CGM studies at intermediate redshifts

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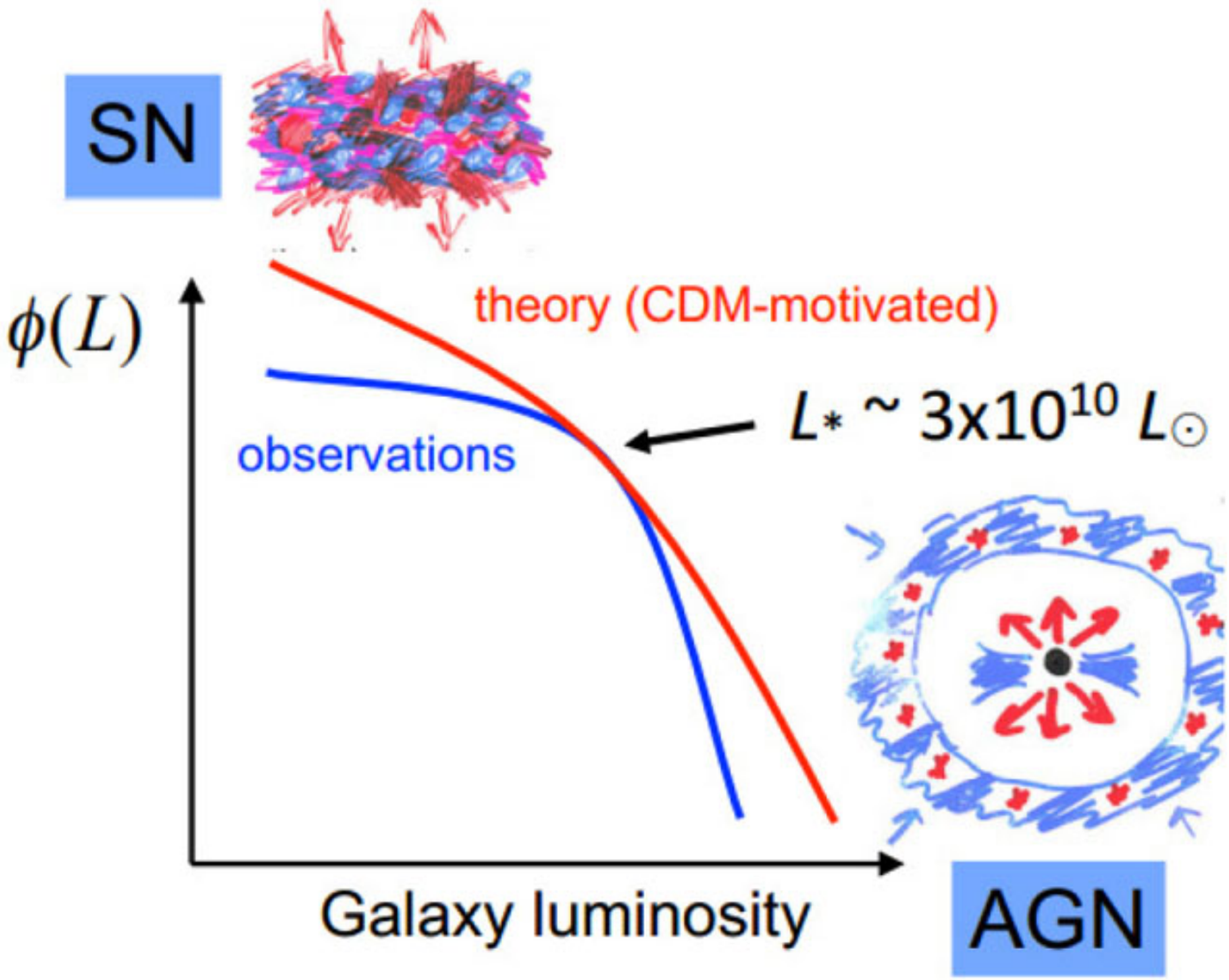
EWASS, Prague June 2017

Regulating galactic growth



- Feedback processes

  — **Galactic winds**

  +

  — **AGN** outflow

***Silk & Mamon**: RAA 2012*

IGM gas accretion

✓ gas depletion time scale

$\tau_{dep} = M_{gas} / SFR < 1$ Gyr

✓ G-dwarf problem: closed-box model fails

✓ψ_{SFR} evolves much faster than Ω_{HI}

***Binney**: MNRAS 2000; **Larson**: Nature 1972; **Madau&Dickinson**: ARAA 2014; **Zafar**: MNRAS 2012*

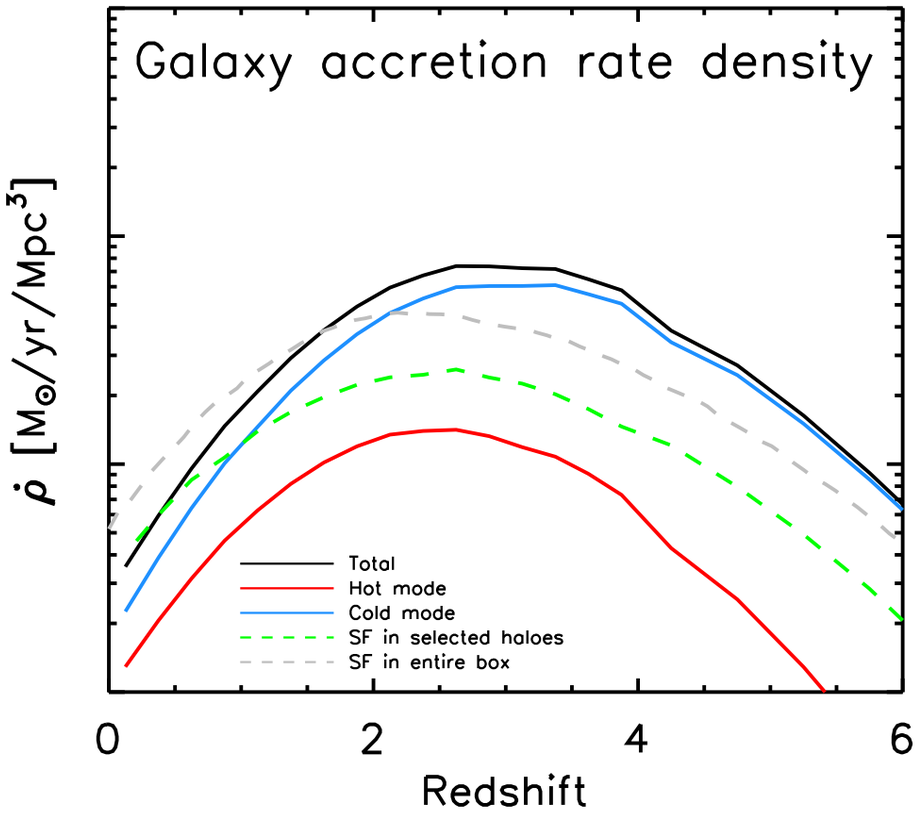
IGM gas accretion

✓ **Hot mode**:

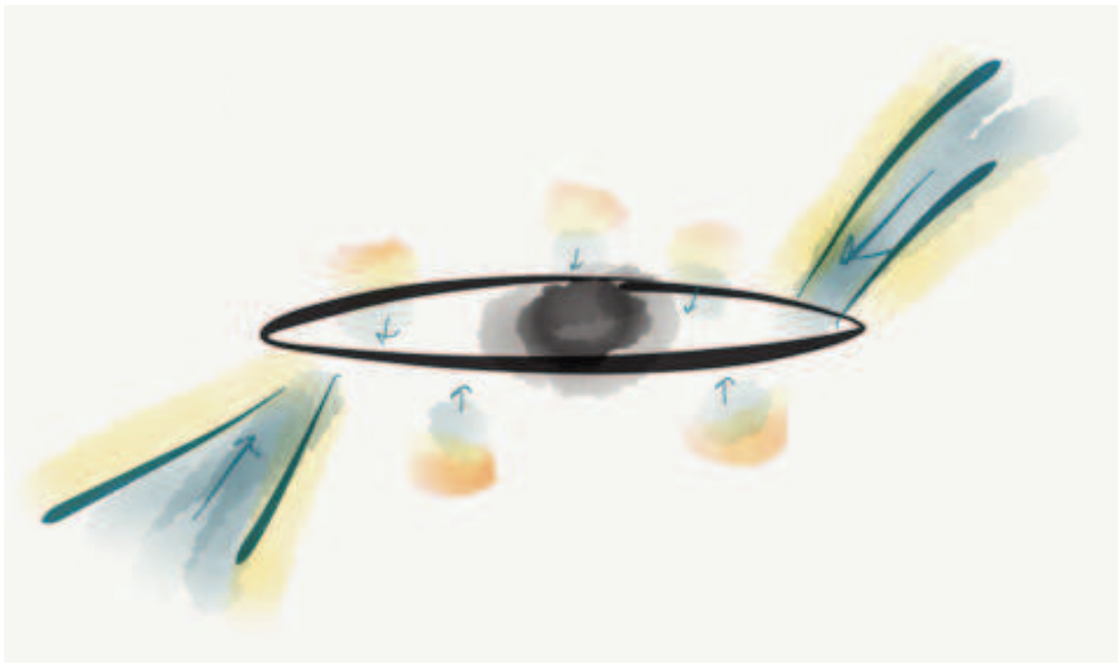
$T \sim T_{vir}$ gas accreting through the hot atmosphere

✓**Cold mode**:

$T<10^5$ K cold-dense IGM filaments directly feeding the galaxy



Keres: *MNRAS 2009****; van de Voort****: MNRAS 2011 …*



Putman*: 2016*

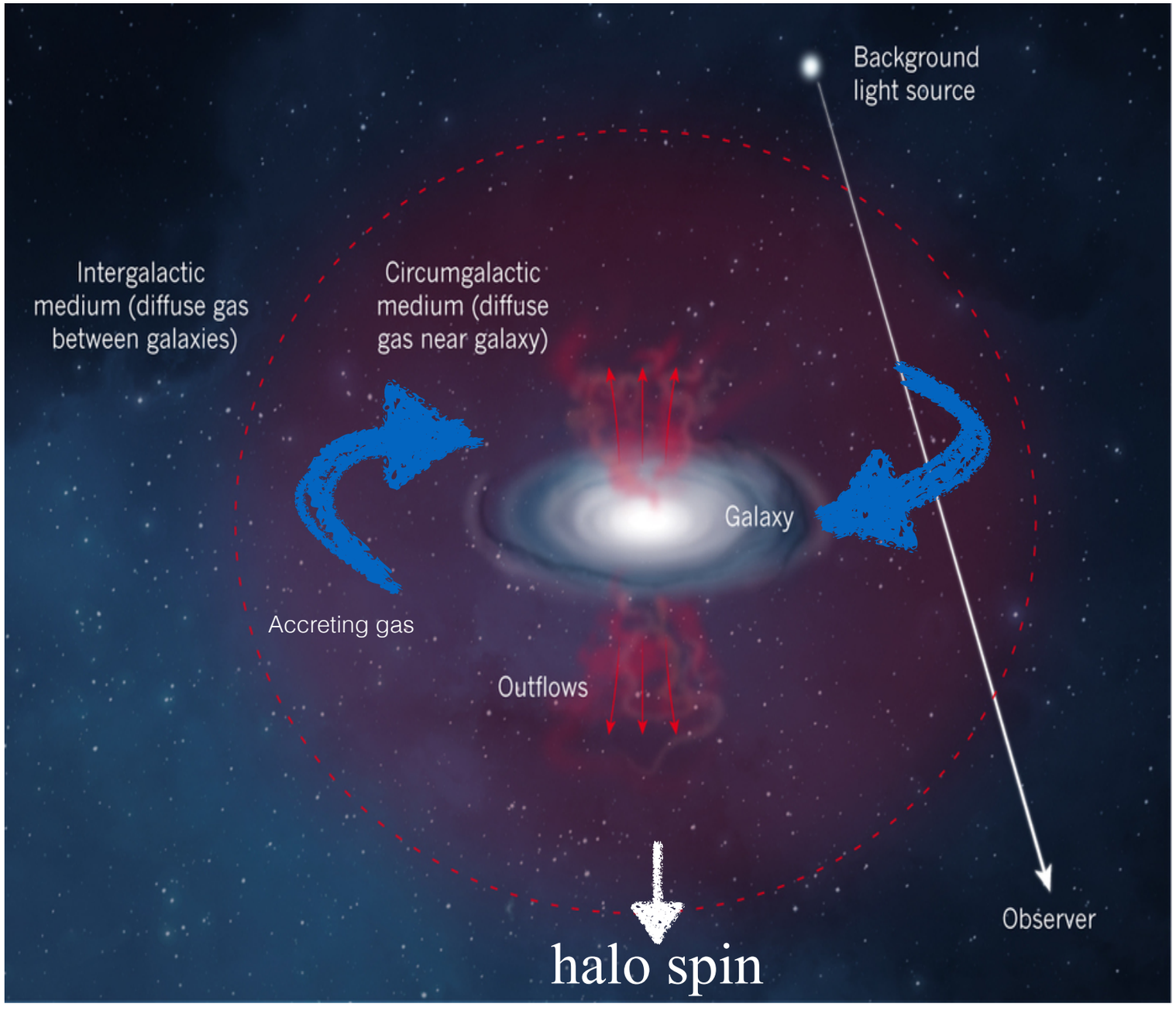
Regulating galaxy growth

✓ outflow:
- perpendicular to the disk
- enriched

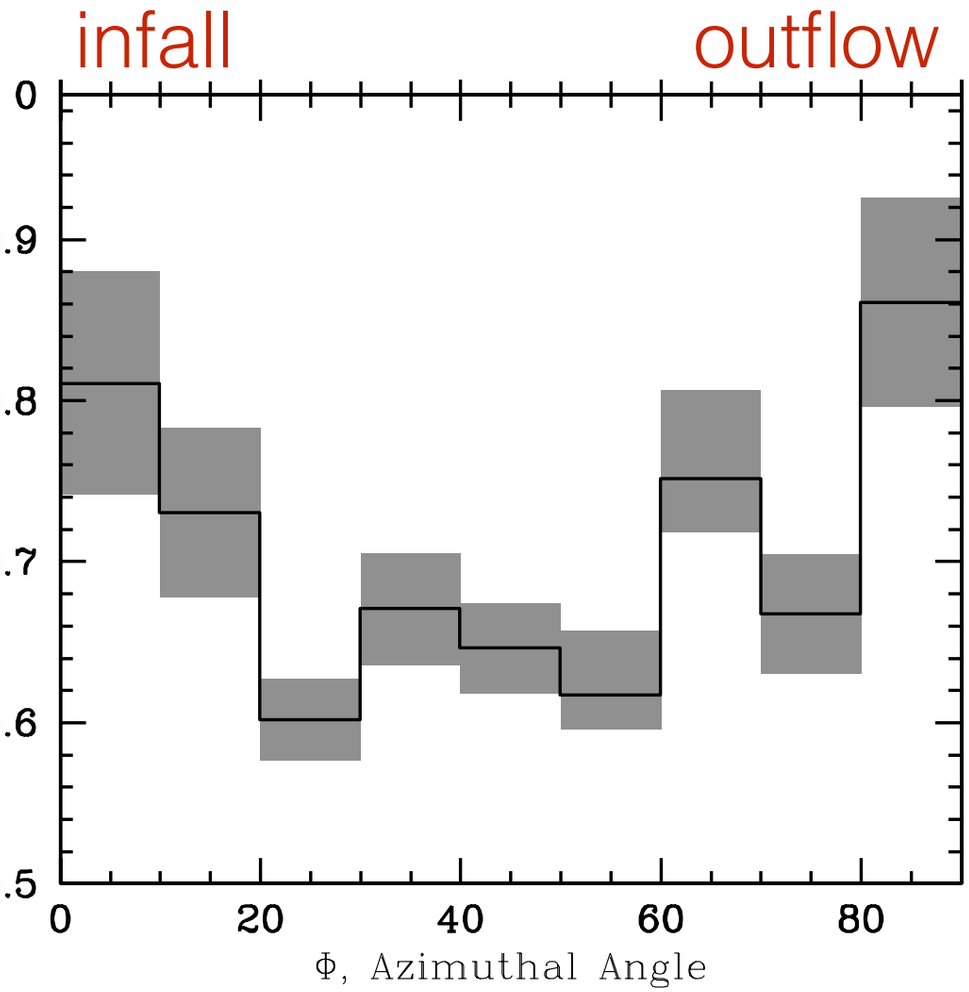
✓IGM accretion
- coplanar
- pristine

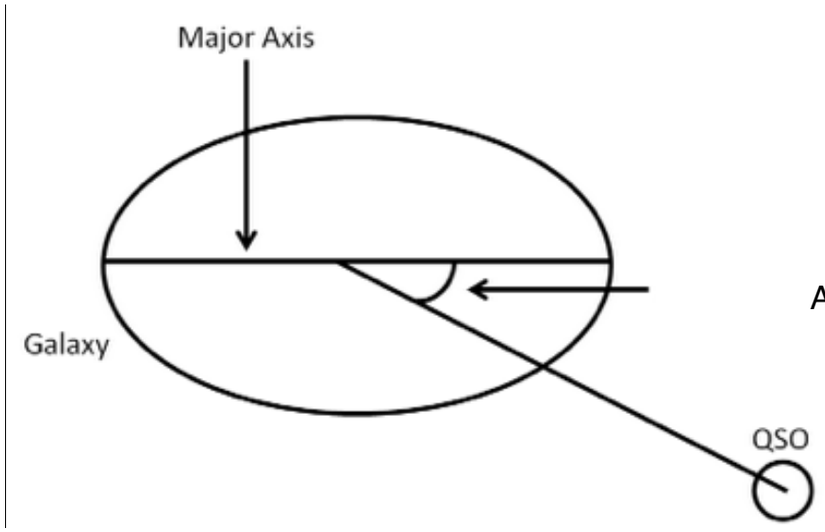
✓bimodality?

✓QSO-galaxy pairs to probe CGM



Bimodality

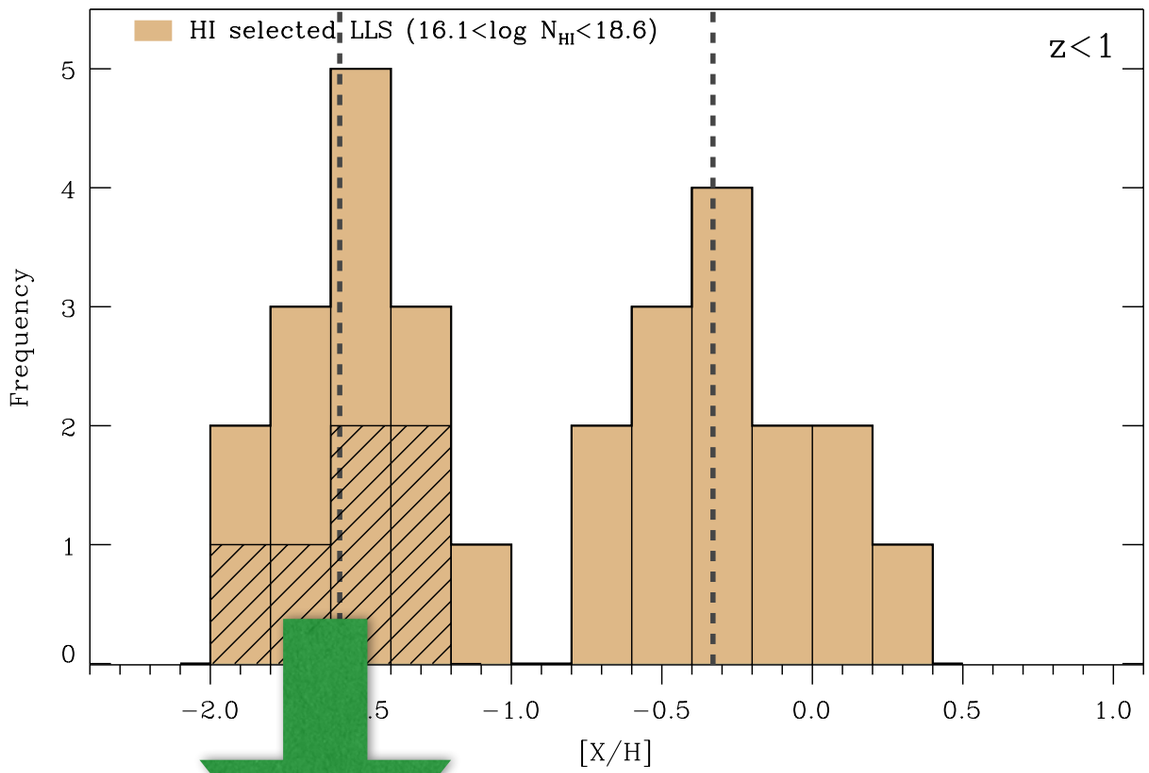




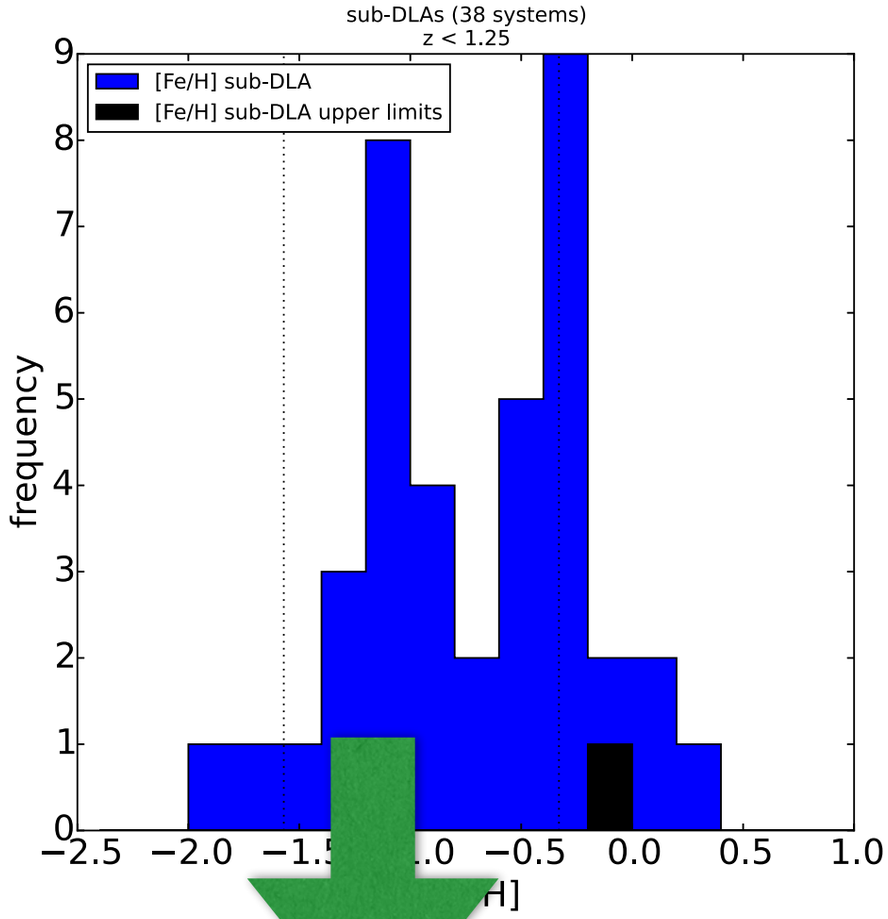
Azimuth Angle (**Φ**)

***Kacprzak**: ApJ 2012; **Bordoloi**: ApJ 2012; ...*

Bimodality



pristine infall?

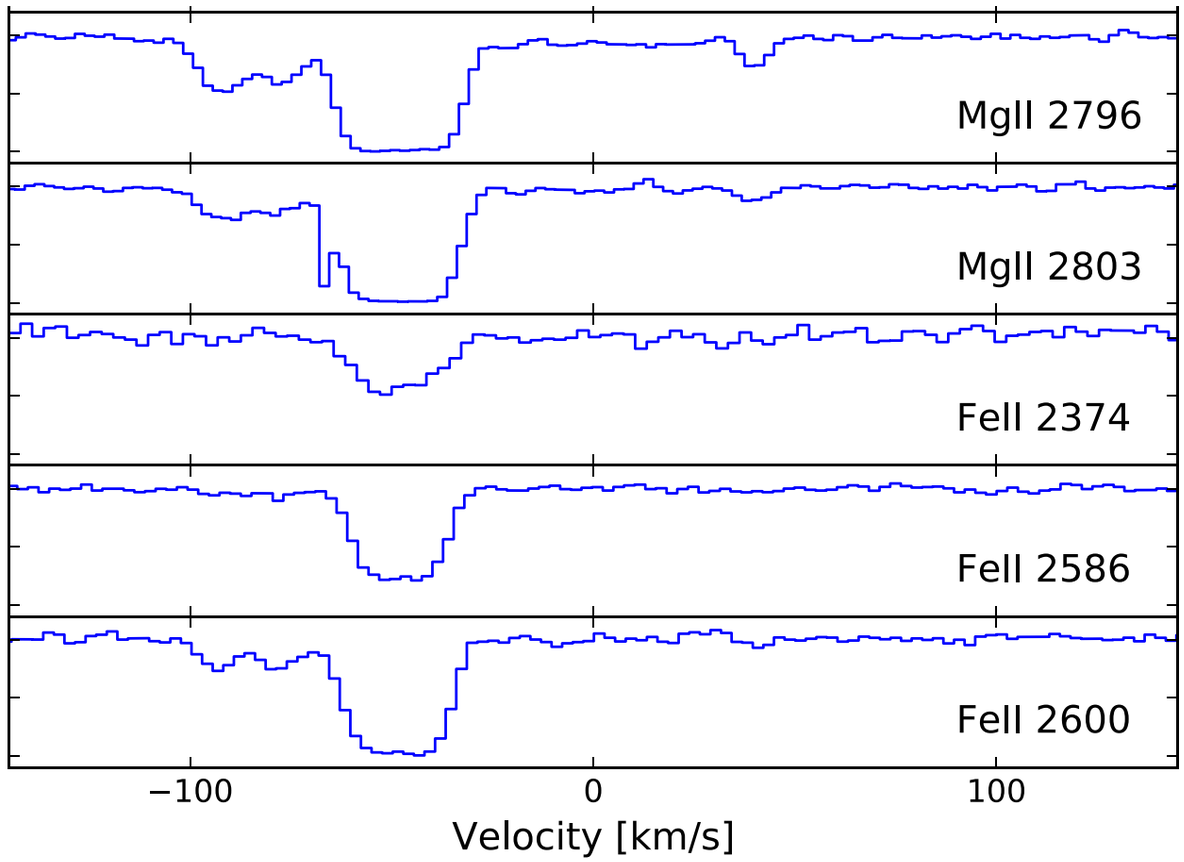


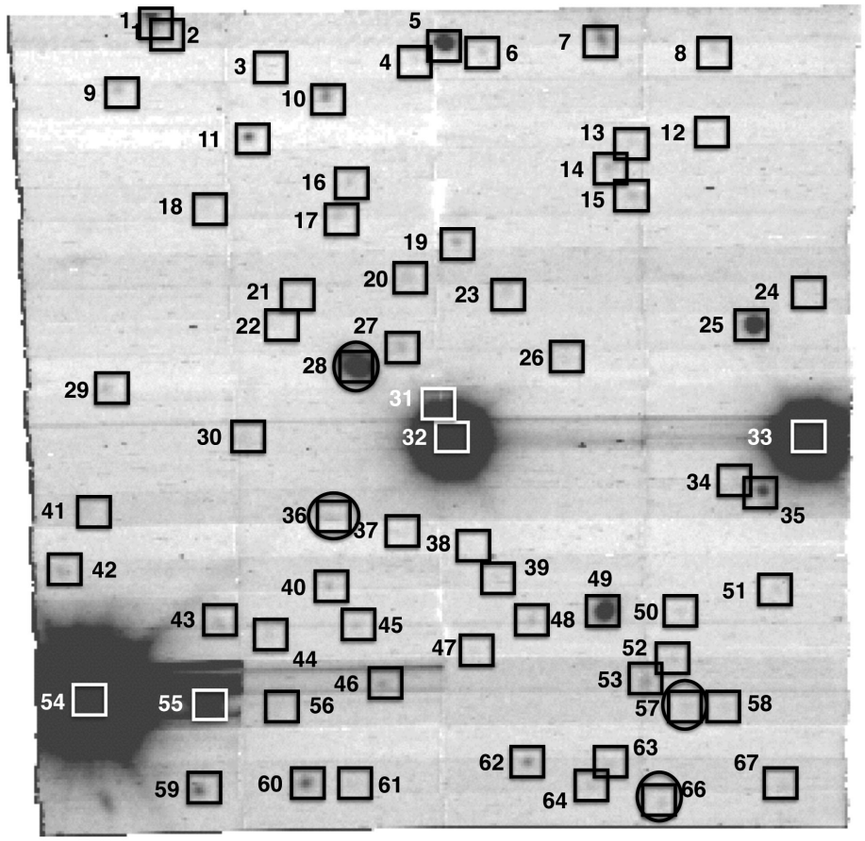
pristine infall?

***Lehner**: ApJ 2013; **Quiret**: MNRAS 2016; **Wotta**: ApJ 2016*

CGM with MUSE

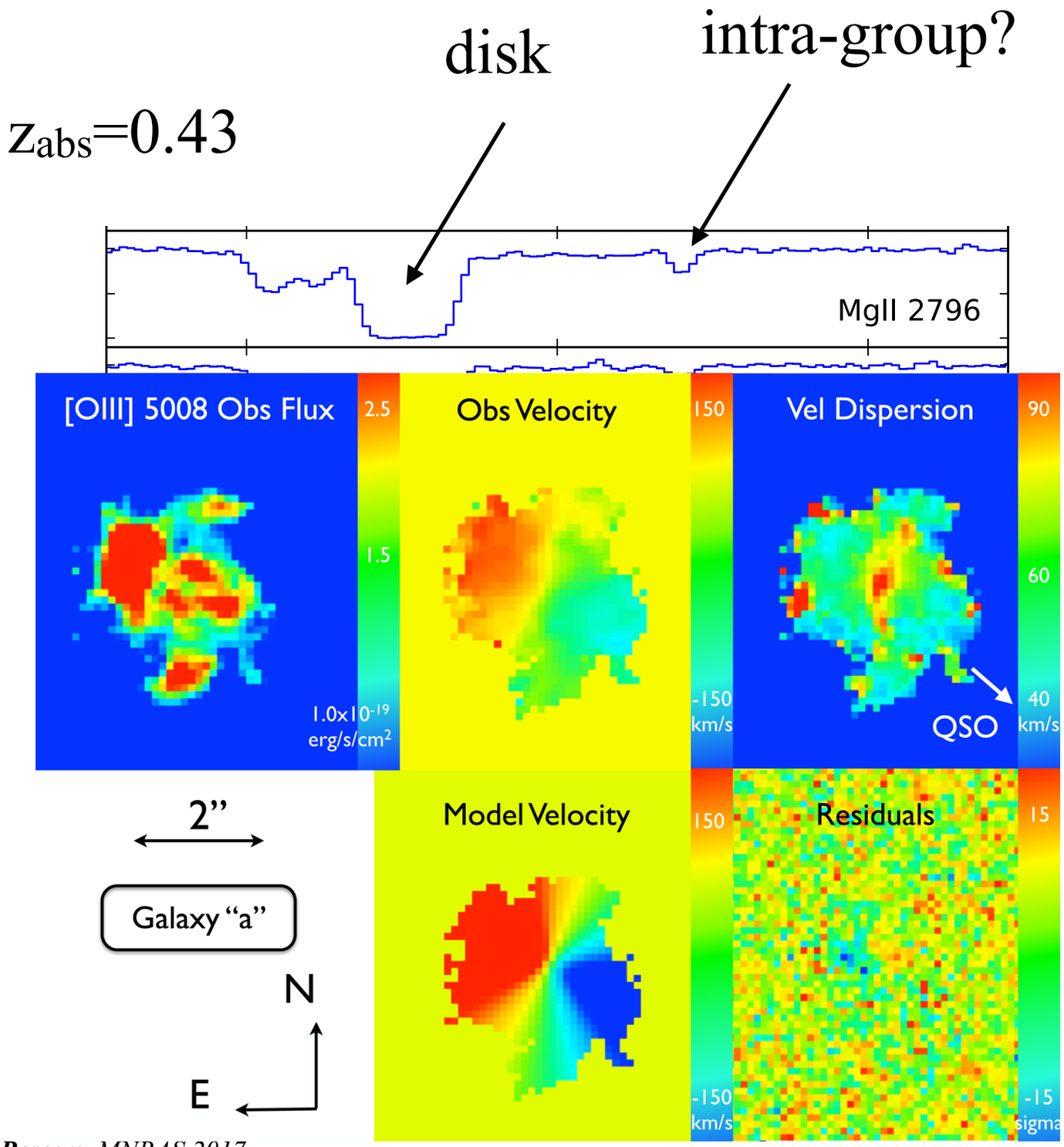
sub-DLA at z_{abs}=0.43, Z~0.3$Z_{\odot}$



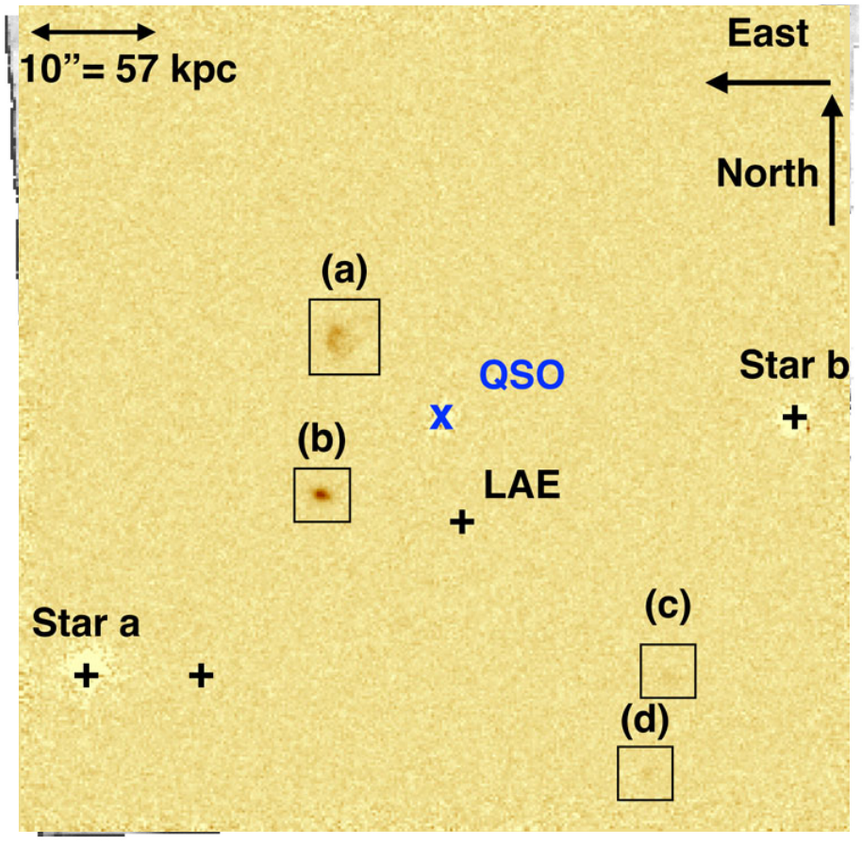


***Peroux et al.**: MNRAS 2017*

CGM with MUSE

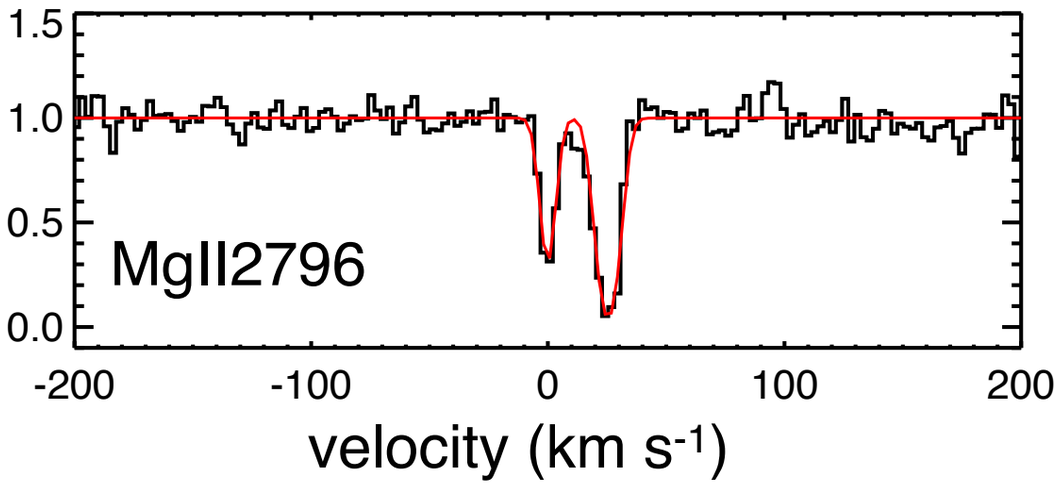


***Peroux**: MNRAS 2017*



MUSE: narrow band OIII

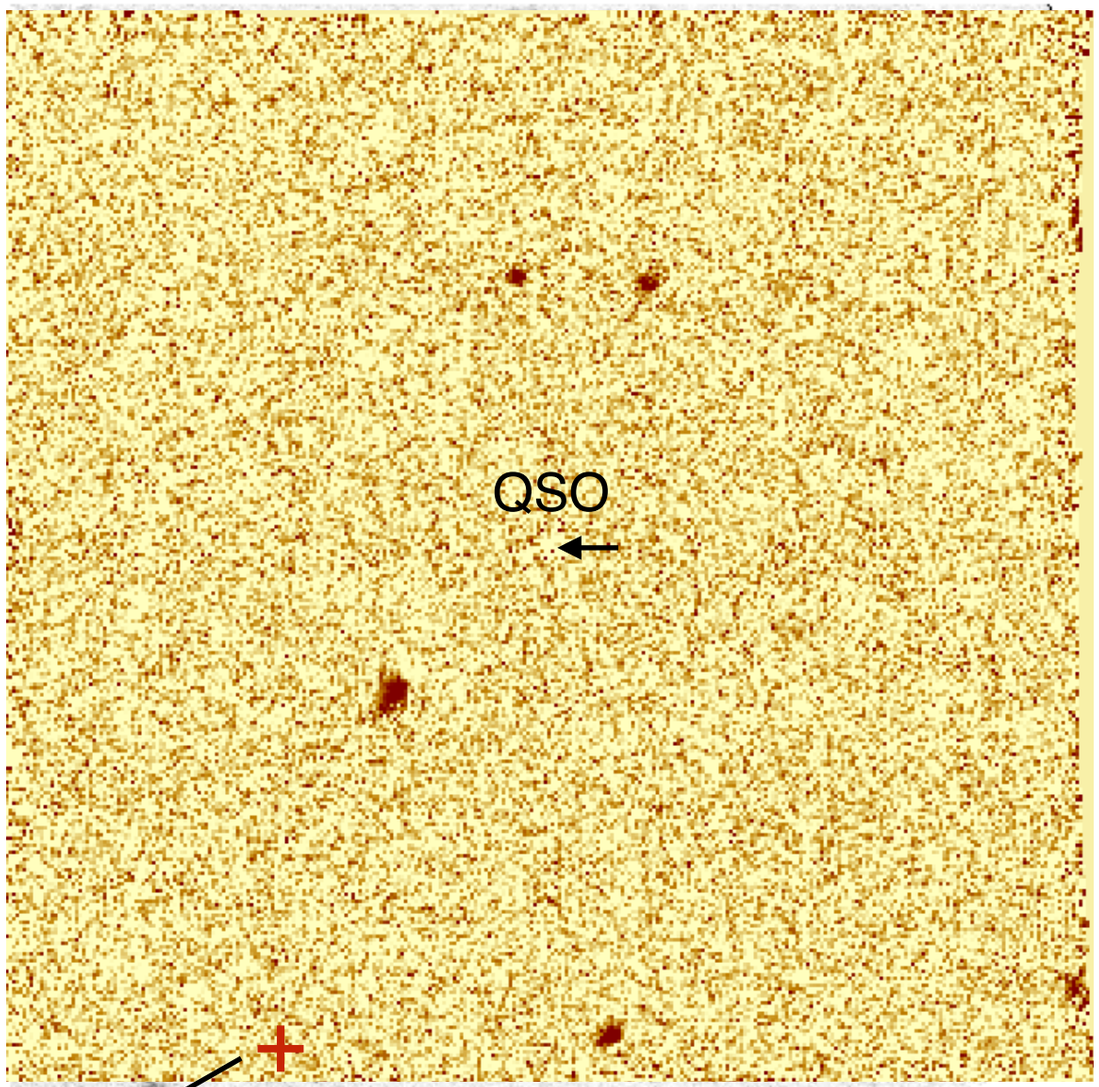
CGM with MUSE



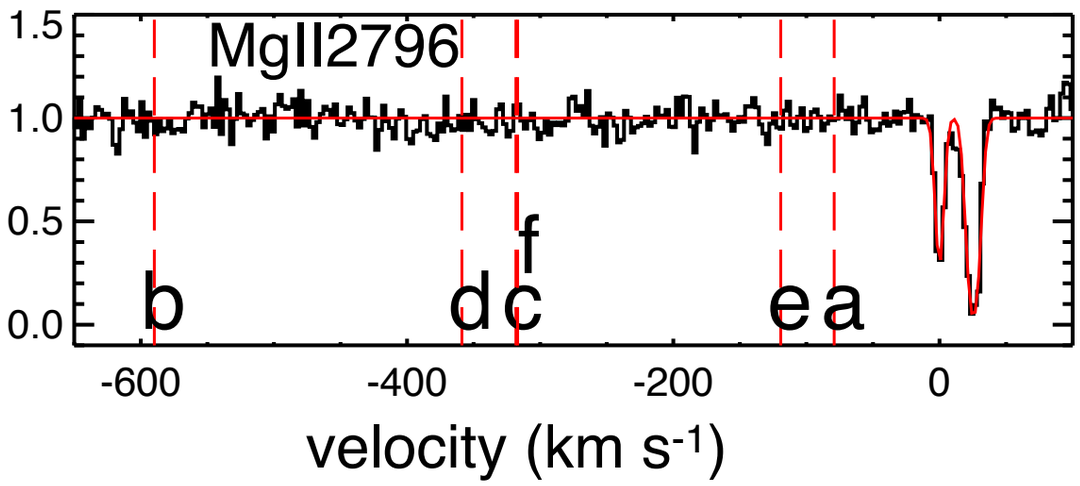
2 narrow components (~3 km s^{-1})

$z = 0.38$

$Z > 0.2\ Z_{\odot}$



CGM with MUSE



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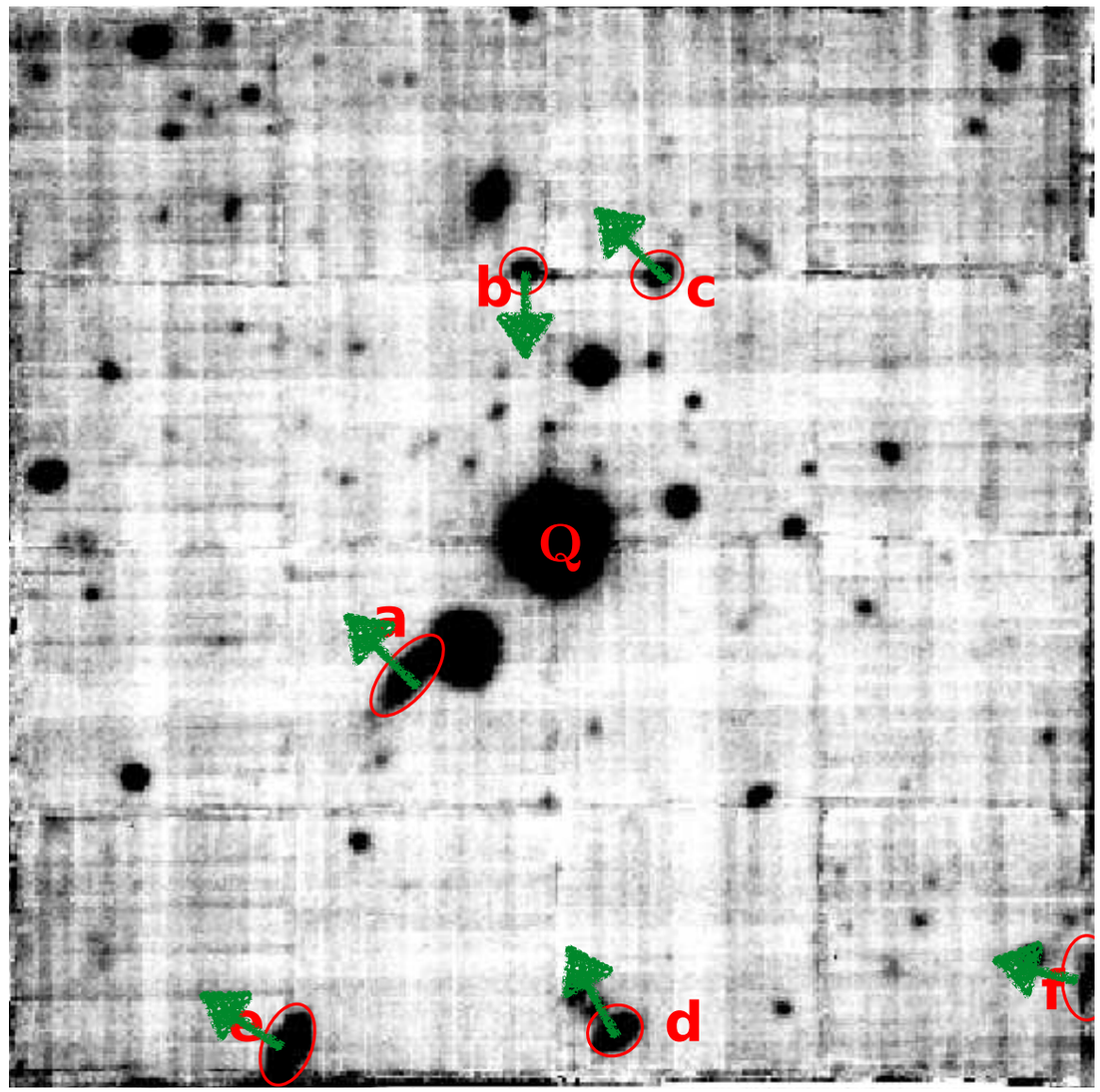


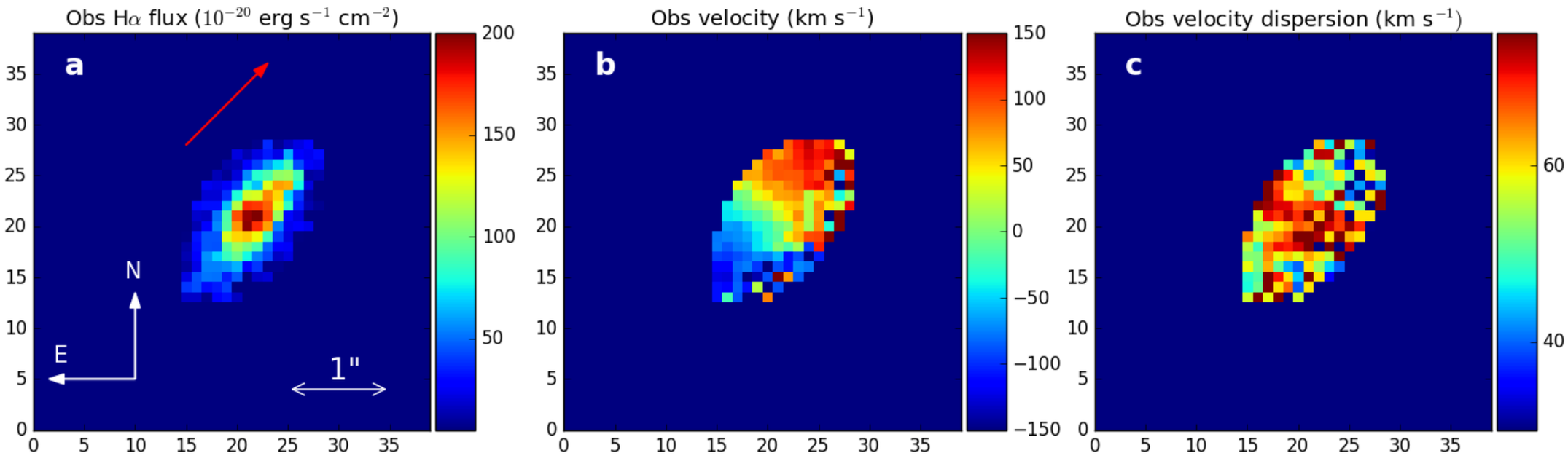
MUSE

Group or a **filament!**

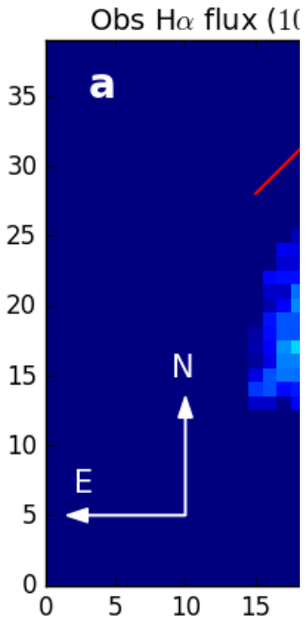
+

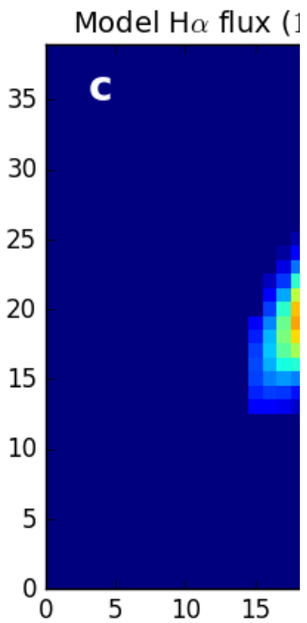
lack of strong interactions

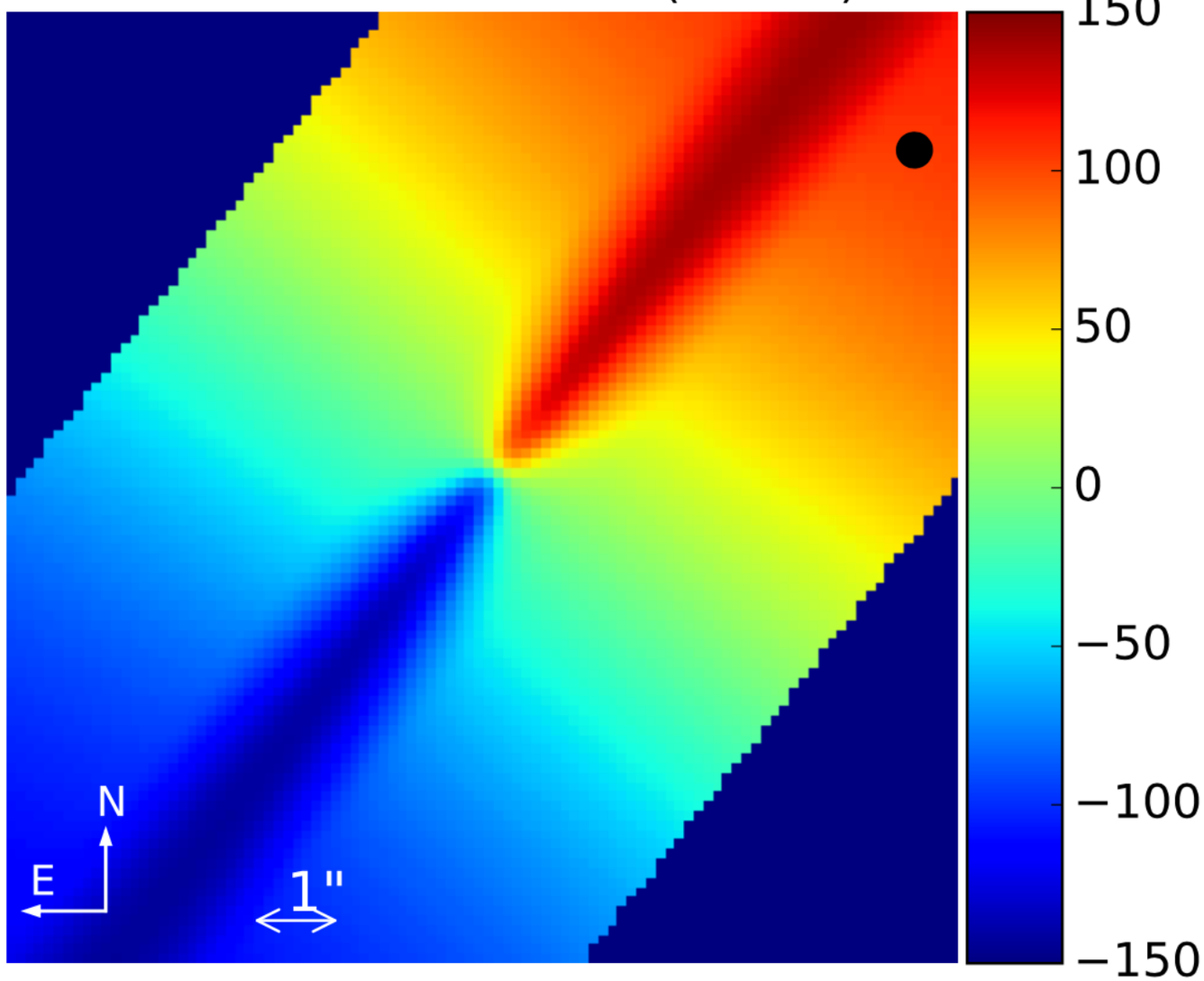
CGM with MUSE

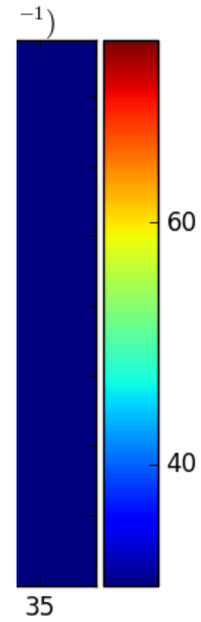


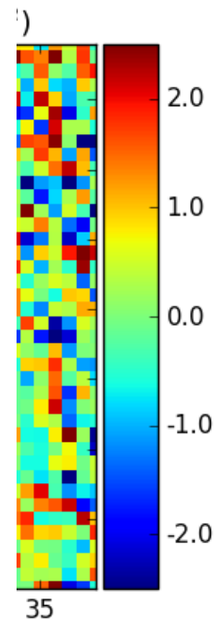
Galaxy	$r_{1/2}$ [kpc]	$\sin i$	position angle [degree]	azimuthal angle [degree]	$V_{\rm max}$ [km s^{-1}]	$M_{\rm dyn}$ [$10^{10} M_\odot$]	$M_{\rm halo}$ [$10^{12} M_\odot$]	R_{vir} kpc	$M_{\rm stellar}$ [$10^{10} M_\odot$]
a	5.4 ± 0.1	0.98 ± 0.01	142 ± 1	10 ± 1	148 ± 2	2.8 ± 0.1	1.2 ± 0.1	160	1.5 ± 0.6

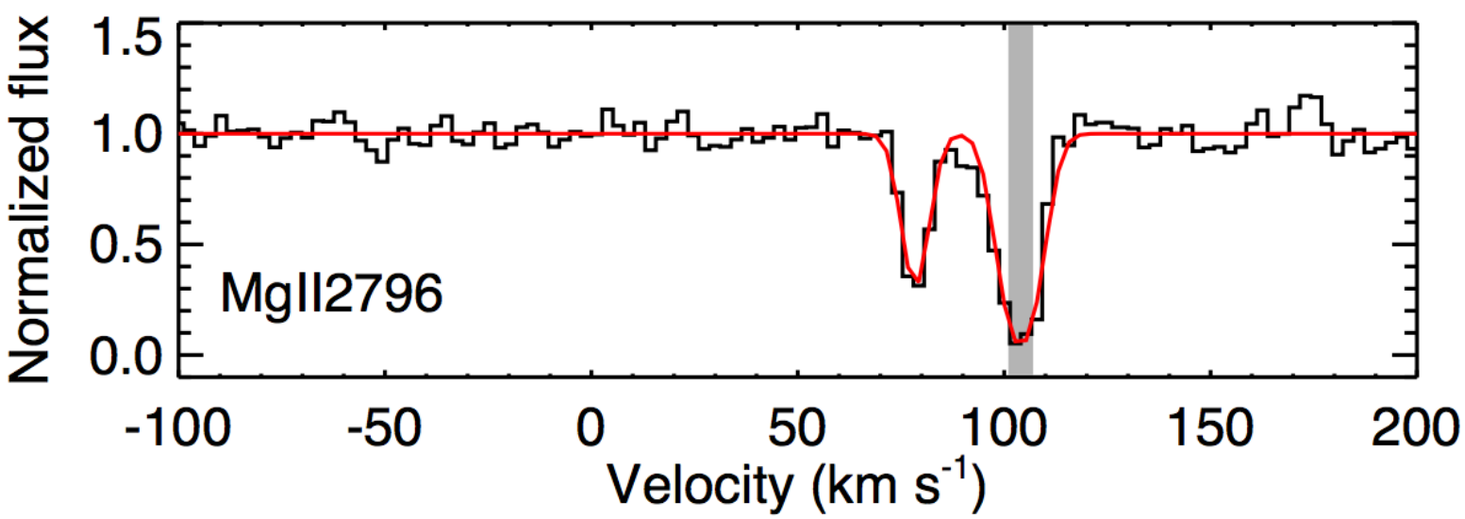








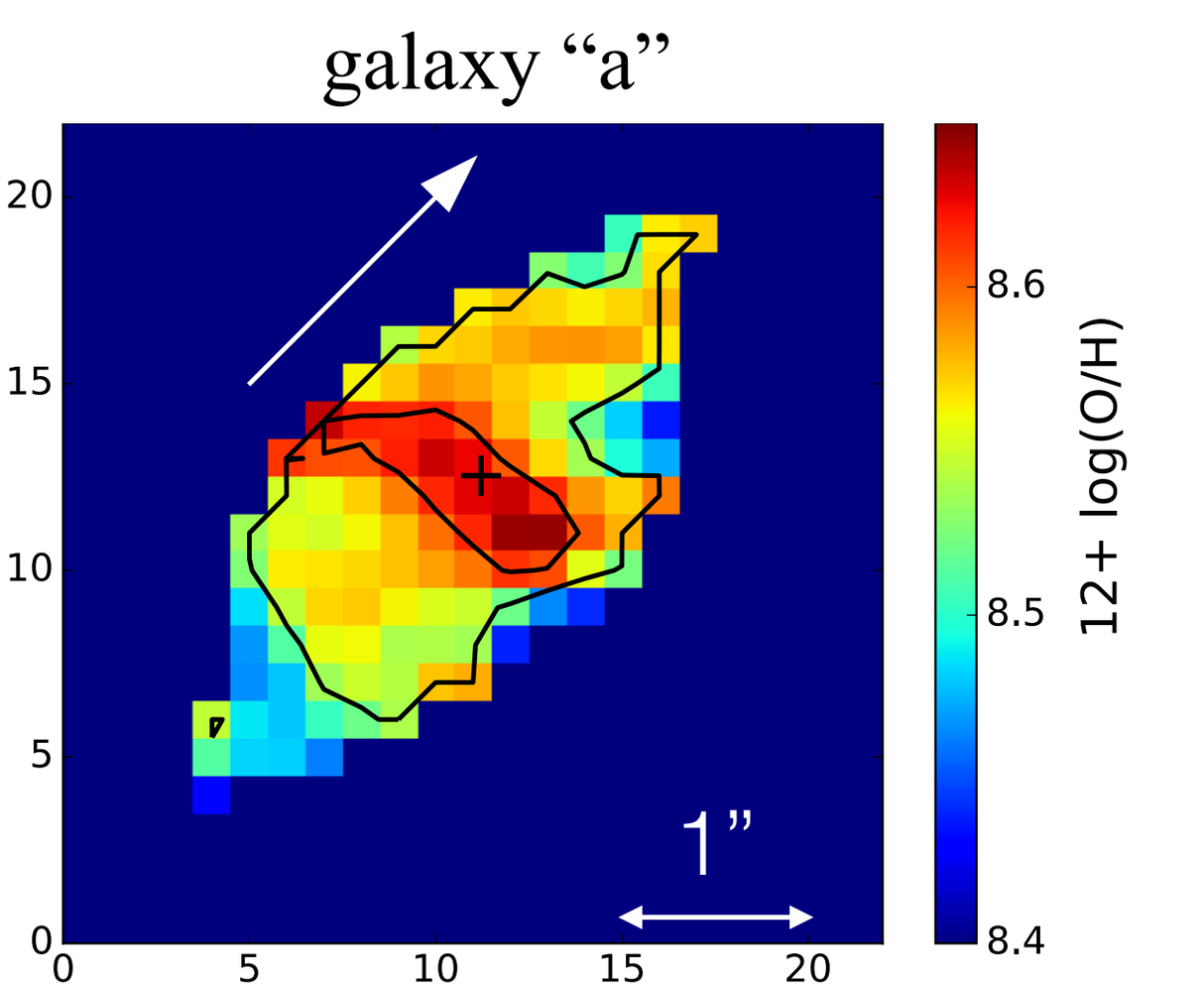


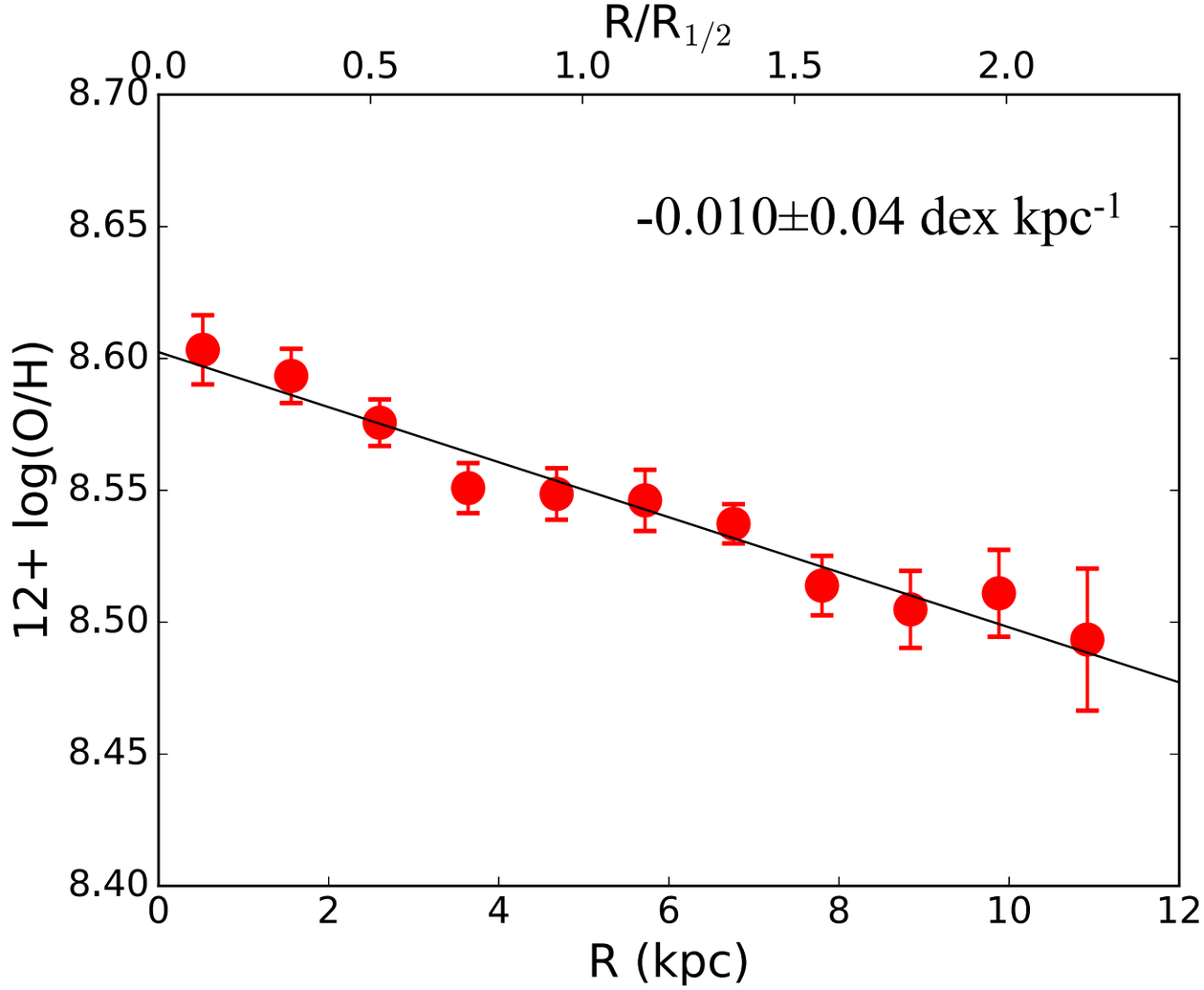


Galaxy	$r_{1/2}$ [kpc]
a	5.4 ± 0.1

$_{vir}$ pc	$M_{\rm stellar}$ $[10^{10} M_\odot]$
60	1.5 ± 0.6

CGM with MUSE





extrapolated emission metallicity ~ 0.2 $Z_\odot$ ($Z_{abs} > 0.2\ Z_\odot$)

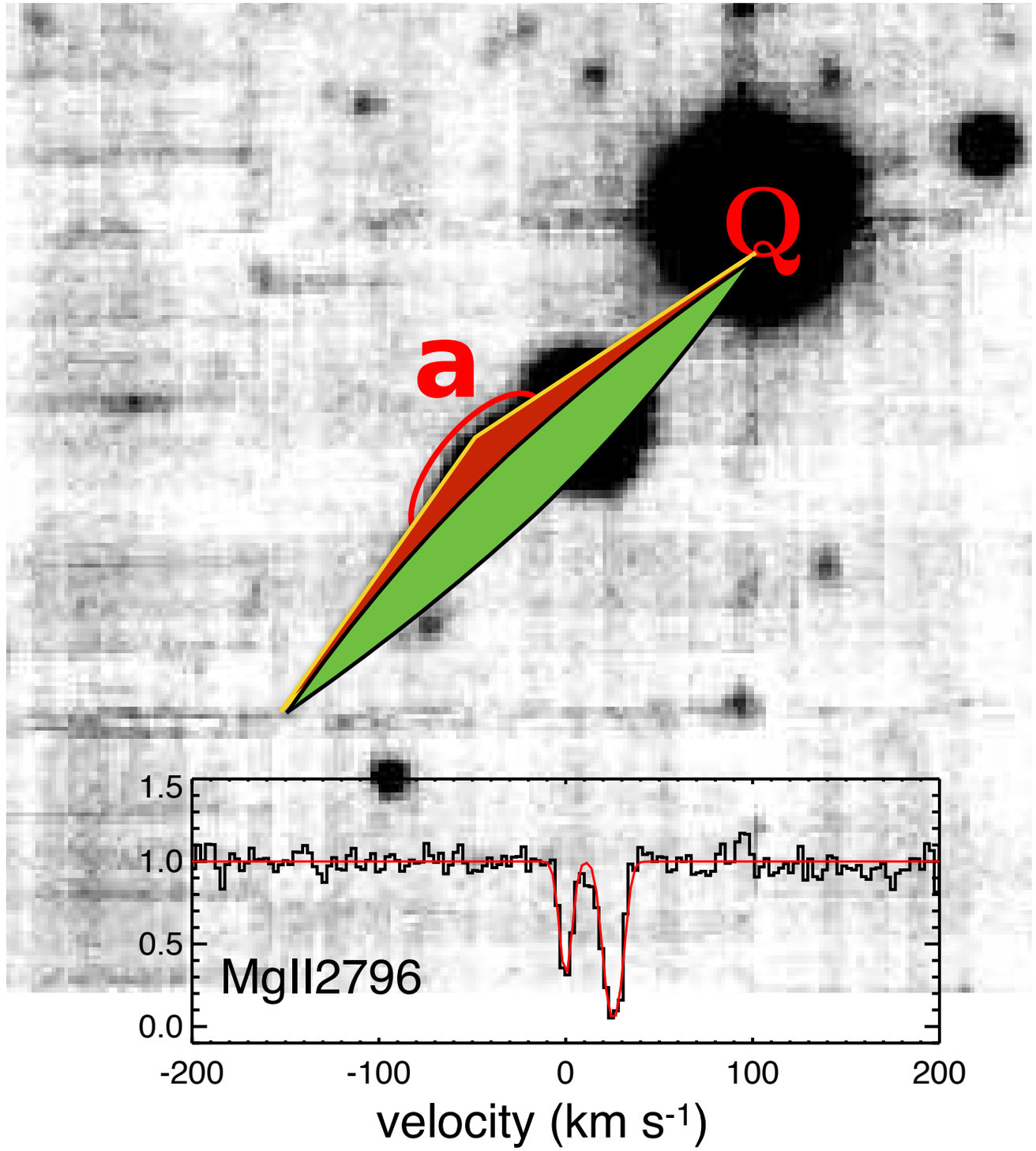
CGM with MUSE

Outflow?

- very wide opening angle ($\Omega_{outflow}$>140°)

- *more complicated* absorption profiles

- Σ_{SFR}~0.01 M⊙ yr^{-1} kpc^{-2} (≪0.1 M⊙ yr^{-1} kpc^{-2})



***Heckman**: ASPC 2002*

CGM with MUSE

Recycled gas (fountain)?

◉ if *ballistic*: *"j"* conserved

$r_{1/2}$ **x** $V_{max} \sim b$ **x** V_{abs}

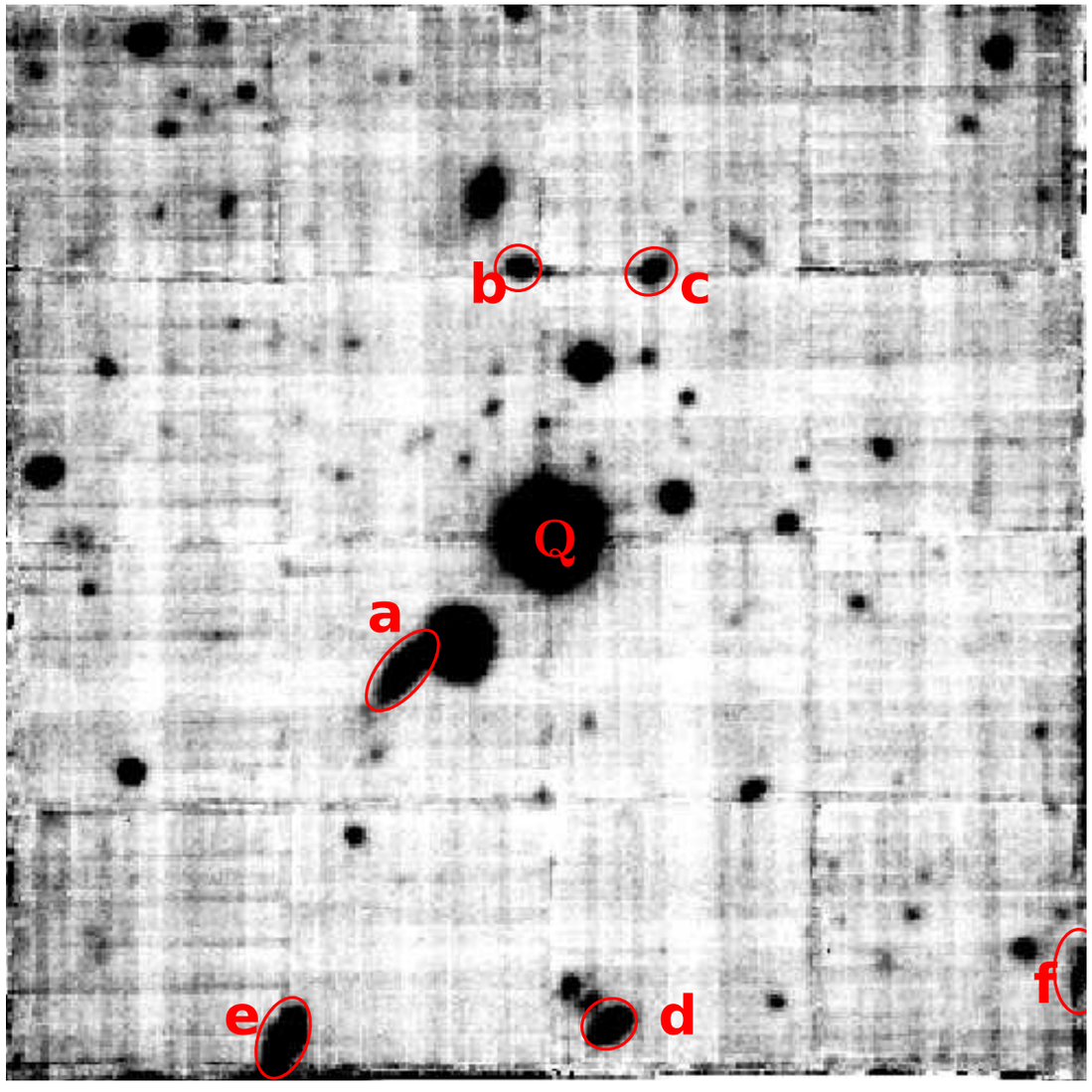
$V_{abs}^{fountain} \sim 12$ km s^{-1}

($<<V_{abs} \sim 80$ km s^{-1})

◉angular momentum lose✕

◉angular momentum gain: 2-3 times

8-10 times gain in "*j*" not expected



***Bregman**: ApJ 1980; **Fraternali & Binney**: MNRAS 2006; **Christensen**: ApJ 2016*

CGM with MUSE

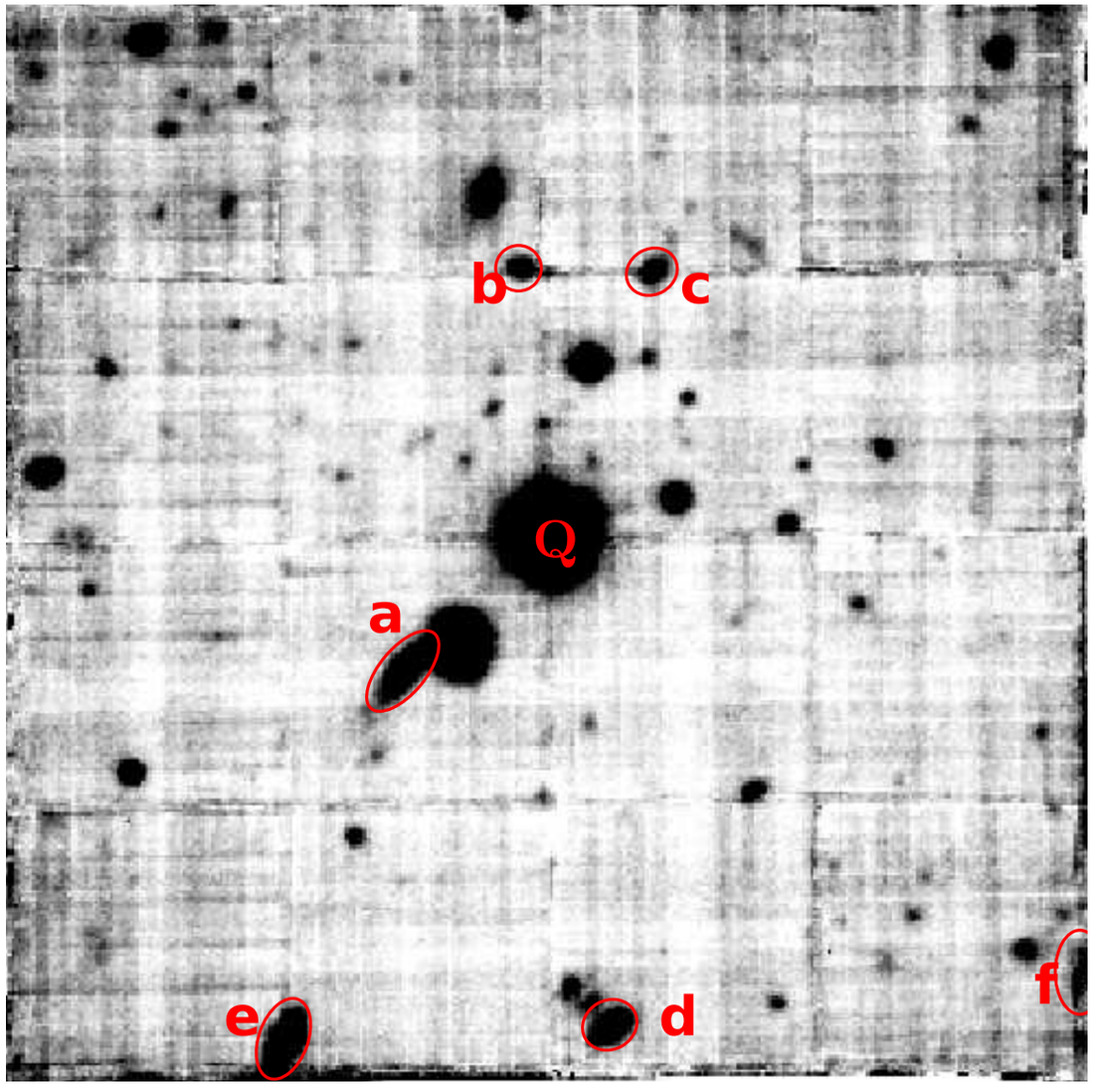
Warped disk?

◉ δv~ 50-100

(V_{abs} ~ *80* km s^{-1}) ✔

◉ coplanar with the disk ✔

◉ $j_{w\text{-}d} \sim 3\, j_{disk}$ ✔



Stewart: *ApJ 2011*

Summary

✓ QSO-galaxy pairs with MUSE at intermediate redshifts

- case 1: disk component + intra-group gas

- case 2:

  intra-group gas ✗

  kinematic disk ✔

  outflow ✗

  recycled/fountain ✗

  warped-disk (cold-flow disk) ✔

✓ Powerful tool for CGM study at intermediate redshifts