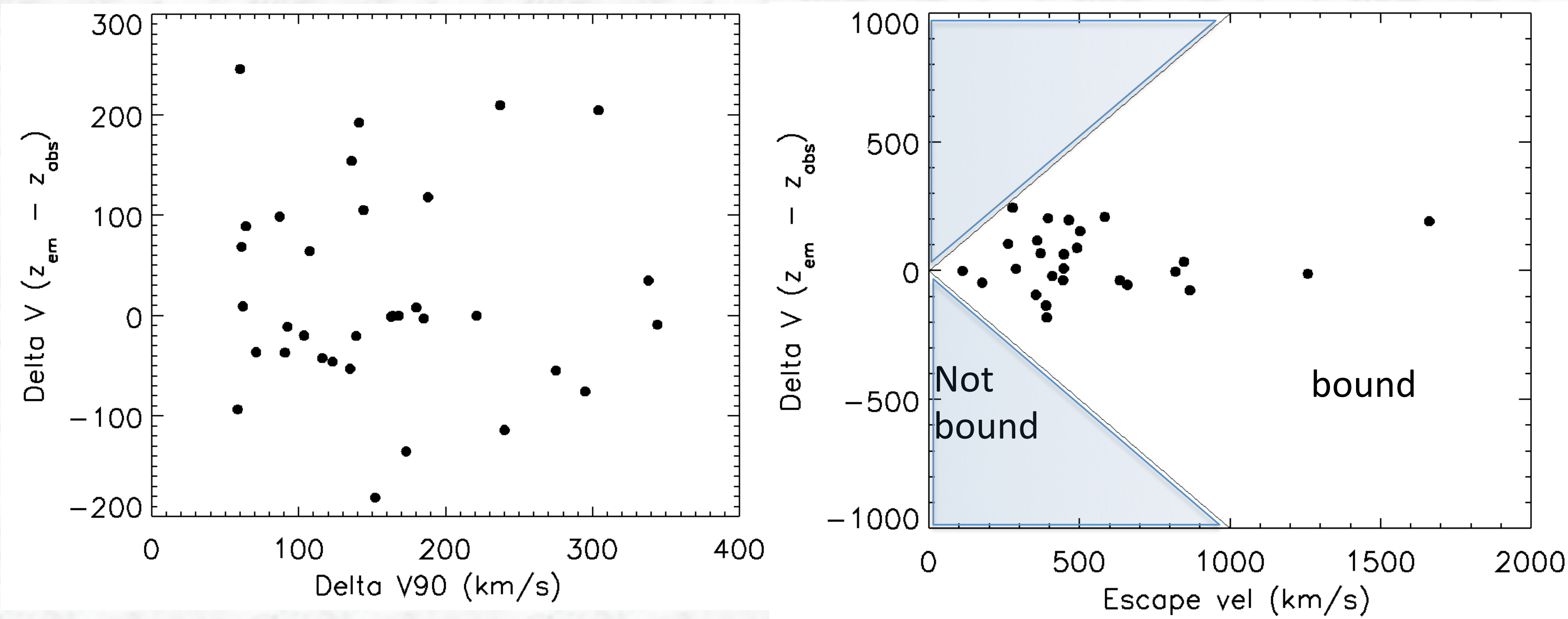
DLA host:
Stellar mass = $10^{10.3}$ Msun

Halo mass = $10^{12.3}$ Msun

Halo virial radius = 95 kpc

Virial velocity = 250 km/s

Clouds bound to halos



No large (projected) velocity offsets - > likely gravitationally bound

(like OIV absorbers in COS-HALO (Tumlingson+11)

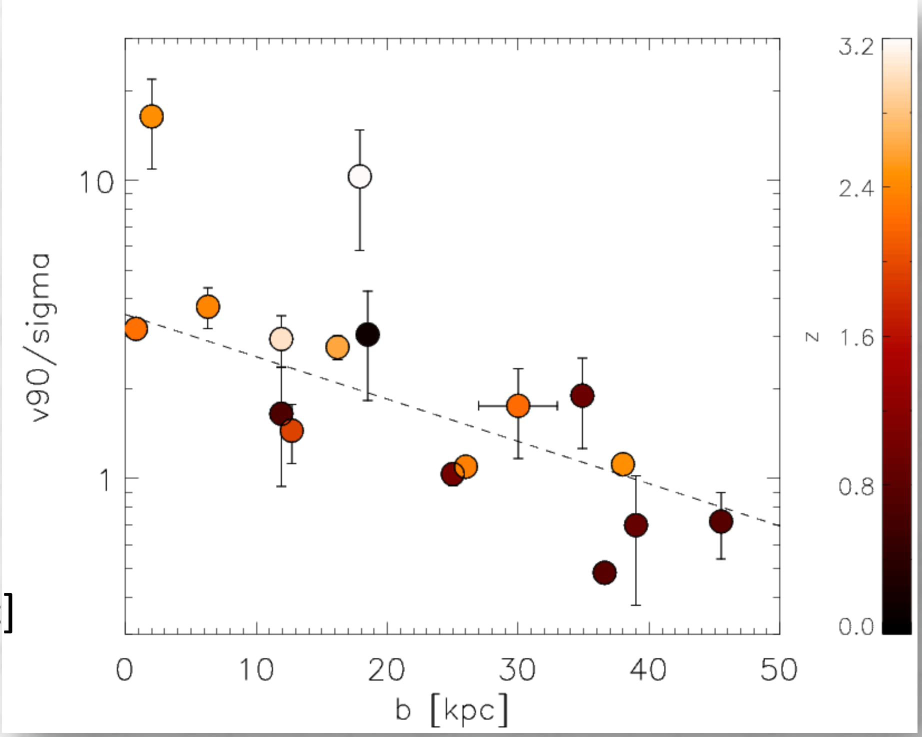
Scaling relations in the CGM with DLAs

ΔV_{90} relation slope decreases by
1.55 dex in [M/H] per log km/s unit
(Ledoux+2006)

M-Z relation : metallicity gradient
[M/H] decrease by –0.022 dex/kpc
(Christensen+14)

ΔV_{90} should decrease with radius as:
– 0.022 / 1.5 = – 0.015 [log km/s /kpc]

But what about the DM halos then?



Møller & Christensen in prep

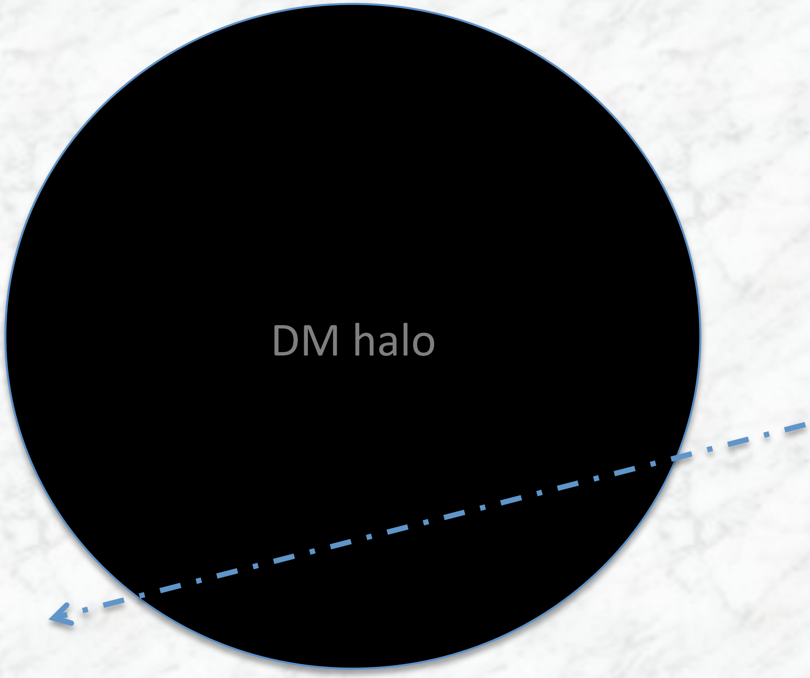
Line of sight velocity dispersions

1) Assume a DM density profile

2) Compute line of sight velocity dispersion, $\sigma(R)$
   (e.g. Dehnen 1993)

3) Choose a normalisation

4) Models include a 'scale radius'
   r_s – (halo) mass dependent
   varies with redshift



Christensen+ in prep

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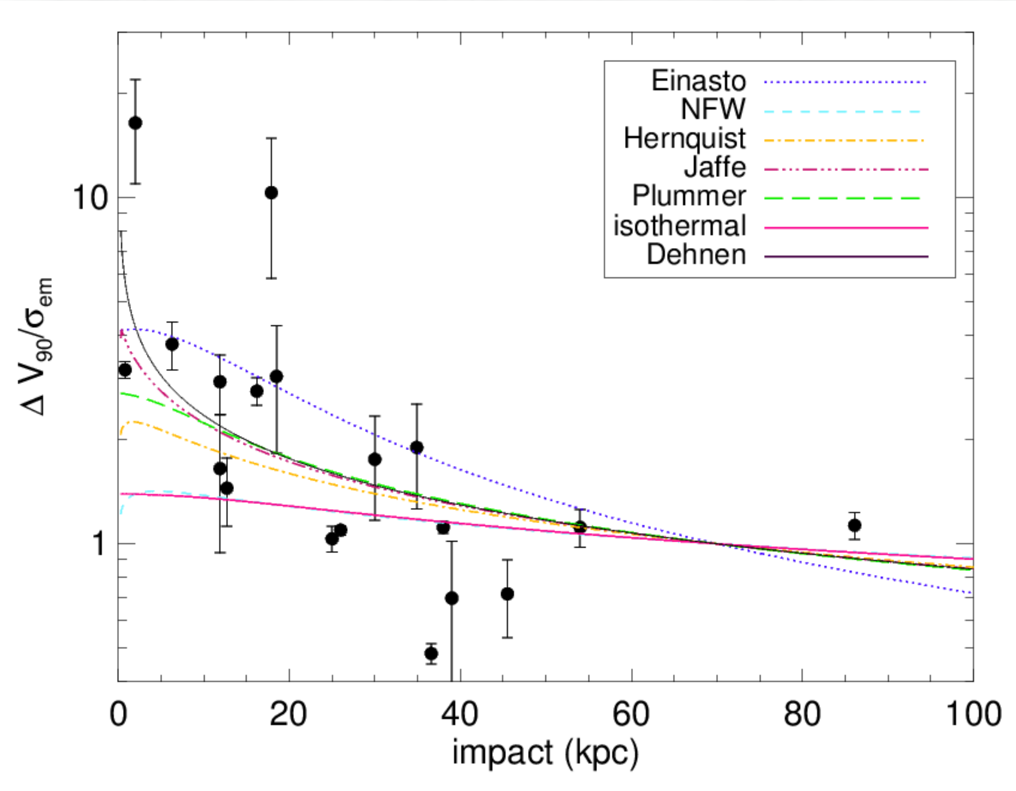

Christensen+ in prep

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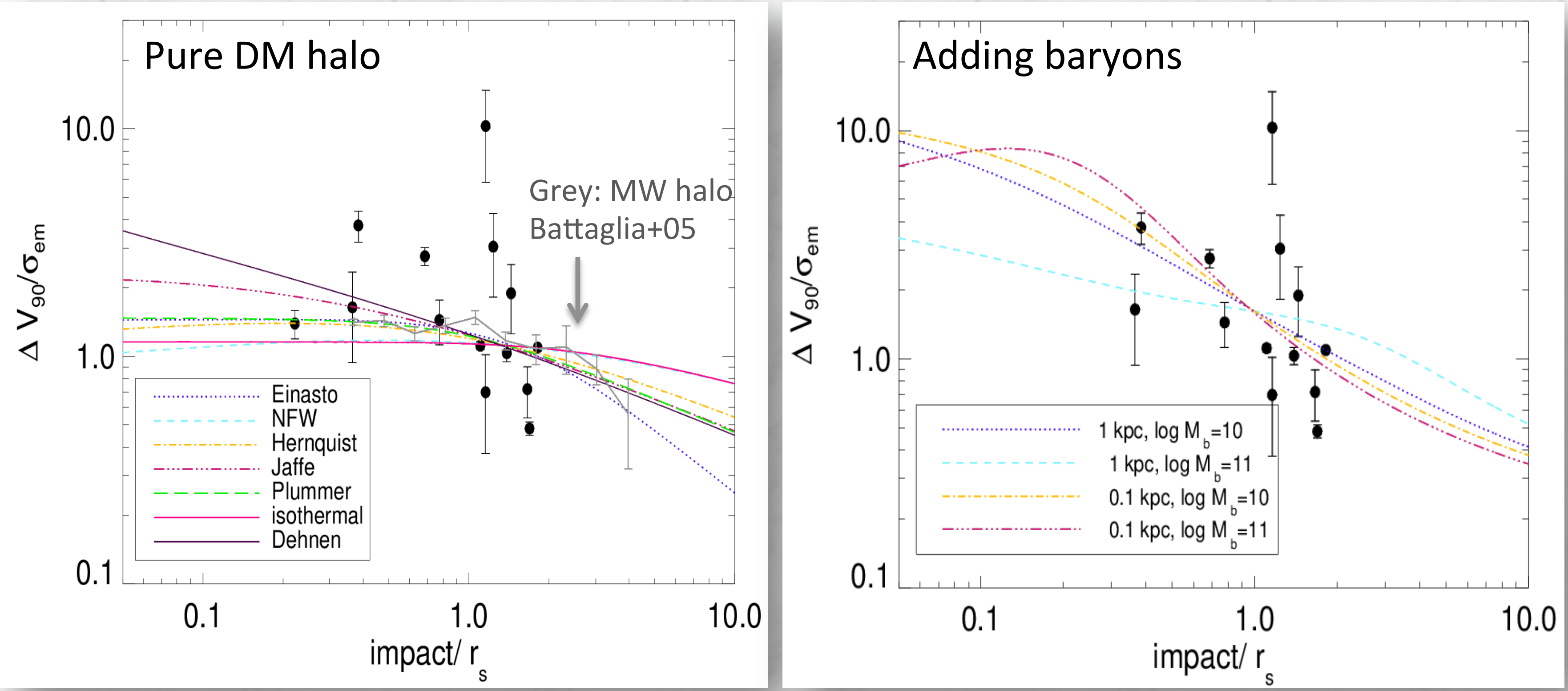


Absorption line velocities in simulations

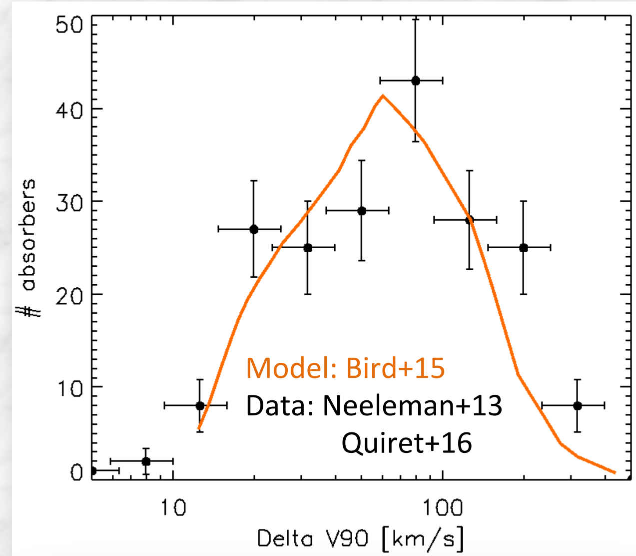
Haehnelt+98: DLAs are 'protogalactic clumps'
V_{90} correlated with DM halo
$<\Delta V_{90}> \sim 0.6\ V_{vir}$, $0.2\text{-}2.0\ V_{vir}$

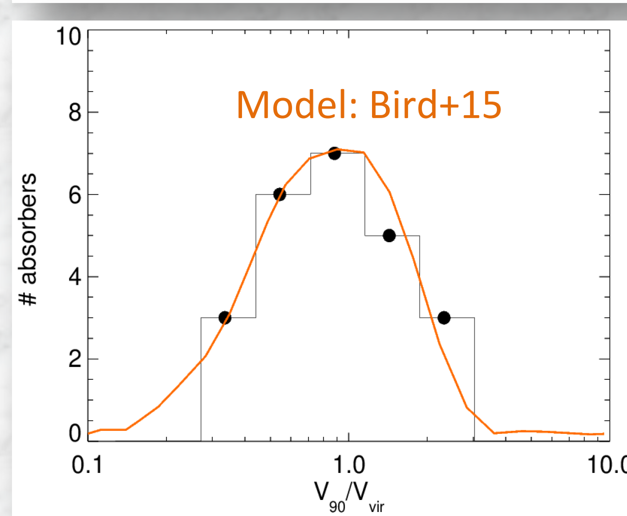
Bird +15: + strong feedback $<\Delta V_{90}> \sim 0.9\ V_{vir}$
$<V_{vir}> = 70$ km/s

Pontzen +08 : Too few $\Delta V_{90} > 100$ km/s
(also Razoumov 09)

Cen +12: no lack of high- V90 absorbers

Data: 24 DLAs with hosts
M* known - > M_{halo} -> V_{vir}





Summary

- Mass-metallicity relation exists for DLAs
- Radial metallicity gradient = – 0.022 dex/kpc to ~ 12 kpc
- $z_{em} - z_{abs}$ below escape velocities – gravitationally bound
- $\Delta V_{90}/\sigma$ decrease with impact parameter
- ΔV_{90} trace potential wells and probe galaxy halos
- Velocities may be higher than expected for infalling material --

  → Starburst driven outflows

To do : Zoom-in simulations of more massive halos
dependence of V_{90} with M* and impact parameters?