Differently- ~~Un~~biased Studies of Galactic Outflows?

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Some collaborators:

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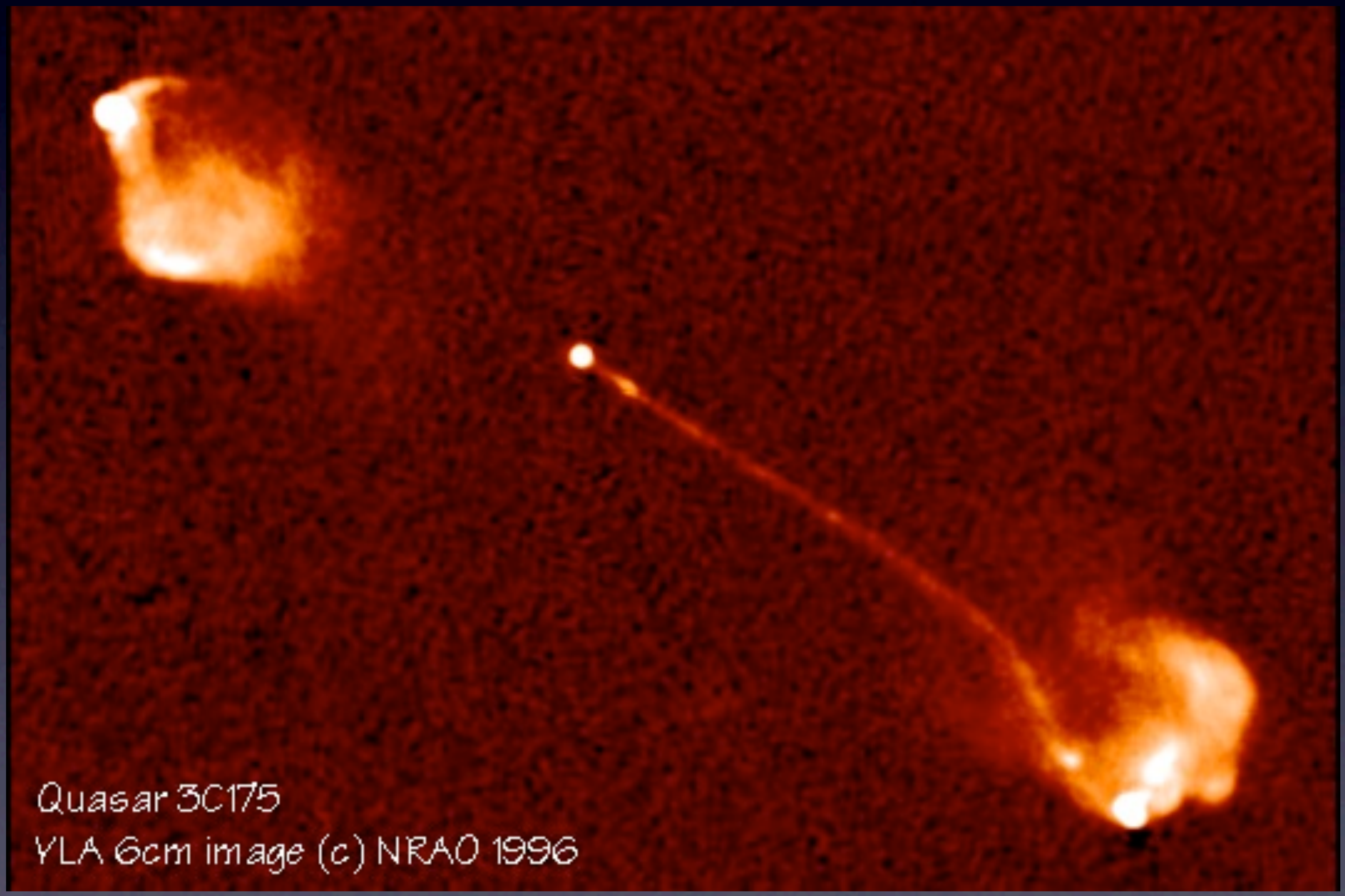
Stefano Zibetti, Vivienne Wild

Outline

- Introduction:
  a) Galactic outflows
  b) Intervening quasar absorption lines
- An ultra-strong MgII absorber – GW connection?
- Composite 〈SFR([OII])〉 in MgII absorber galaxies
- What fraction of the global SFR density at z~0.7 do USMgII absorbers trace?
- Conclusions

a) Galactic Outflows

AGN-outflows:

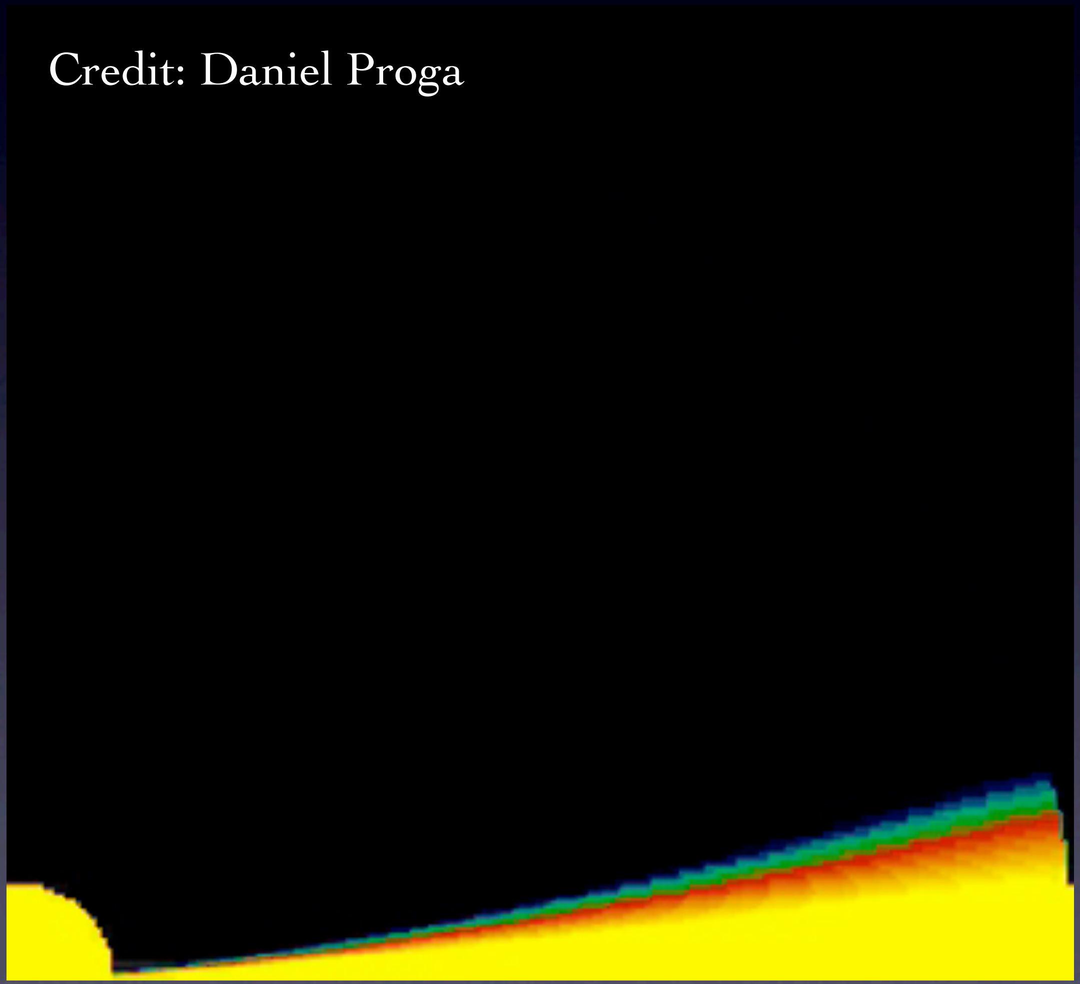


AGN jets

a) Galactic Outflows

AGN-outflows:

Accretion-disk outflows



a) Galactic Outflows

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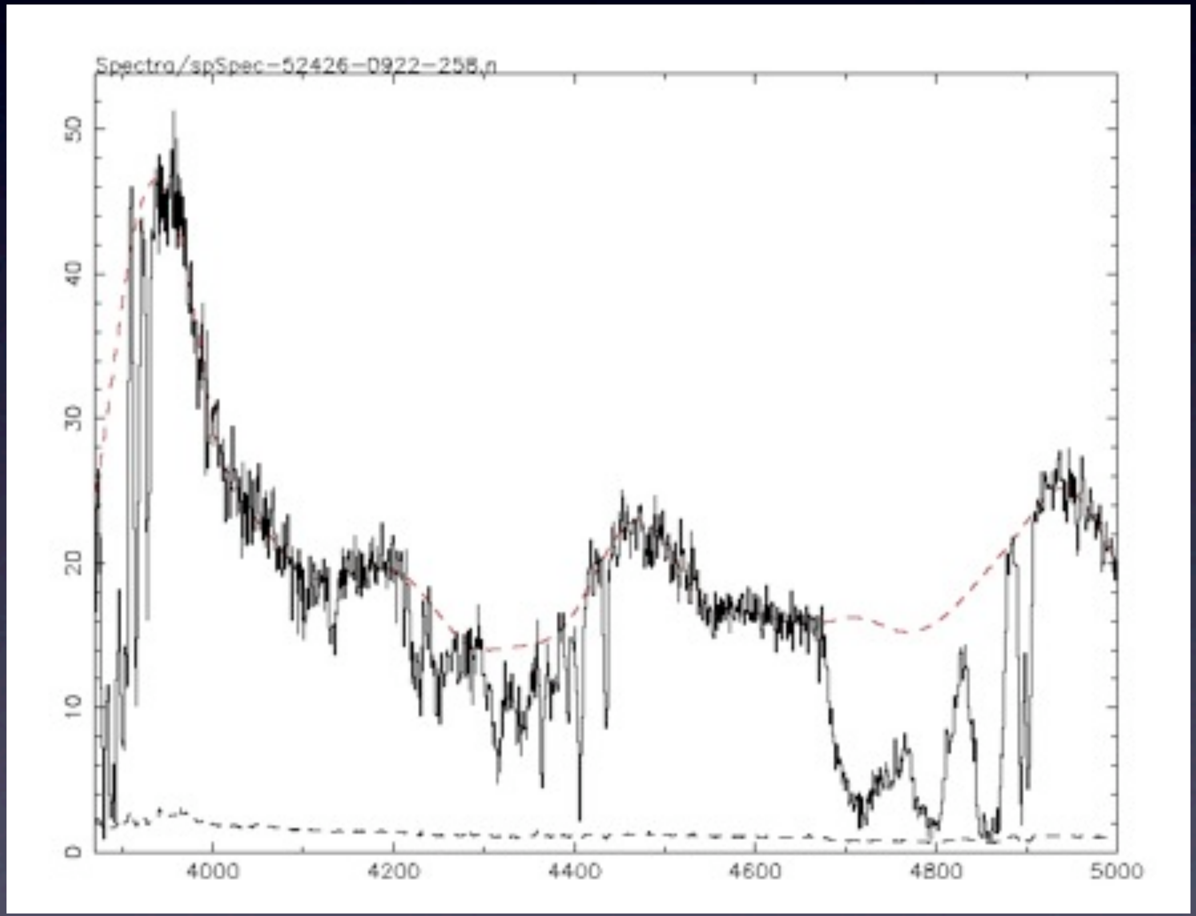
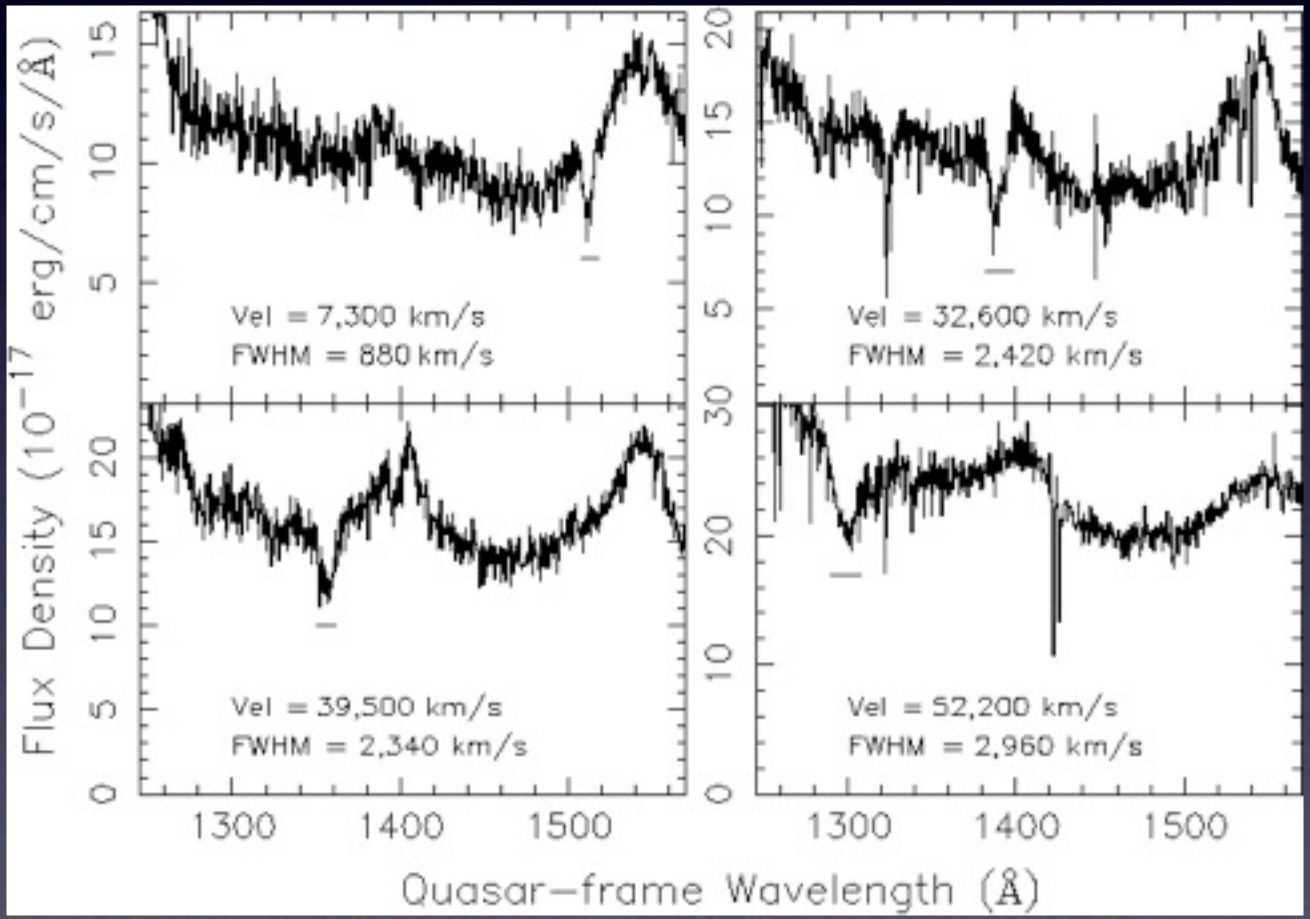


Broad Absorption-lines (BALs)

a) Galactic Outflows

AGN-outflows:

Mini-BALs



Rodríguez Hidalgo, Hamann & Nestor, 2009

a) Galactic Outflows

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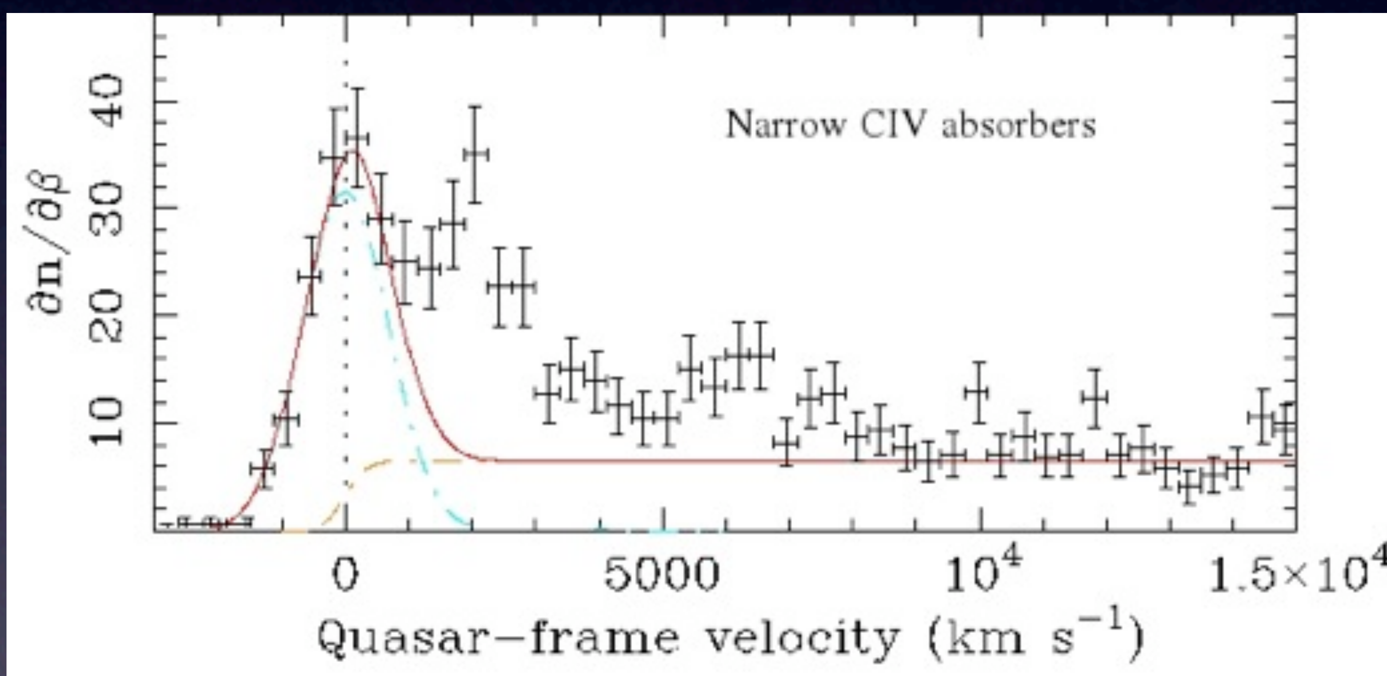


Nestor, Hamann &Rodríguez Hidalgo, 2008

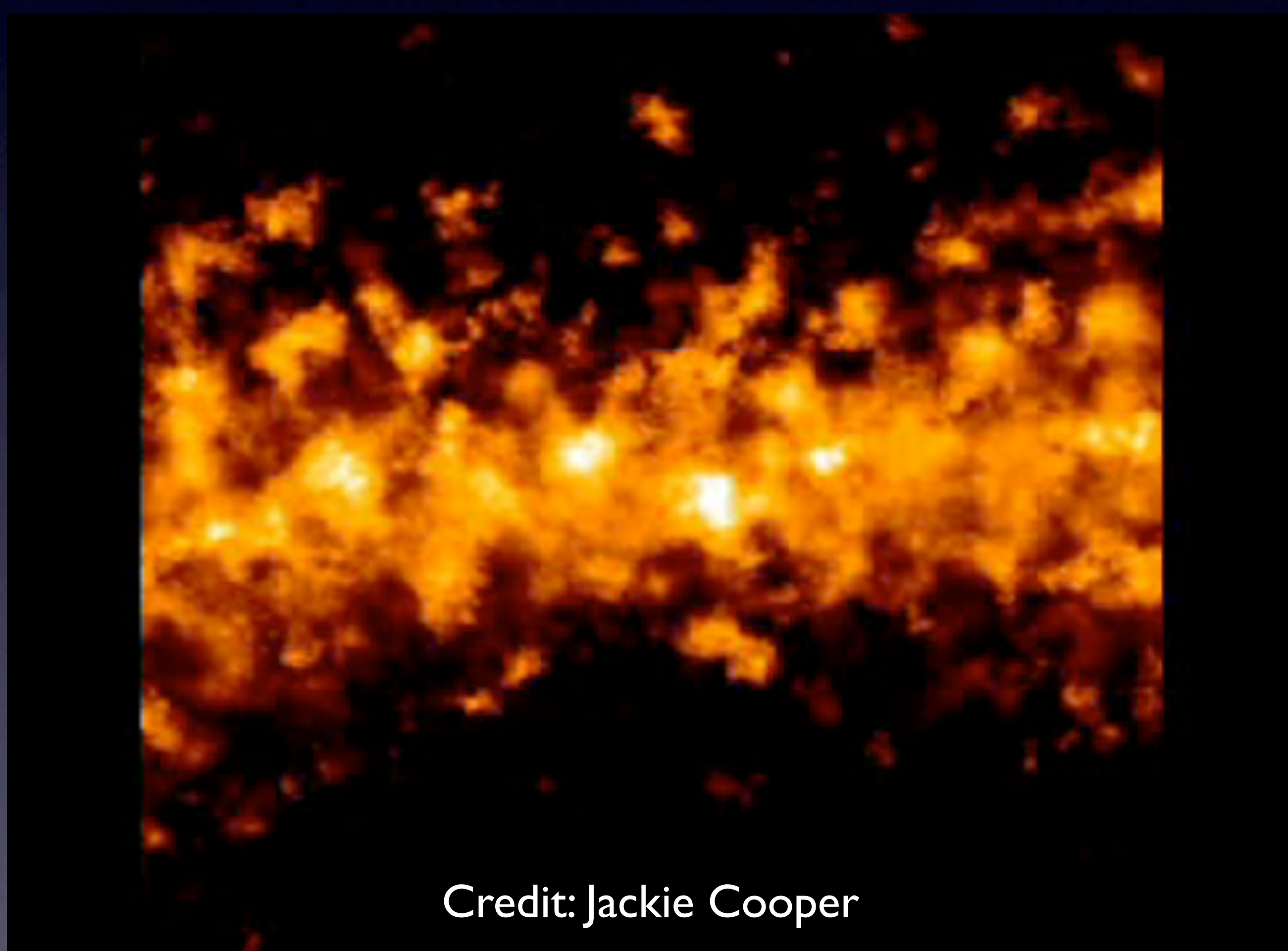
Narrow associated systems

a) Galactic Outflows

Starburst-driven

Galactic Winds:

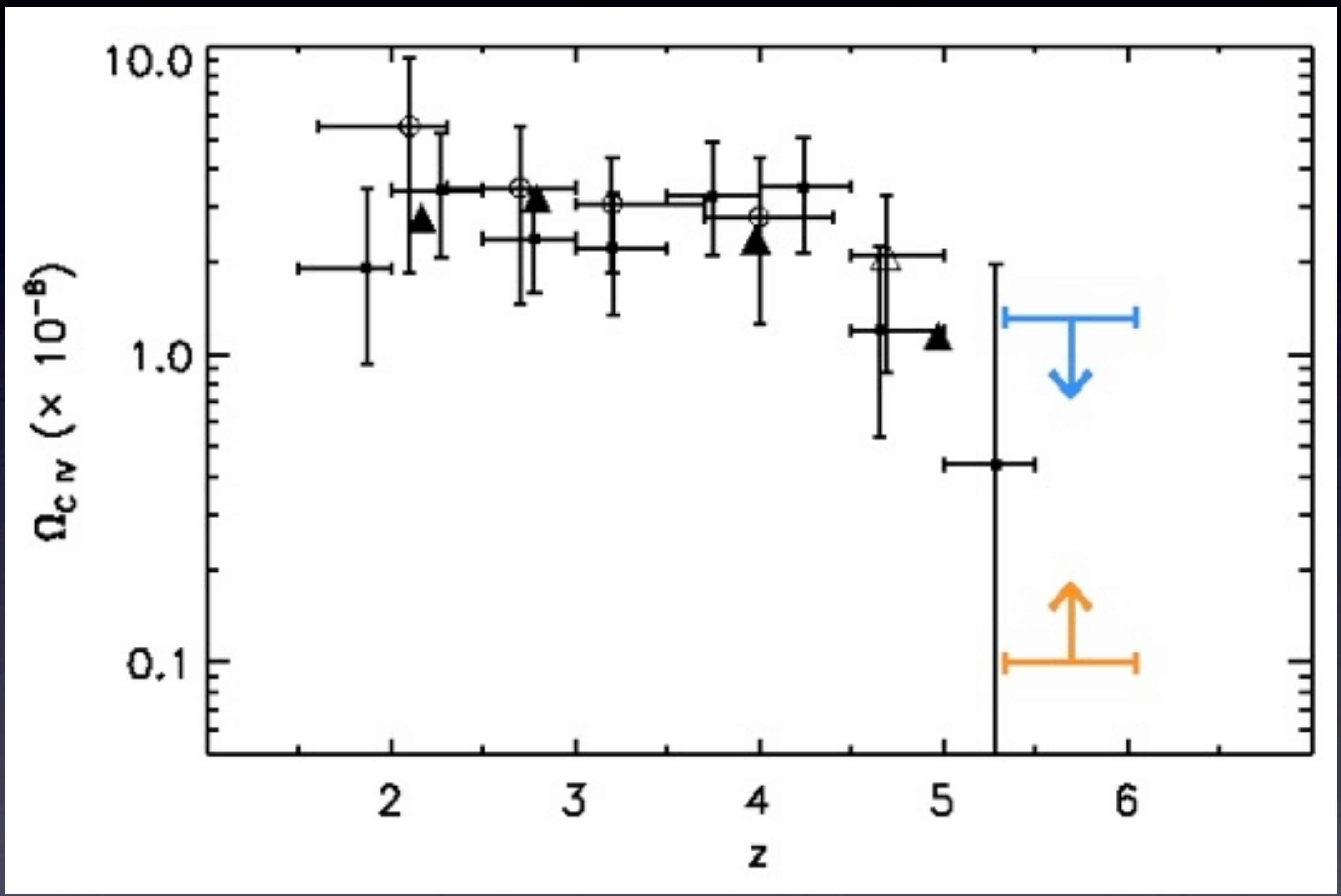
$t \lesssim 3$ Myr:	OB winds
$t \sim 3$-6 Myrs:	WR winds
$t \lesssim 40$ Myrs:	SNeII



- Observed in all galaxies where $\Sigma_{SF} \gtrsim 0.1\ M_{sol}\ yr^{-1}\ kpc^{-2}$
- Cool gas observed in blushifted absorption
  - Velocity: from few hundreds of km s^{-1} to $\approx$1000+ km s^{-1}
- Mass? EM $\propto \rho^2$, miss most of the hot gas if diffuse

a) Galactic Outflows

Important for understanding:

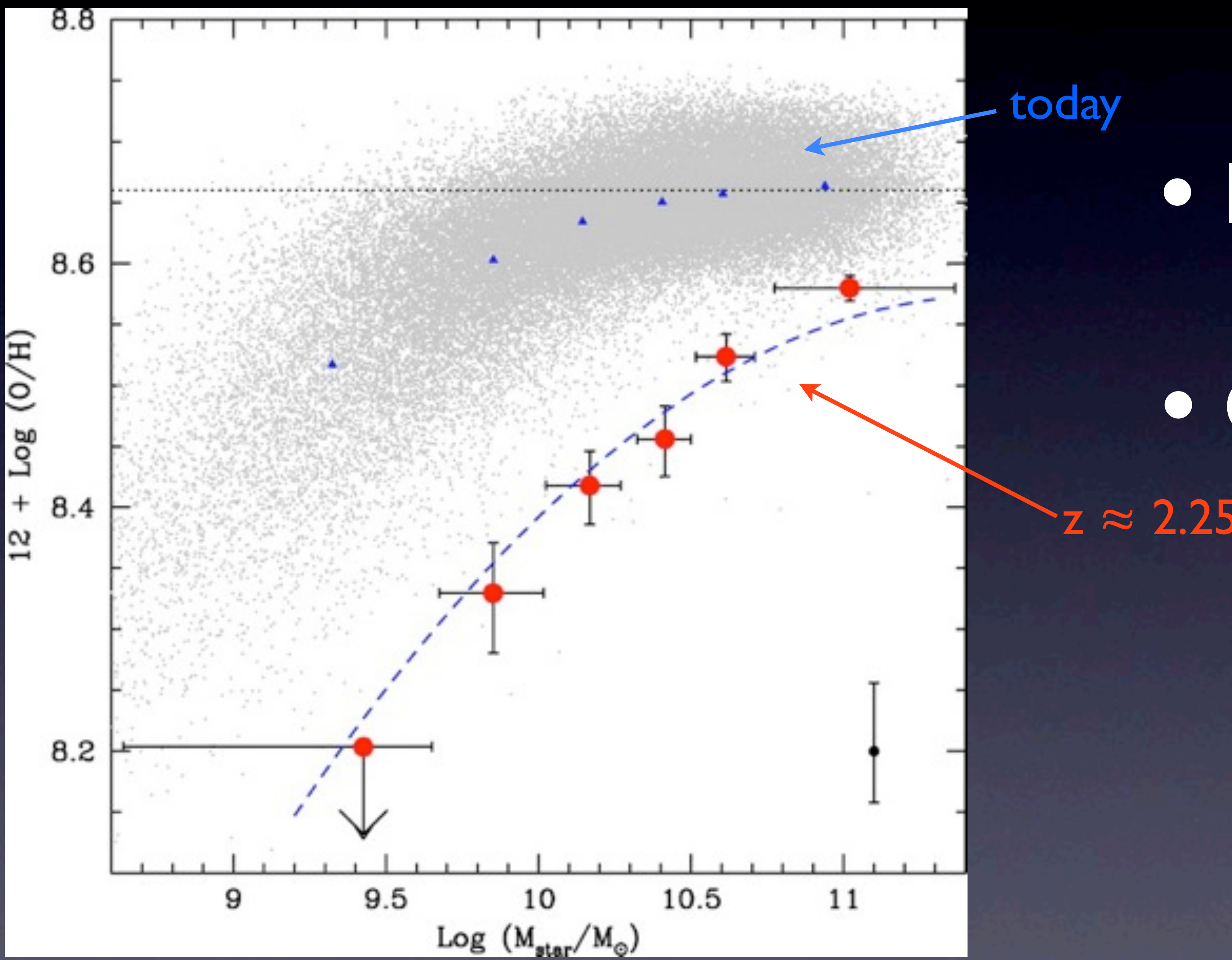


Becker, Rauch & Sargent, 2008

- Enrichment of the IGM

a) Galactic Outflows

Important for understanding:



Erb et al., 2006

- Enrichment of the IGM
- Galaxy M-Z relation

a) Galactic Outflows

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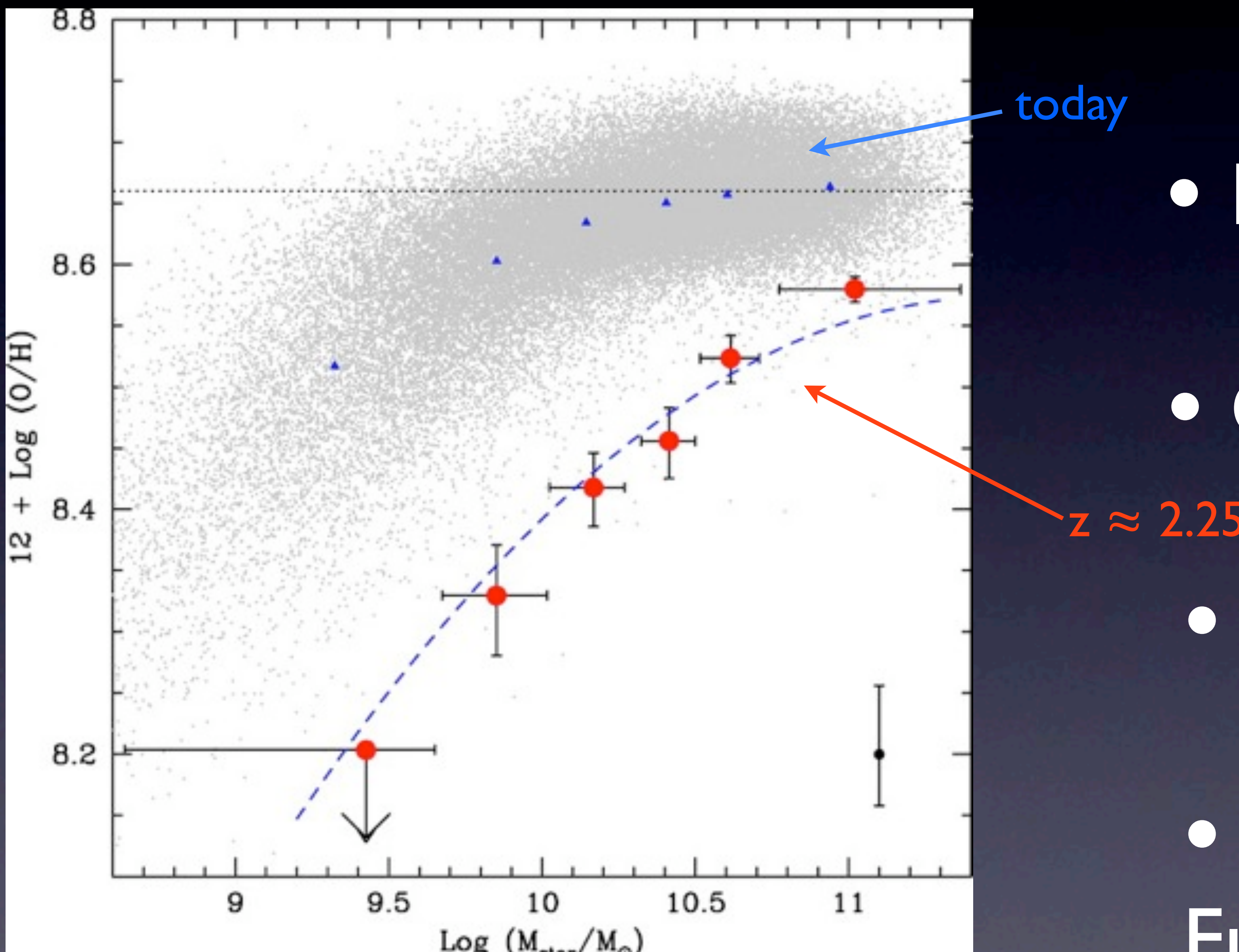

Erb et al., 2006

- Enrichment of the IGM
- Galaxy M-Z relation
- Sizes of disks
- Galaxy Luminosity Function

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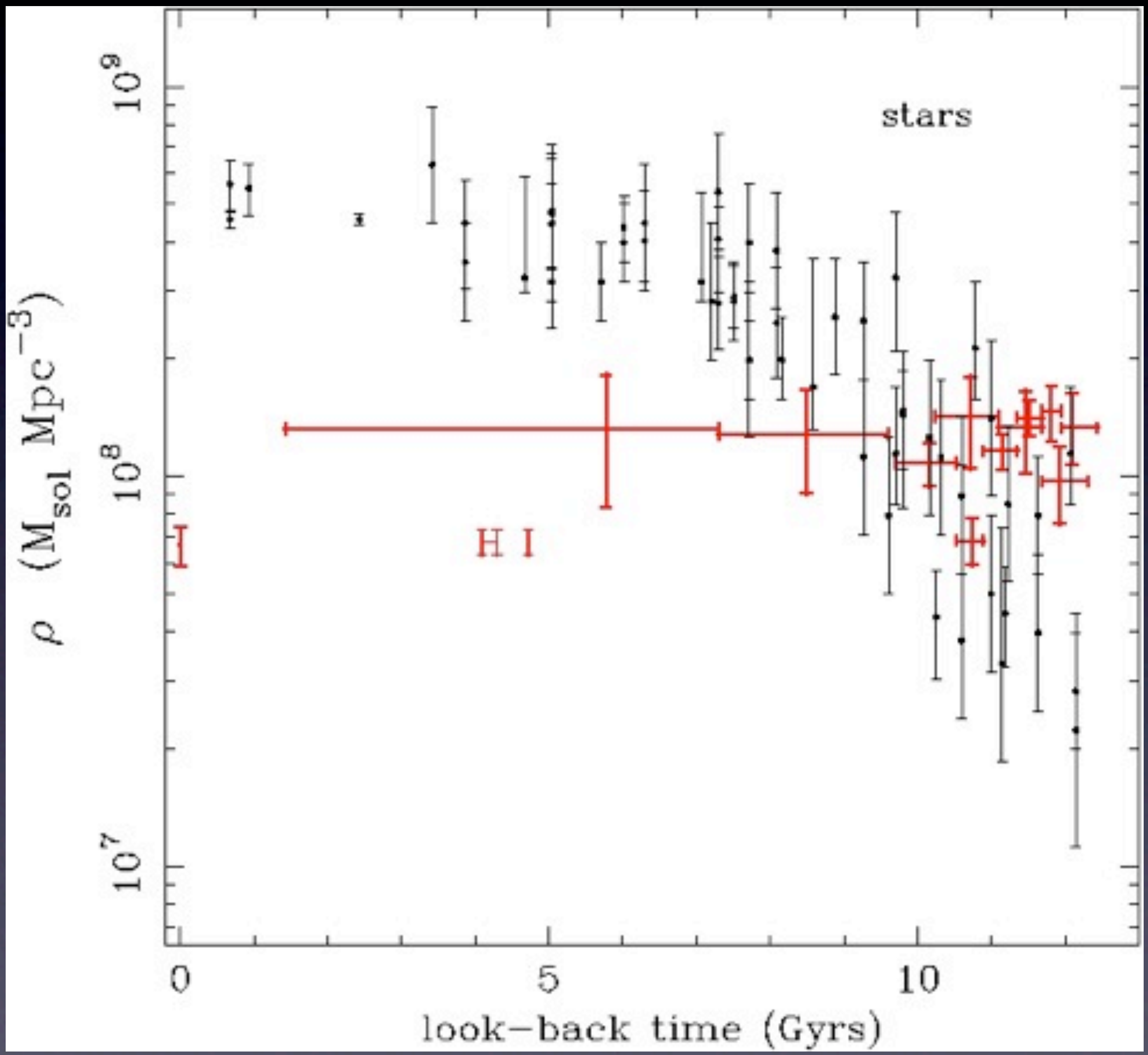

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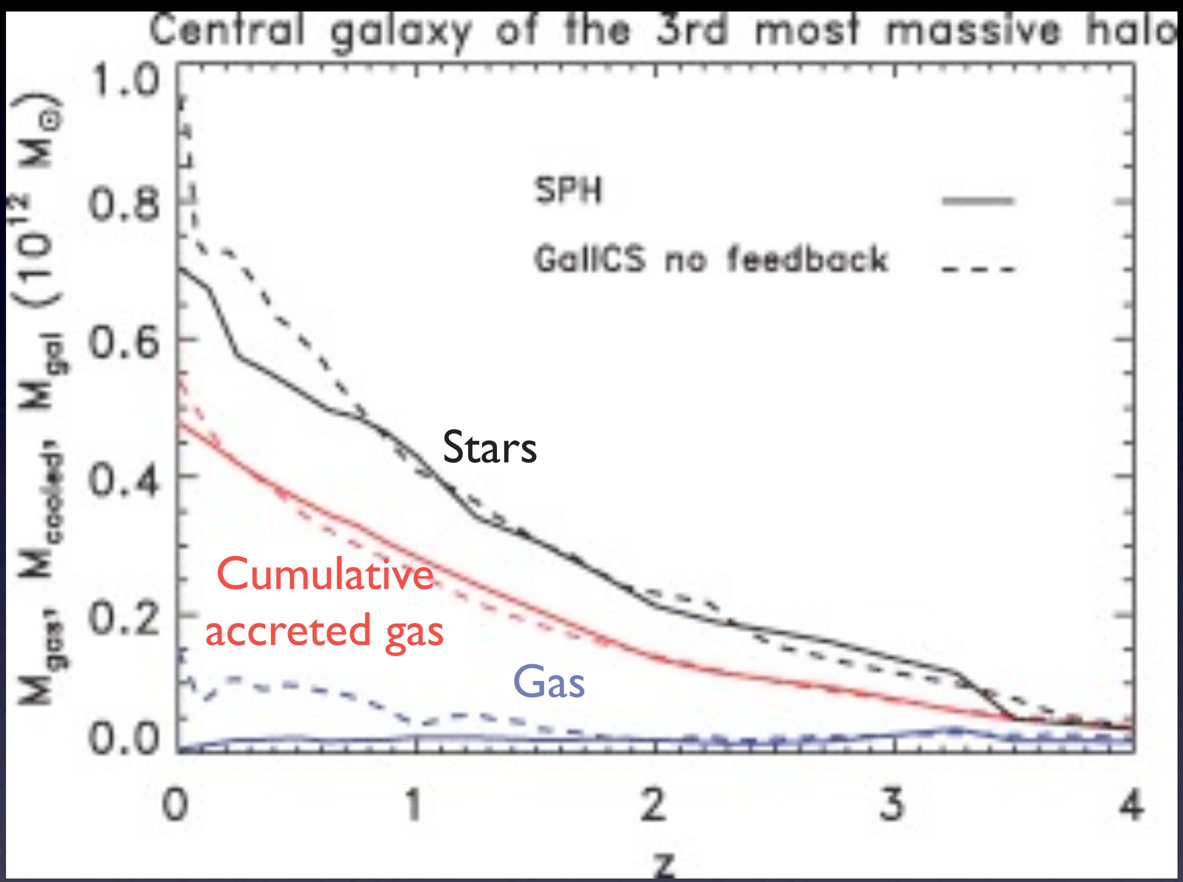
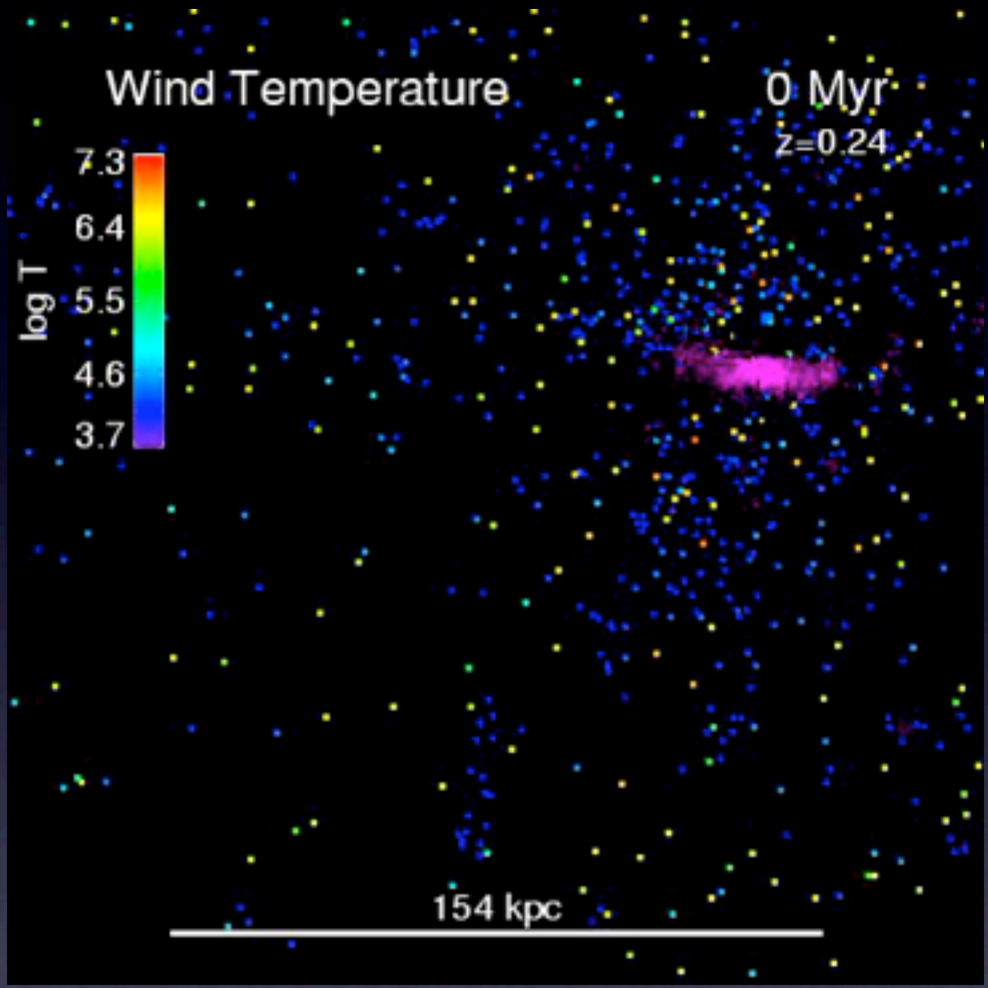


Catteneo et al., 2007



Credit: Ben Oppenheimer

E.g.: Davé 2009 (arXiv0901.3149); Kereš et al. 2009 (arXiv0901.1880); Scannapieco et al., 2008 (MNRAS 389, 1137); etc.

b) Intervening MgII absorbers

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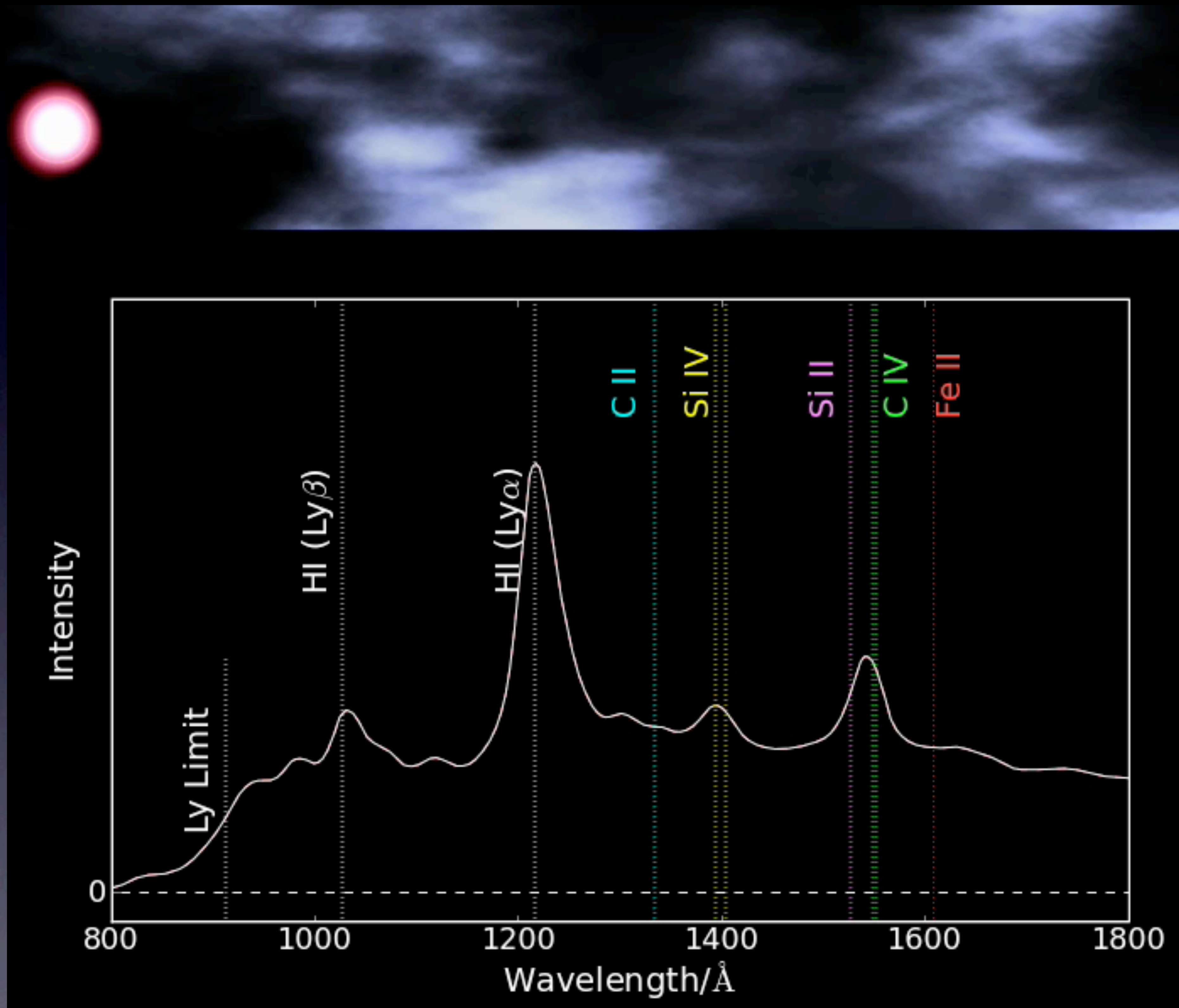

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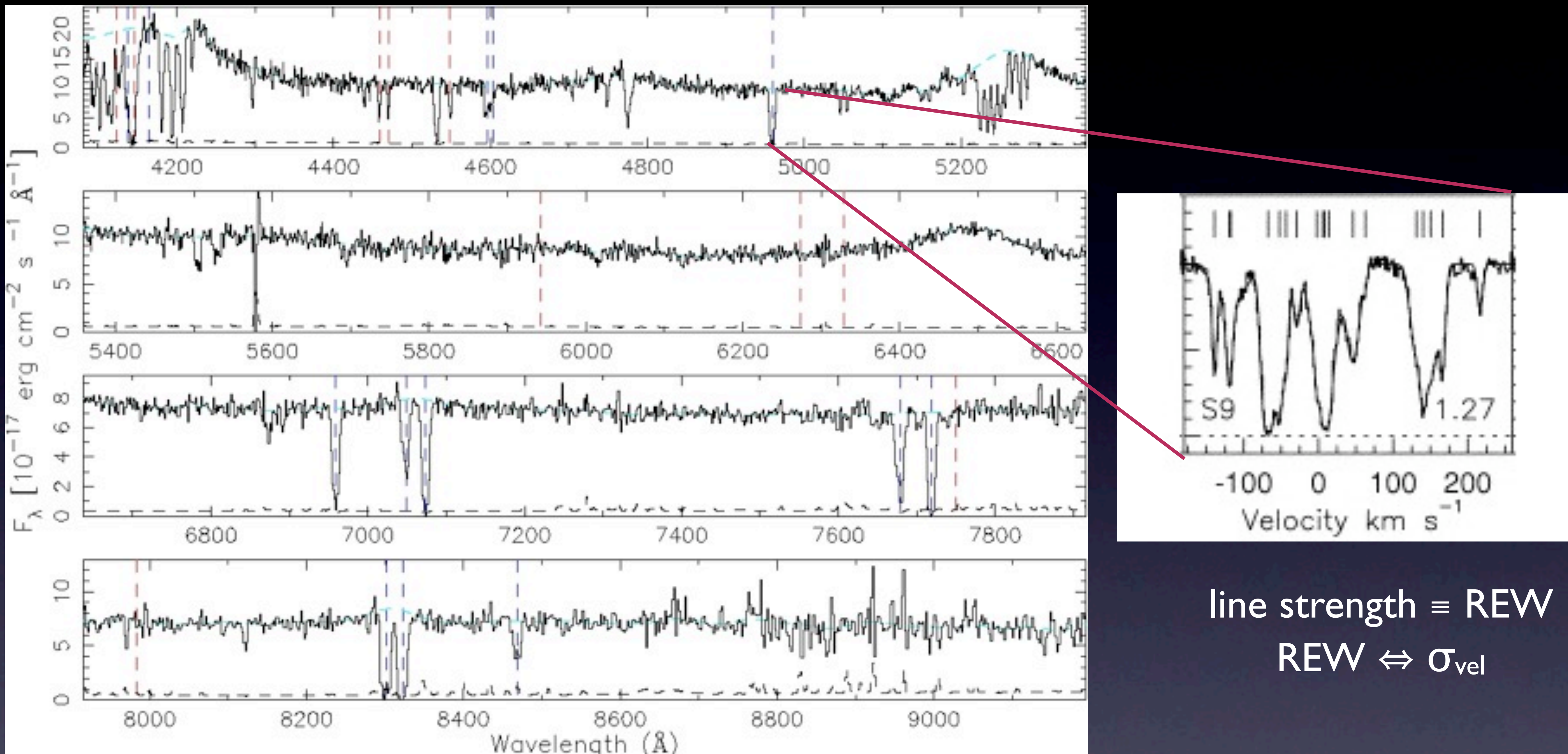


line strength ≡ REW

REW ⇔ σ_{vel}

QALs easily identify galaxies at virtually any *z*

but what do we really know...

b) Intervening MgII absorbers

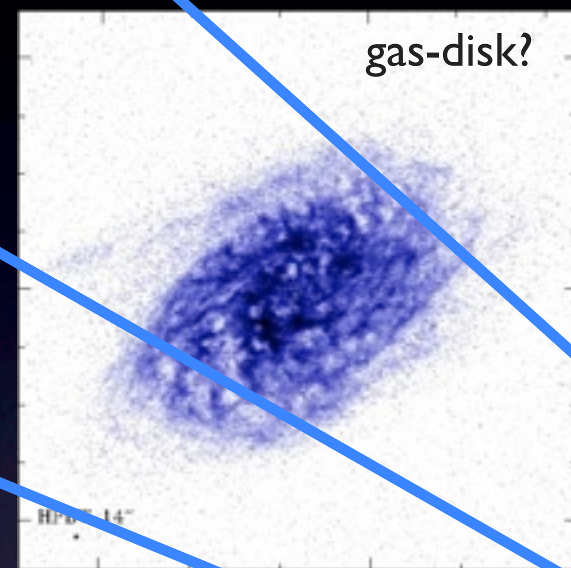
Q

virialised clouds?

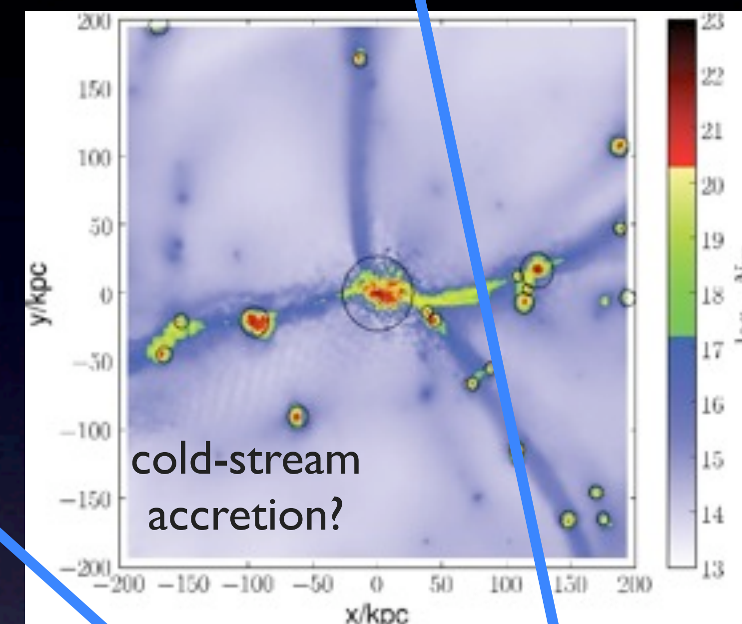
$$2\langle T\rangle = -\sum_{k=1}^{N}\langle \mathbf{F}_k\cdot\mathbf{r}_k\rangle$$

Q

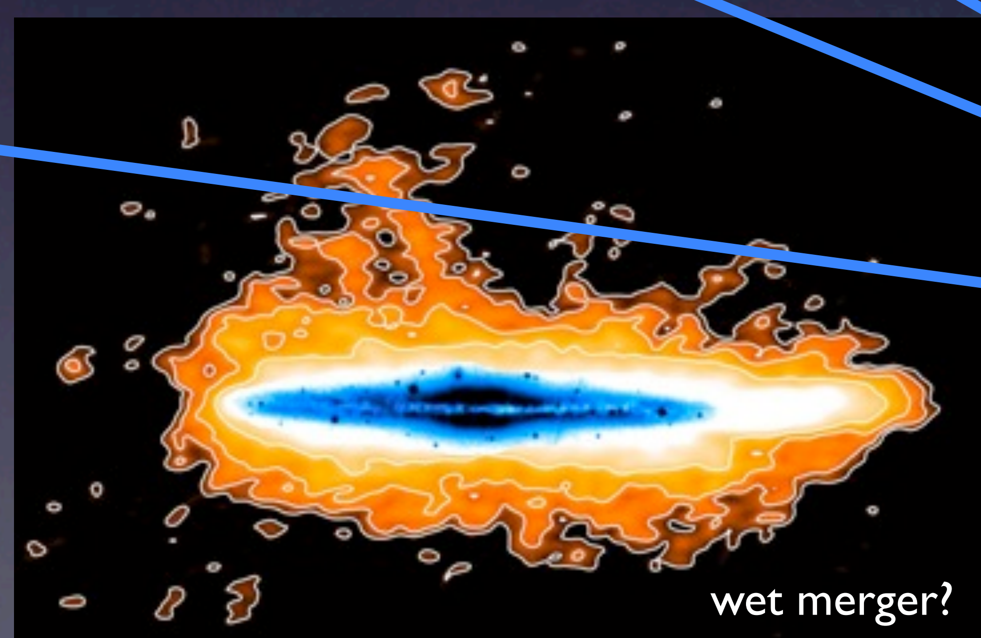
Q



Q



Q



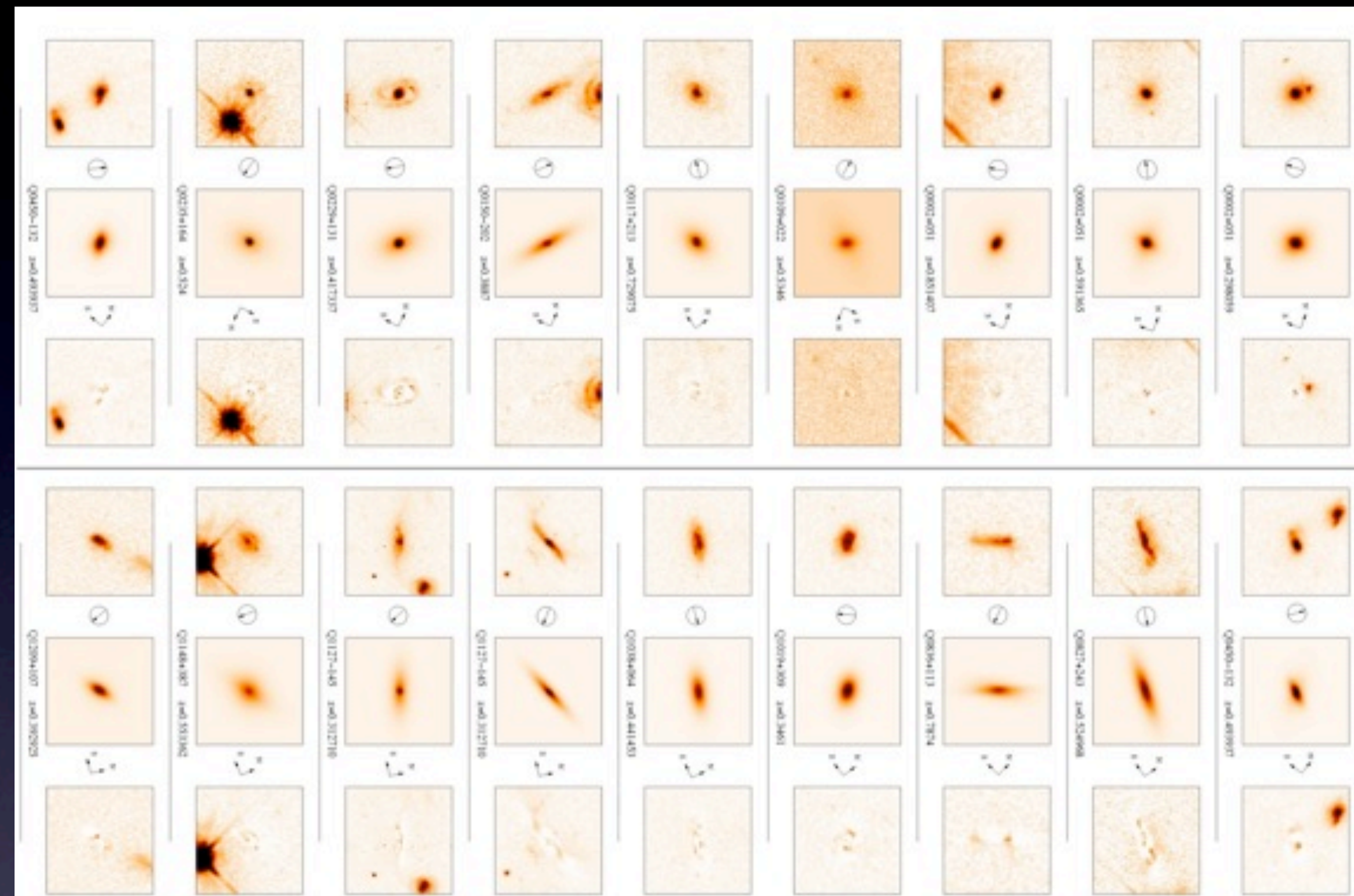
...how to interpret them?

b) Intervening MgII absorbers

Past work:

MgII absorbers can be identified with galaxies of various:

- colours,
- morphologies,
- impact-parameters,
- orientations,
- etc.



Emission/absorption correlations are generally not found (which is a problem).

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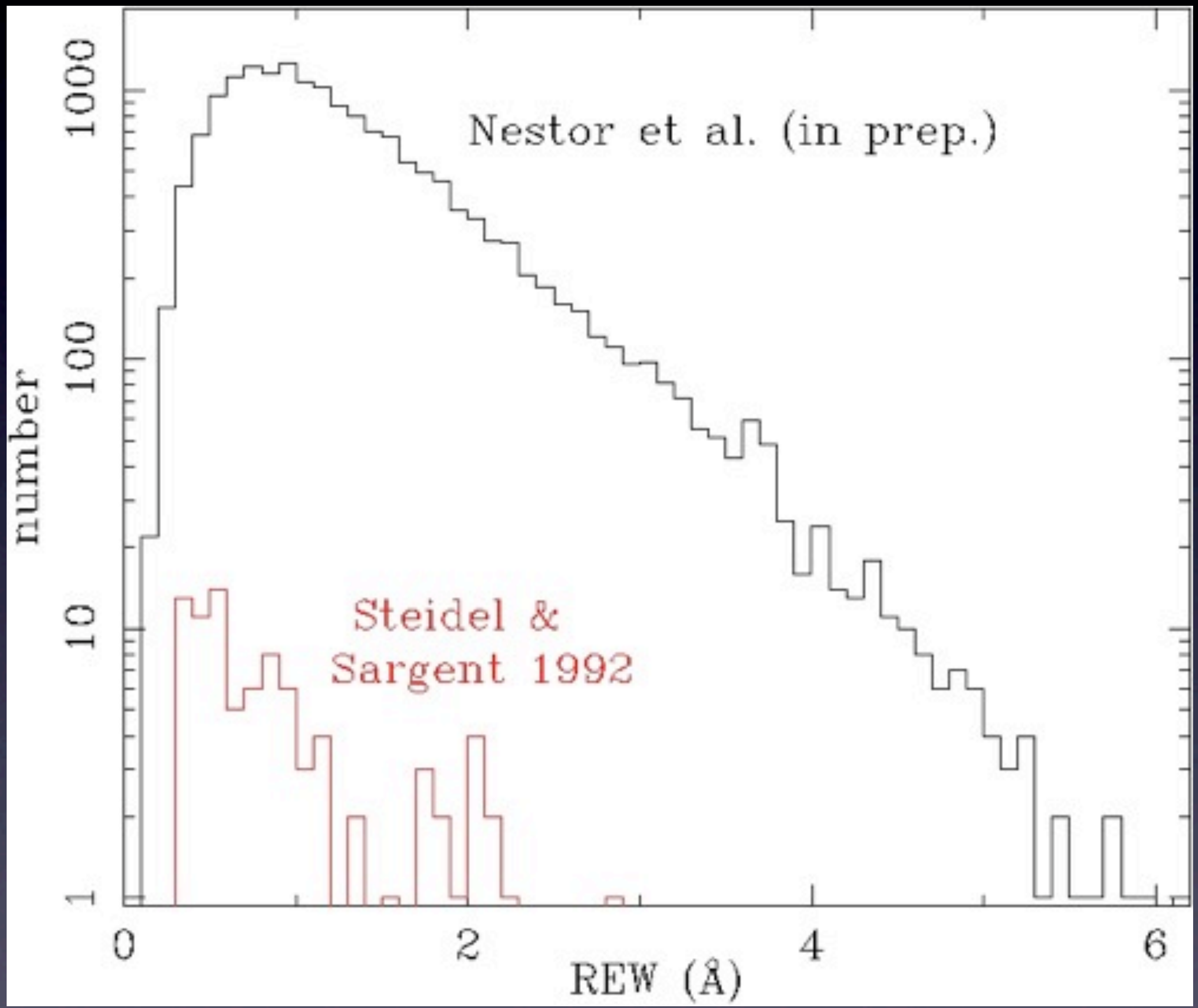
Ultra-strong MgII absorber – GW connection

SDSS: allows for *huge* absorption-line surveys



Clues to the nature of QALs in:

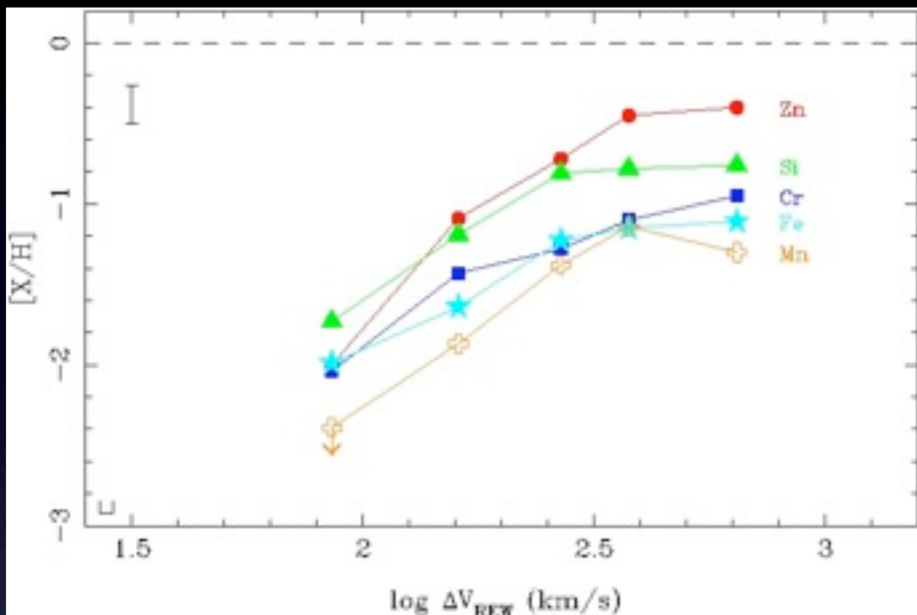
precision statistics?

ultra-strong MgII absorbers?

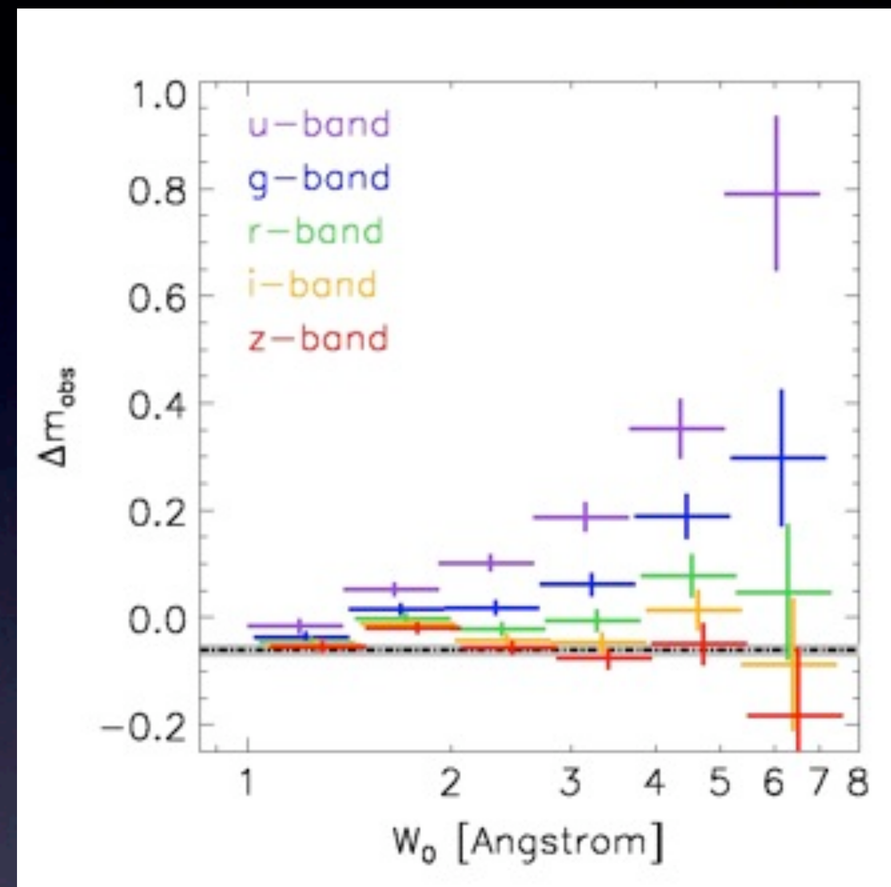
($\Delta V \geq 107$ km s^{-1} × REW λ2796)

Ultra-strong MgII absorber – GW connection

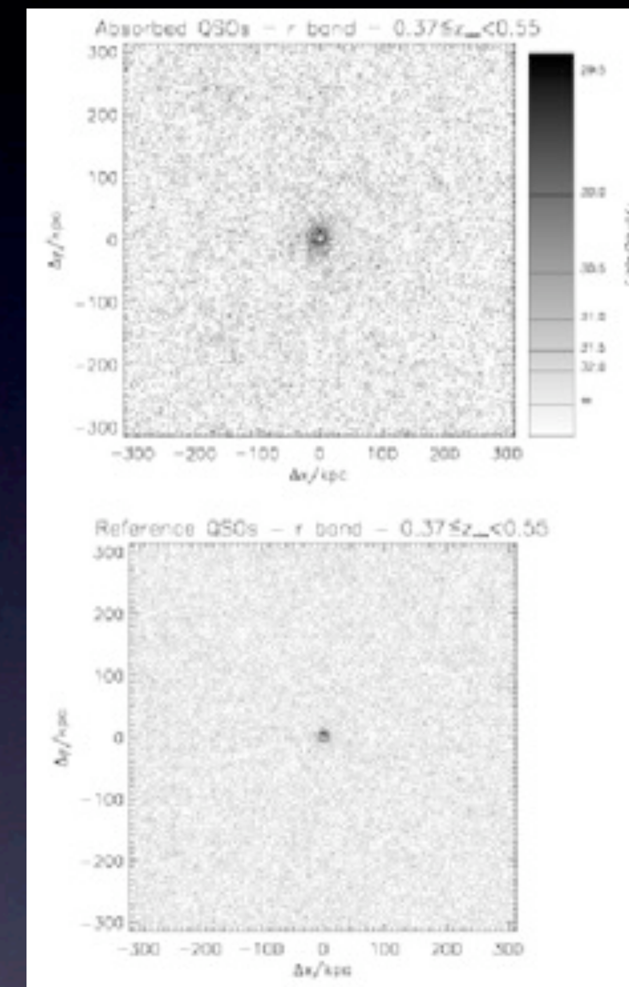
Average properties: stronger systems are...



...more enriched
(Nestor et al., 2003;
Turnshek et al., 2005)

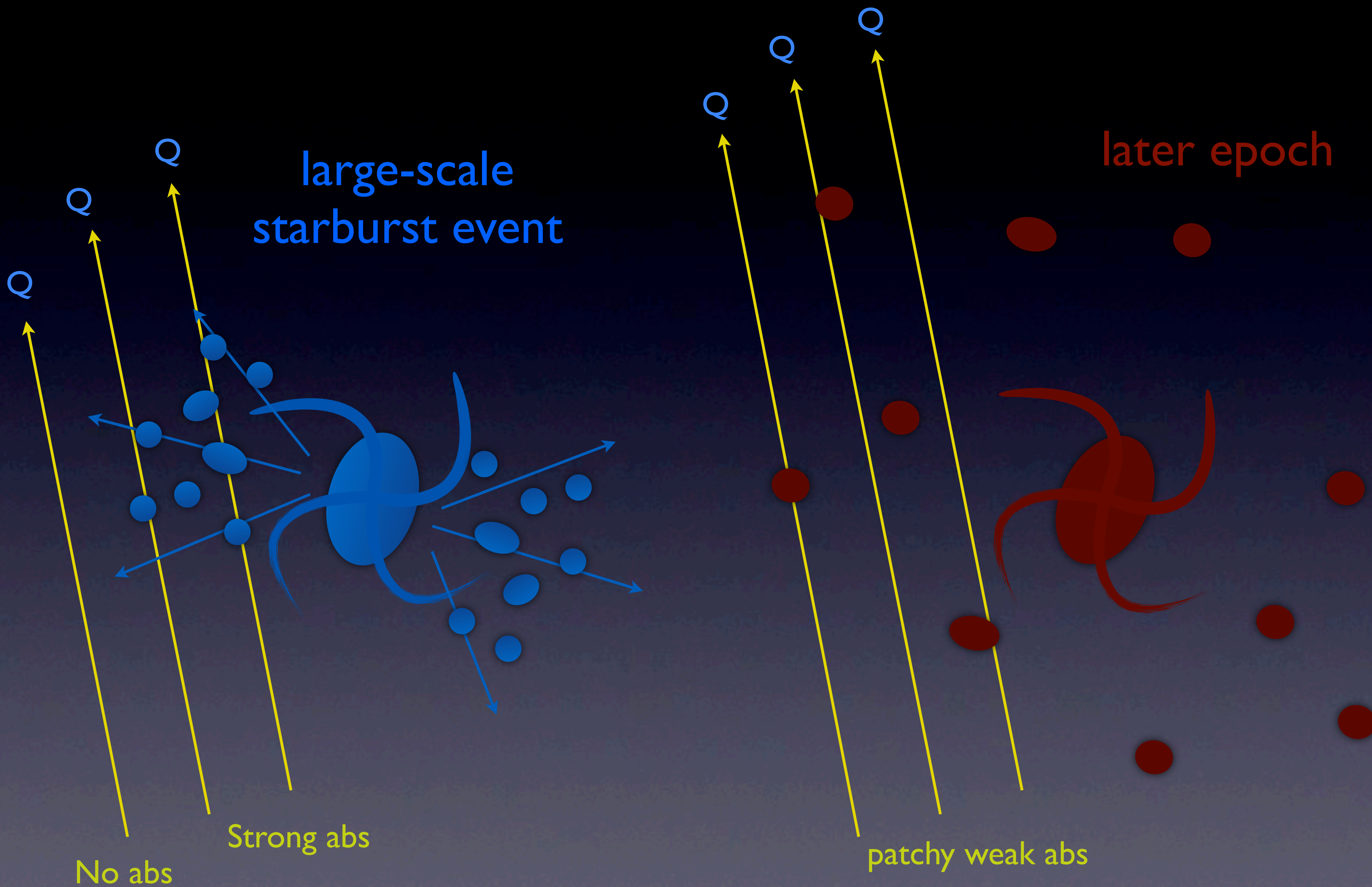


...dustier.
(Ménard, Nestor
et al., 2008)



...associated w/ bluer,
lower-*b* galaxies.
(Zibetti, Ménard, Nestor
et al., 2007)

Ultra-strong MgII absorber – GW connection



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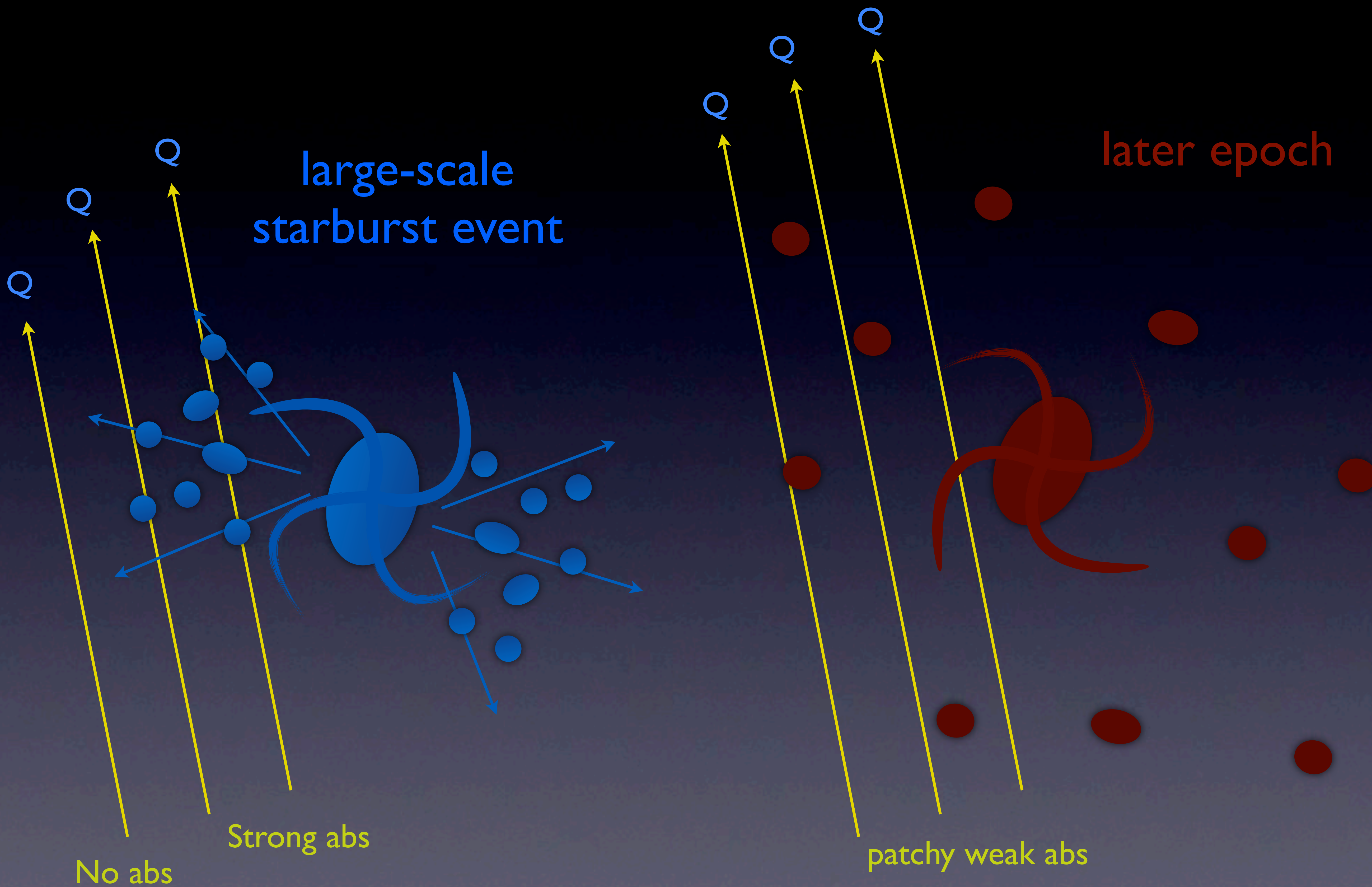


Ultra-strong MgII absorber – GW connection

First proposed:

- Bond, Churchill, Charlton & Vogt (2001, ApJ 562, 641)
  "High-Redshift Superwinds as the Source of the Strongest Mg II Absorbers: A Feasibility Analysis"

Direct detection of outflows in known (post-)starburst galaxies at $z > 0$ (*n.b. – not QAL*):

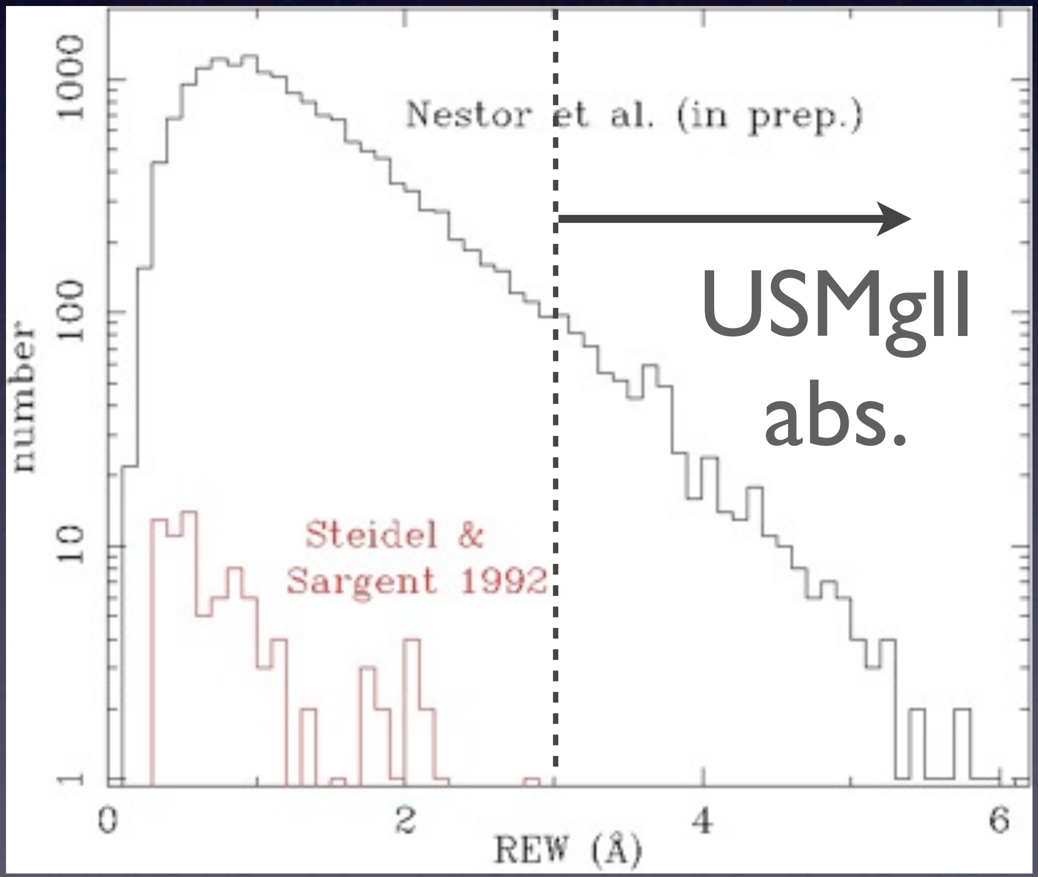
- Tremonti, Moustakas & Diamond-Stanic (2007, ApJ, 663, 77)
  "The Discovery of 1000 km s^{-1} Outflows in Massive Poststarburst Galaxies at z=0.6"

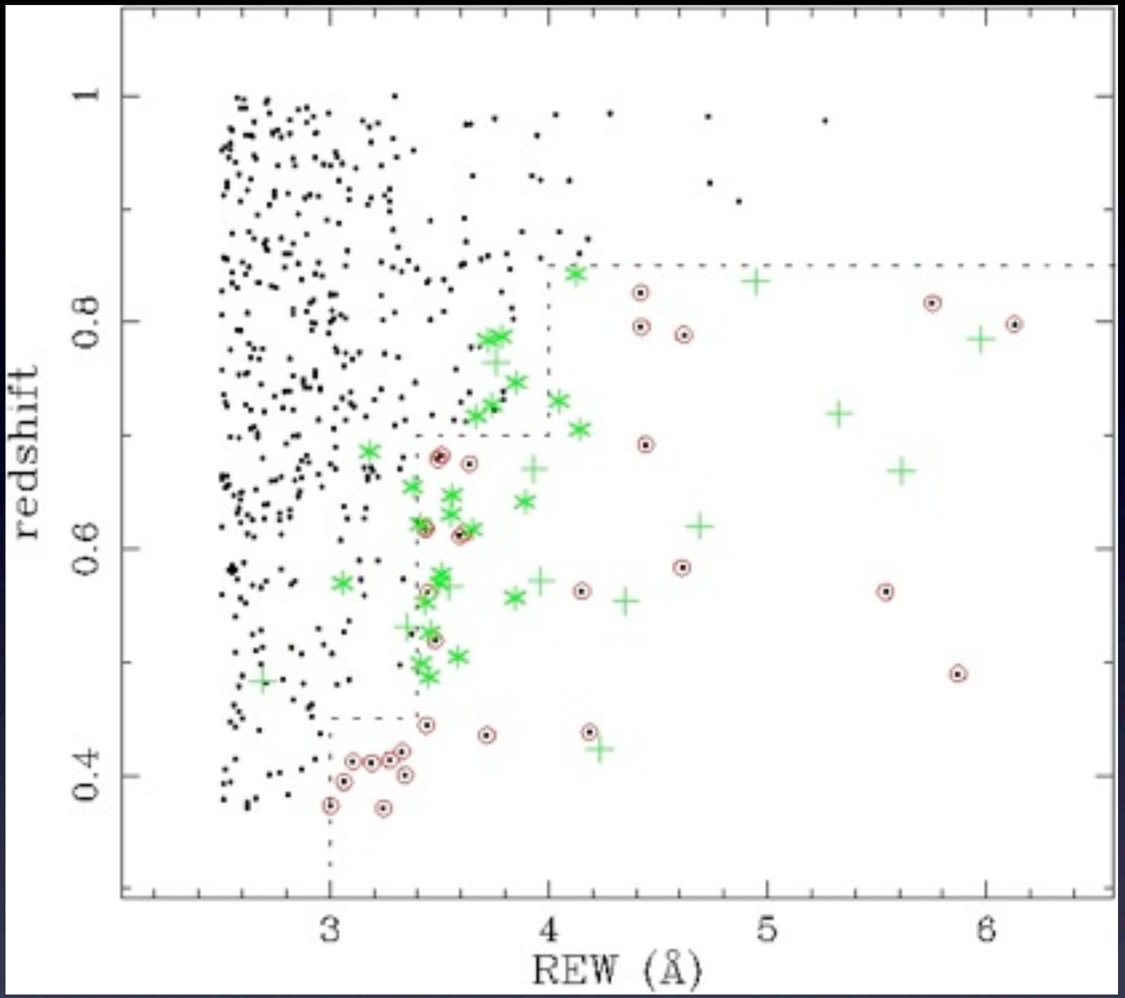
- Weiner et al. (2009, ApJ, 692, 187)
  "Ubiquitous Outflows in DEEP2 Spectra of Star-Forming Galaxies at z = 1.4"

- Shapley et al. (2003, ApJ, 588, 65)
  "Rest-frame Ultraviolet Spectra of z~3 Lyman Break Galaxies"

Ultra-strong MgII absorber – GW connection

Explore sample of individual "ultra-strong" MgII absorbers



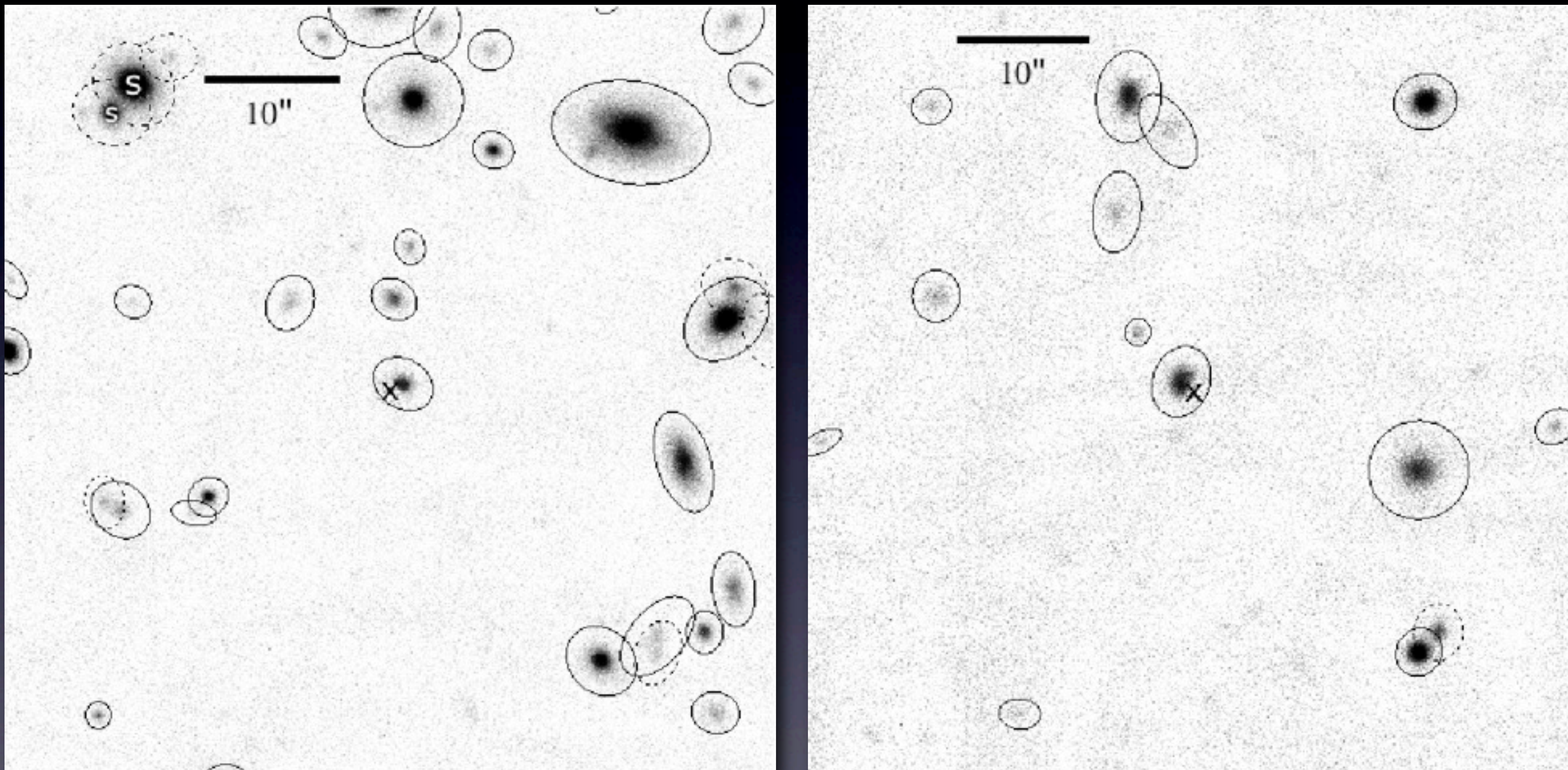


+ in Nestor, Turnshek & Rao, 2007

* imaging obtained

○ targets for April & May observing runs

Ultra-strong MgII absorber – GW connection



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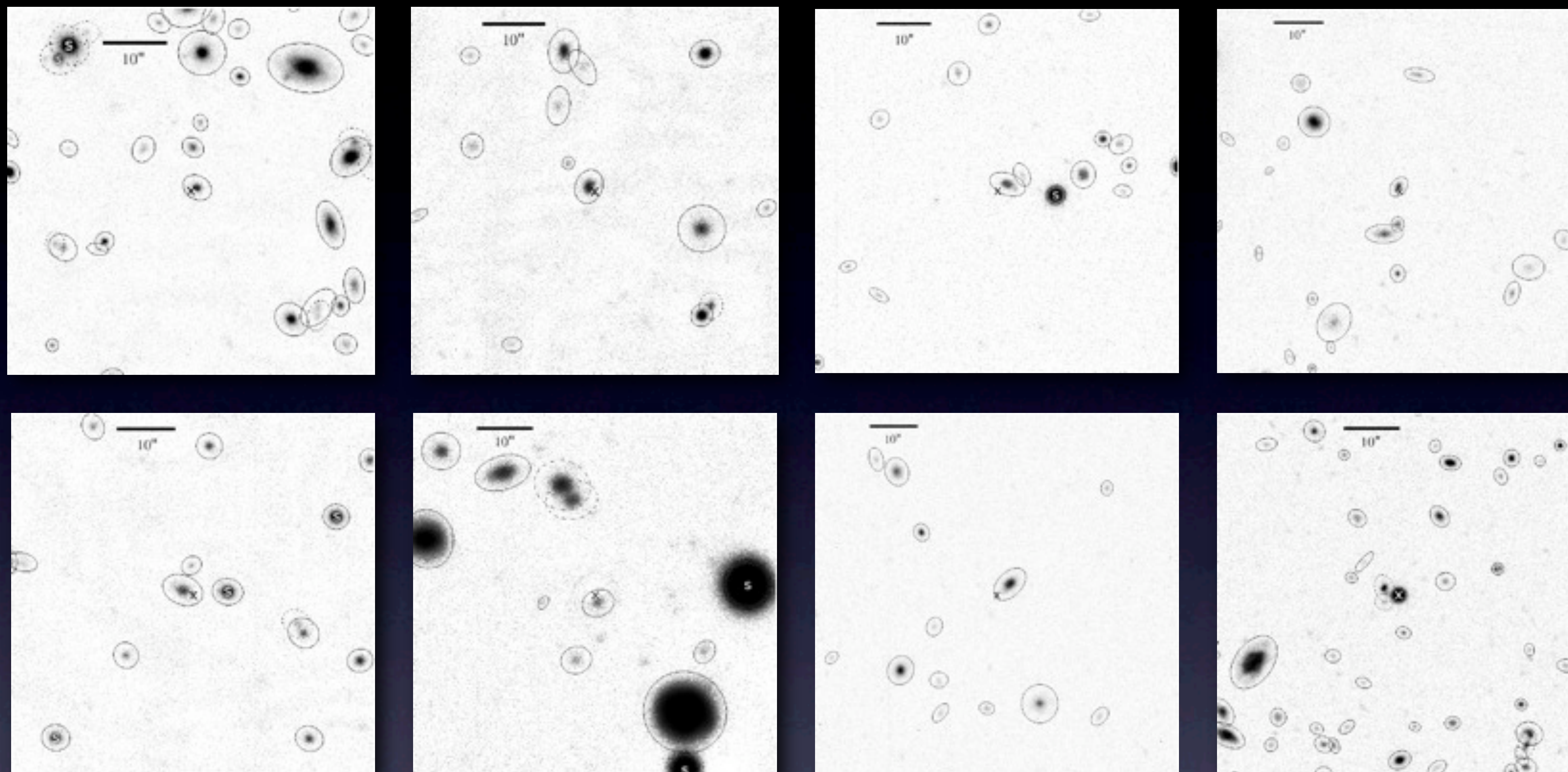

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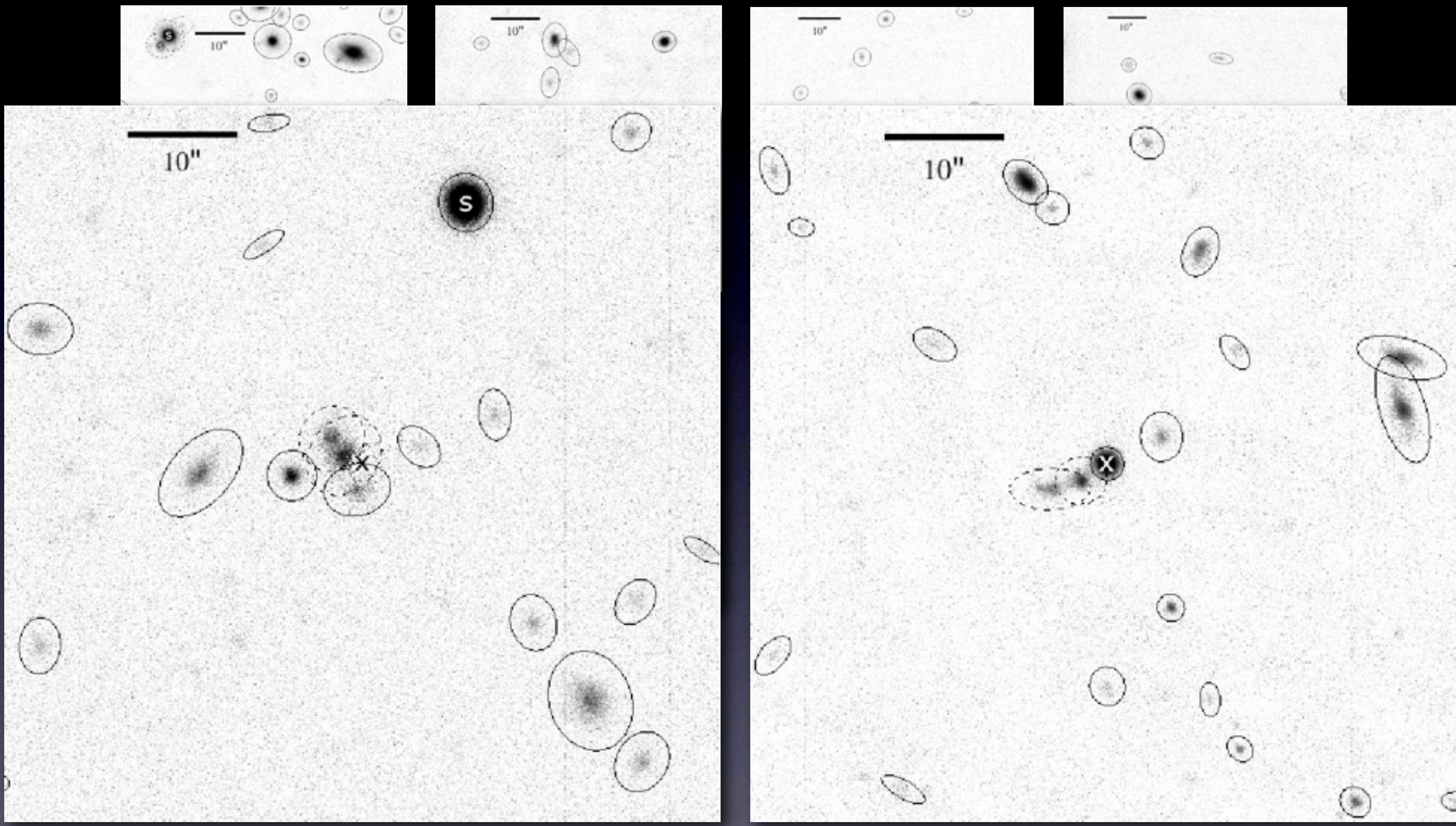

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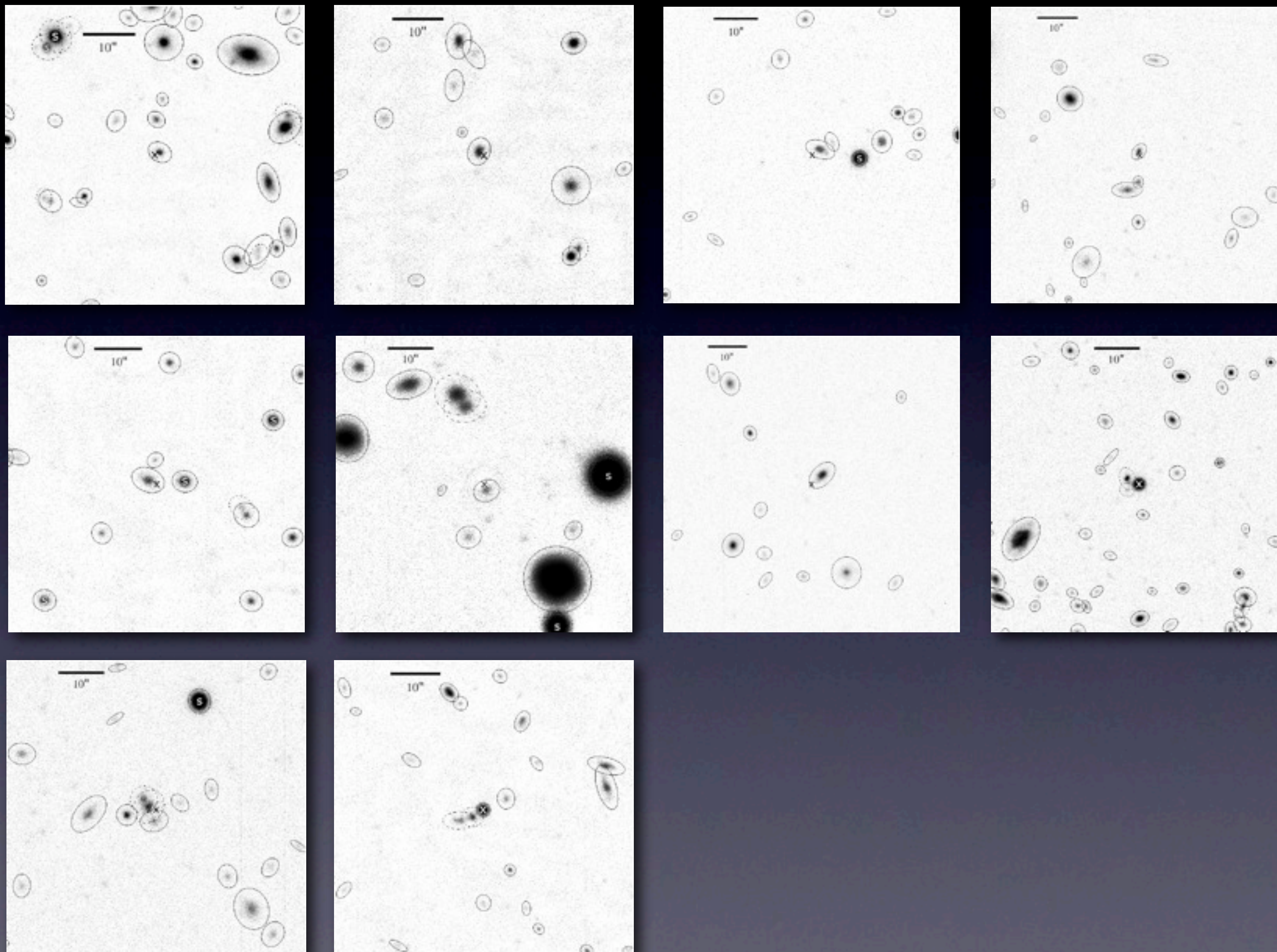

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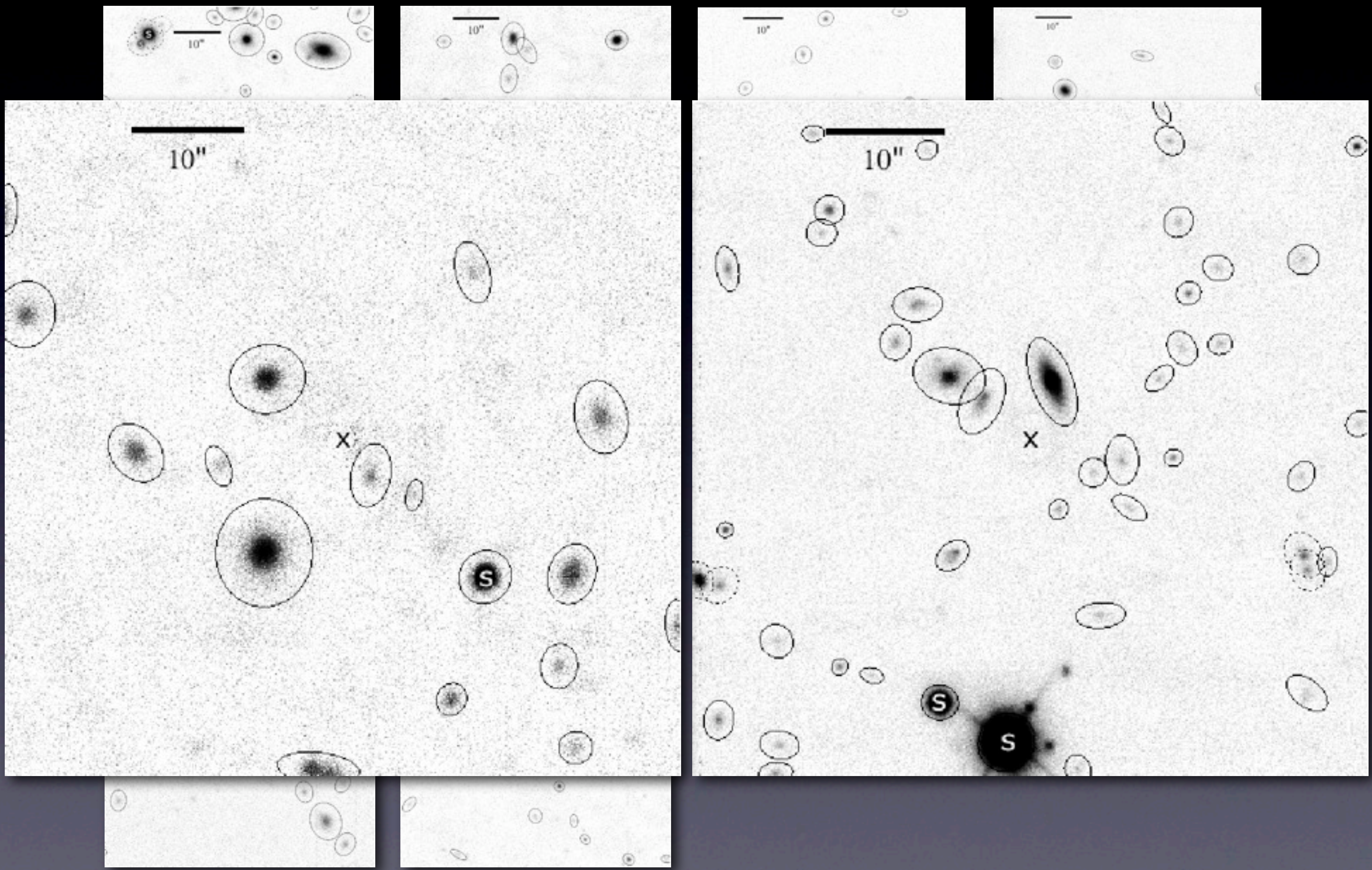
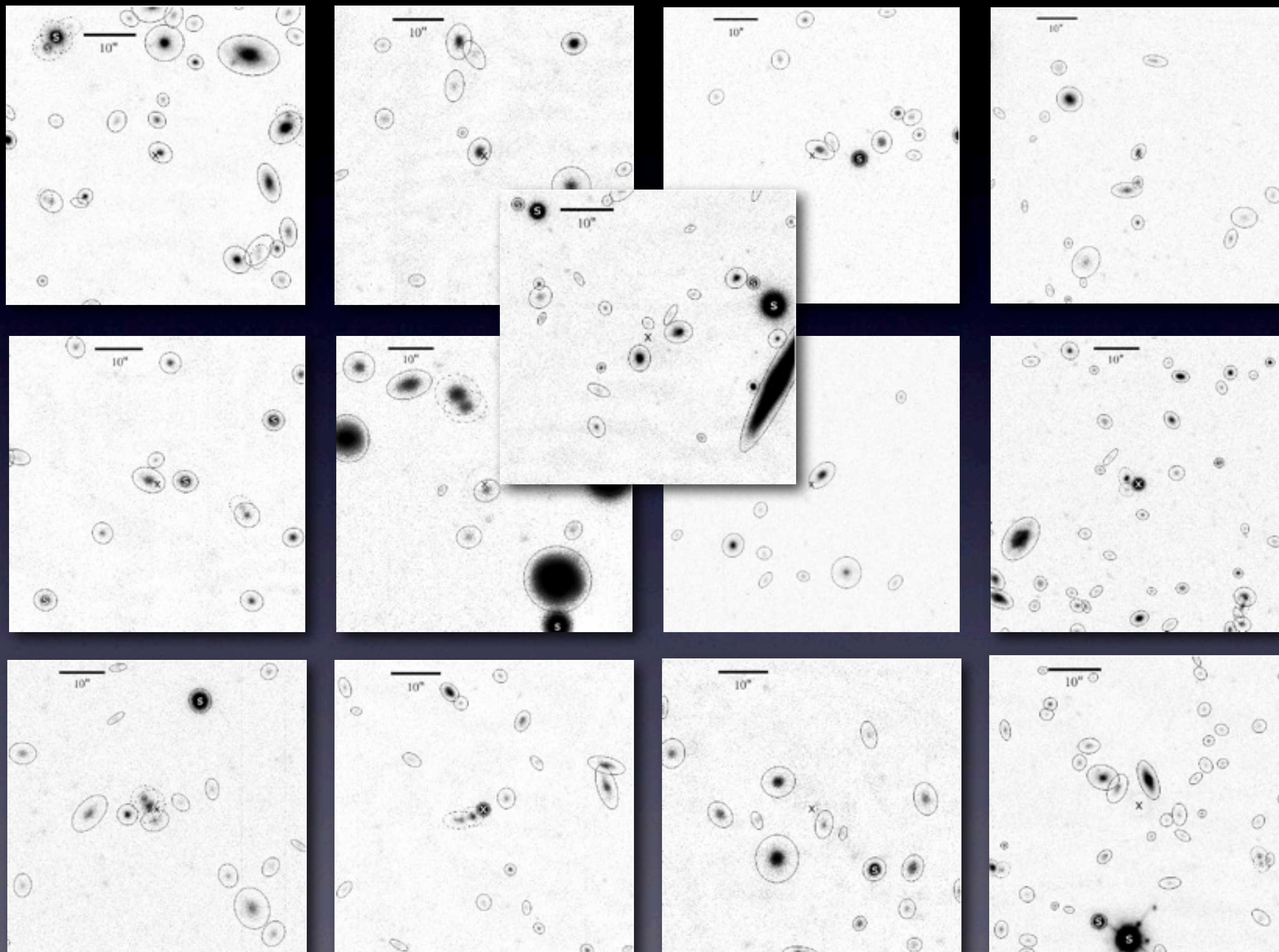


Monday, 30 March 2009

Ultra-strong MgII absorber – GW connection



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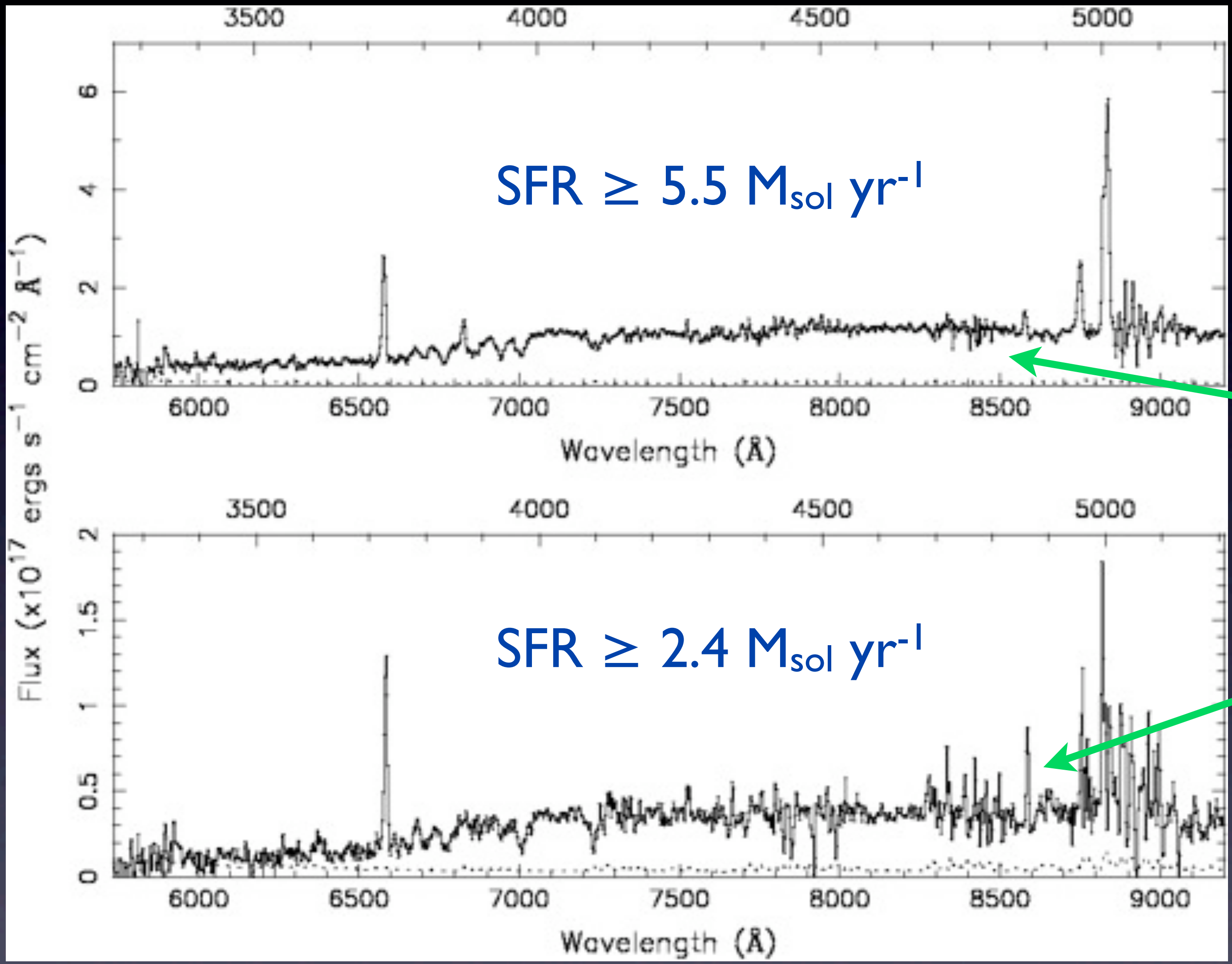

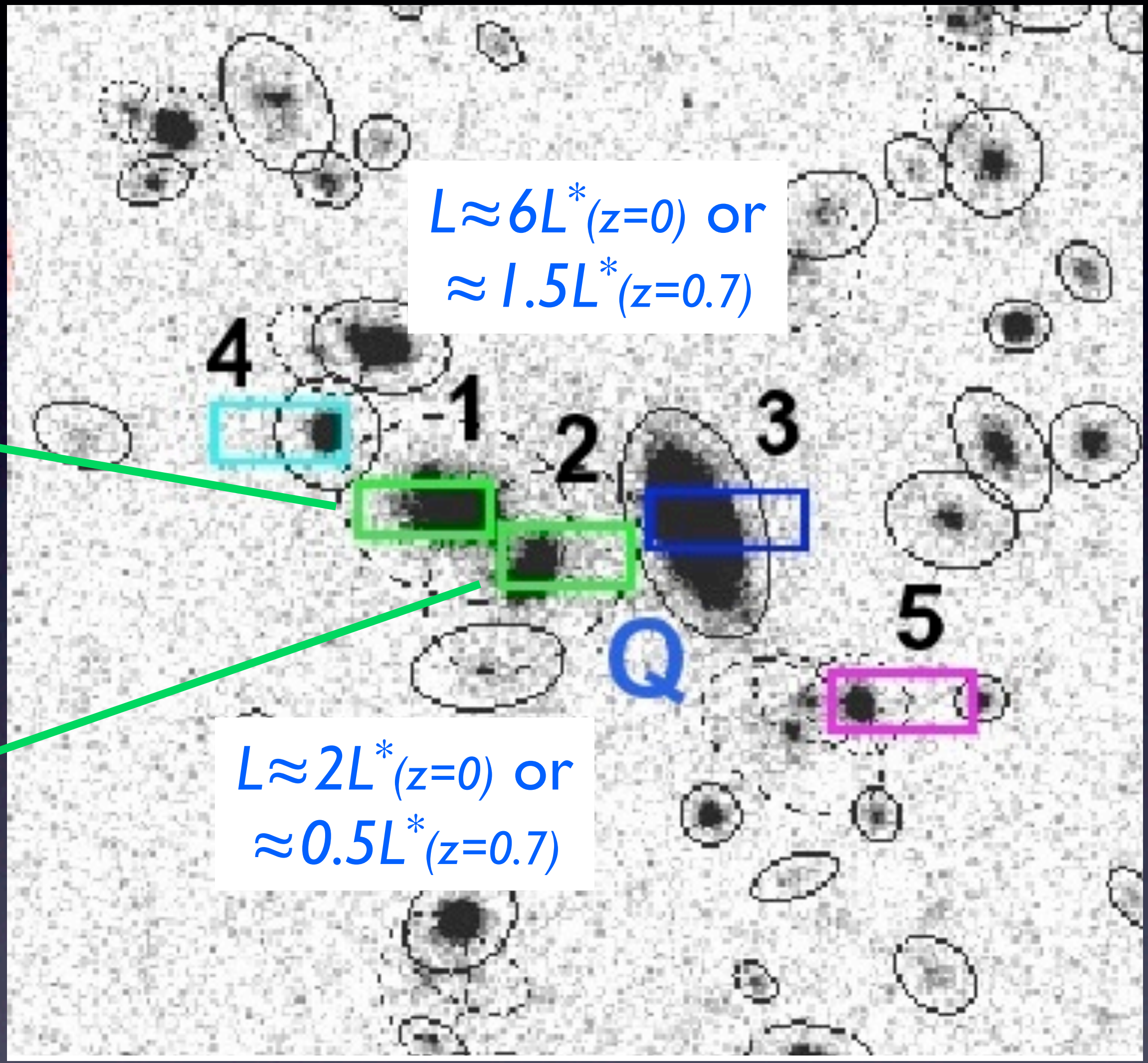

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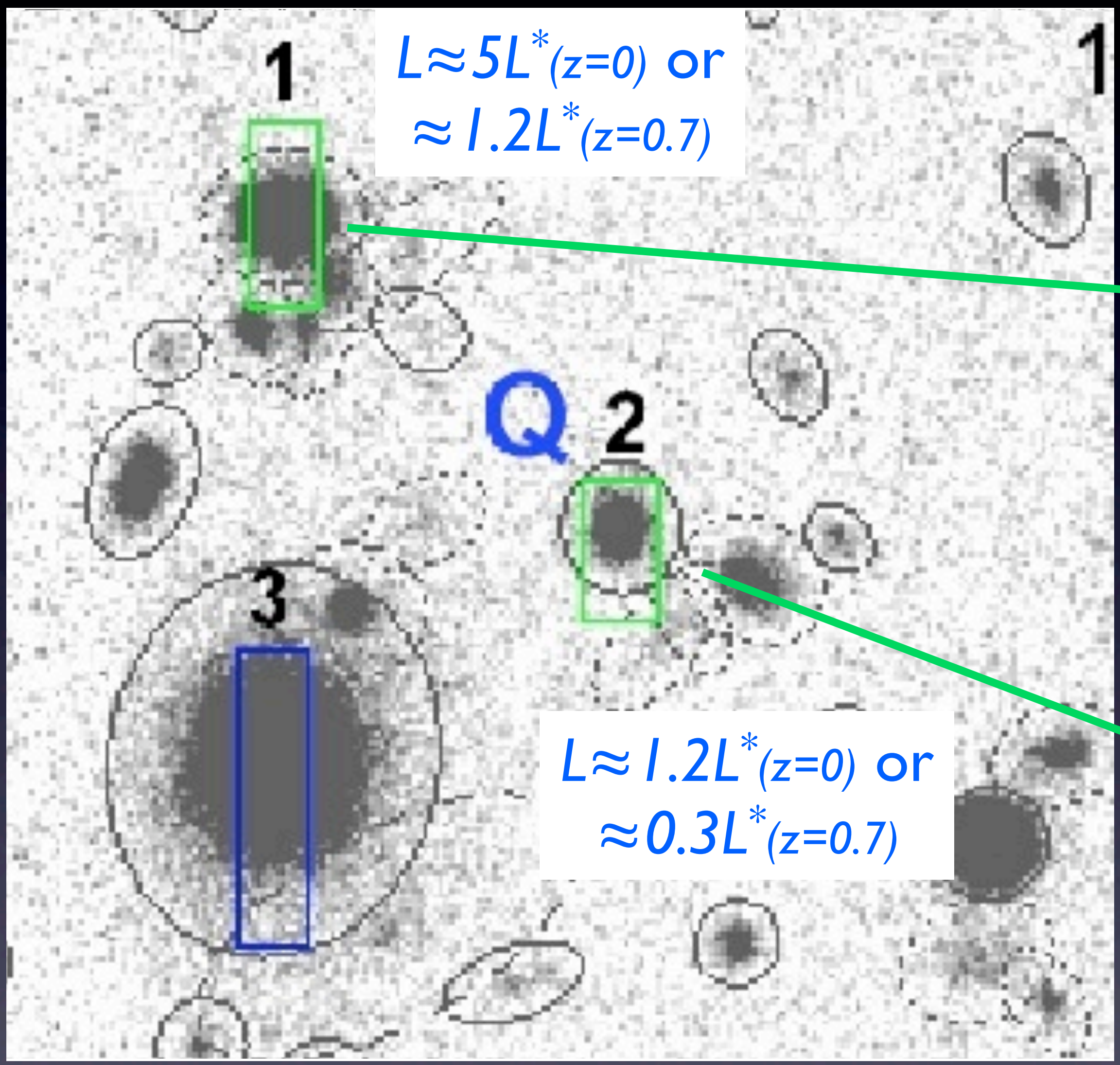

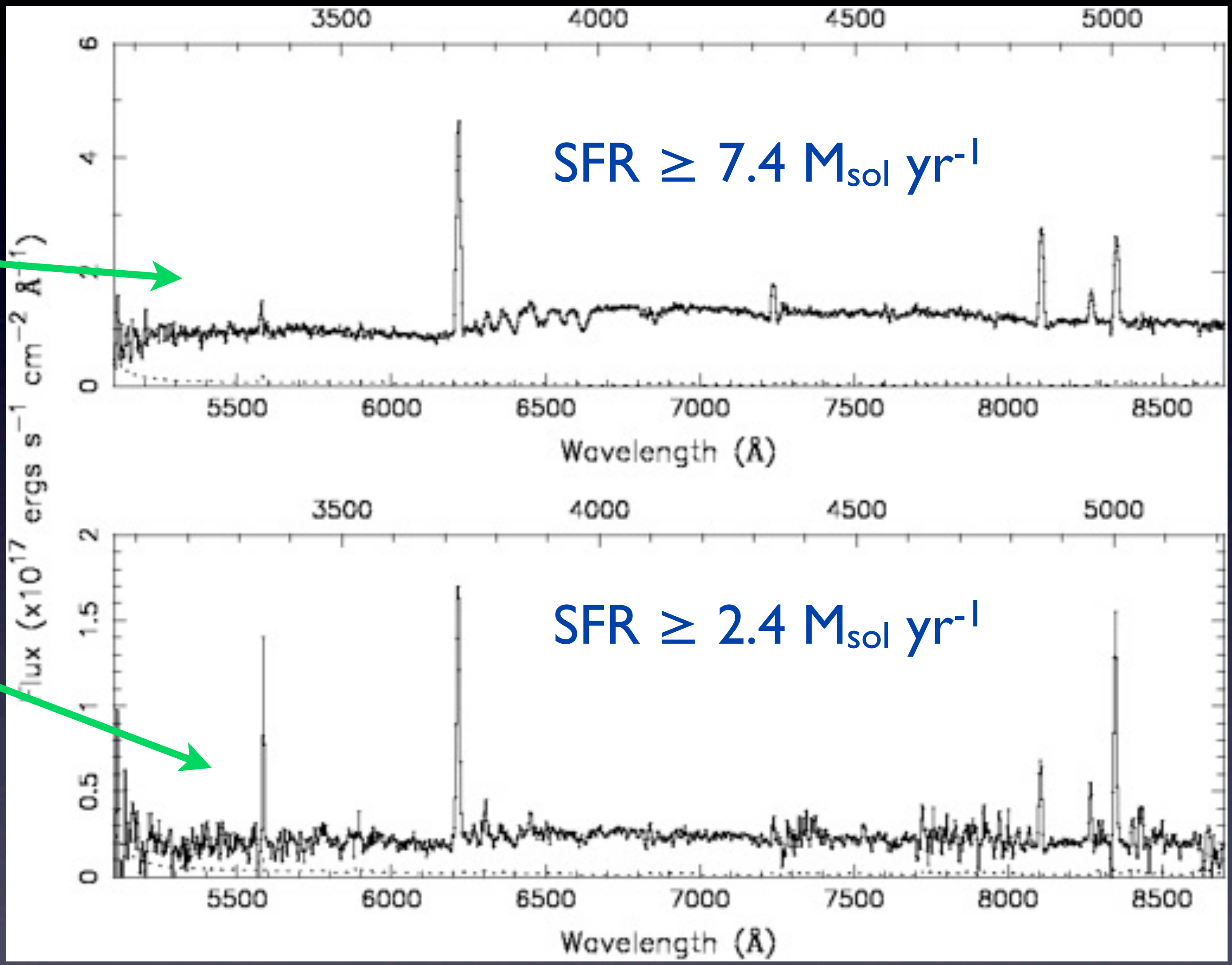

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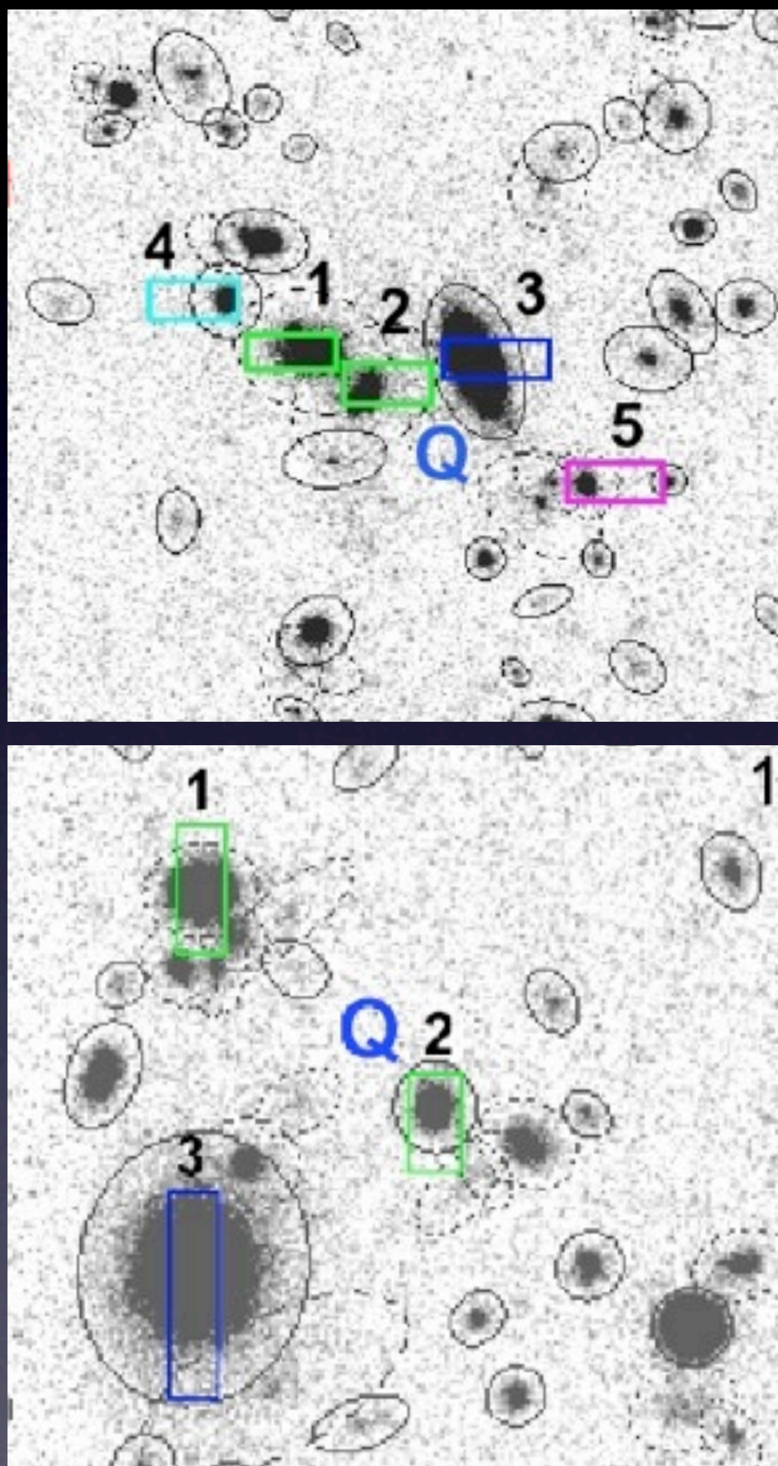
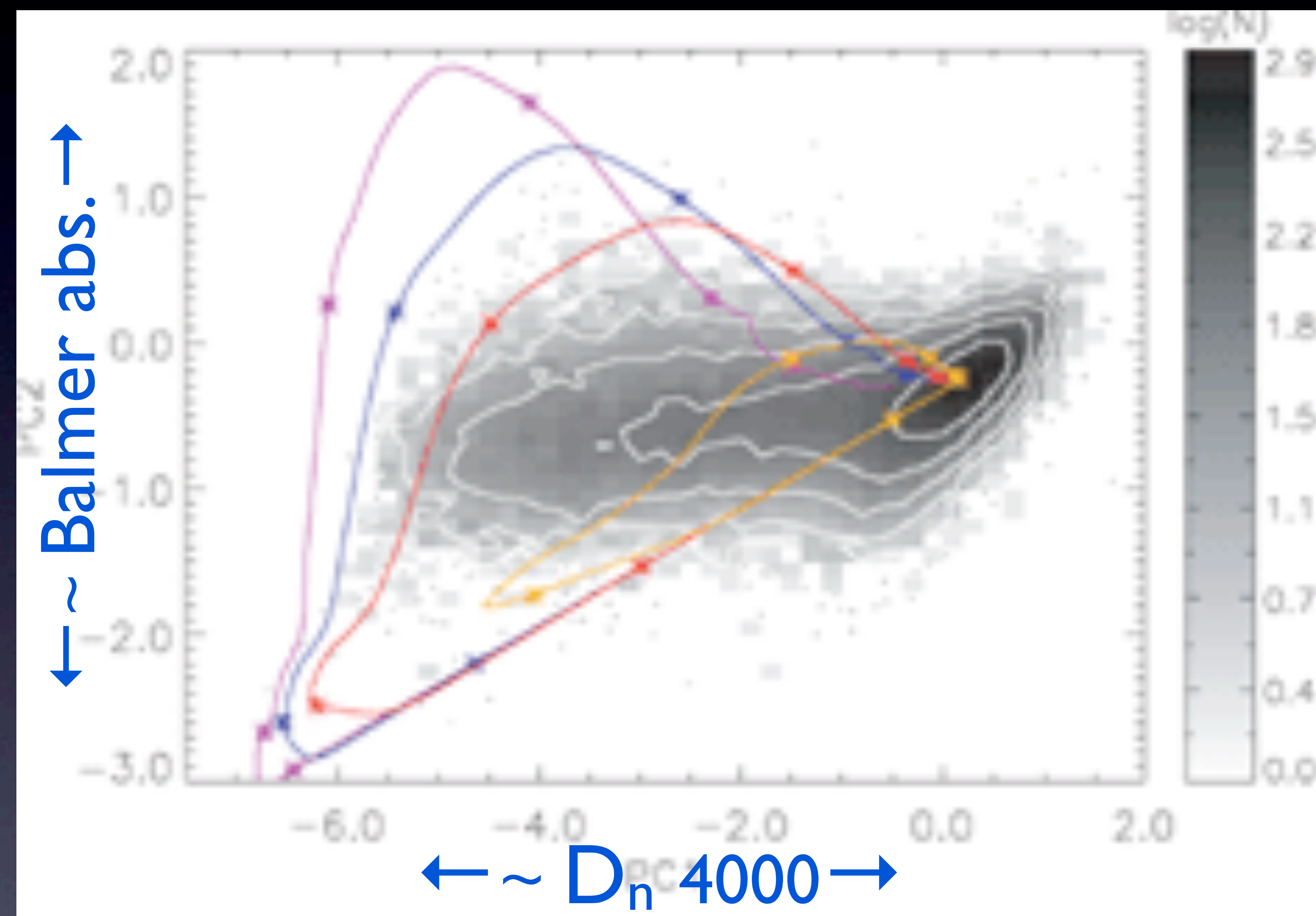
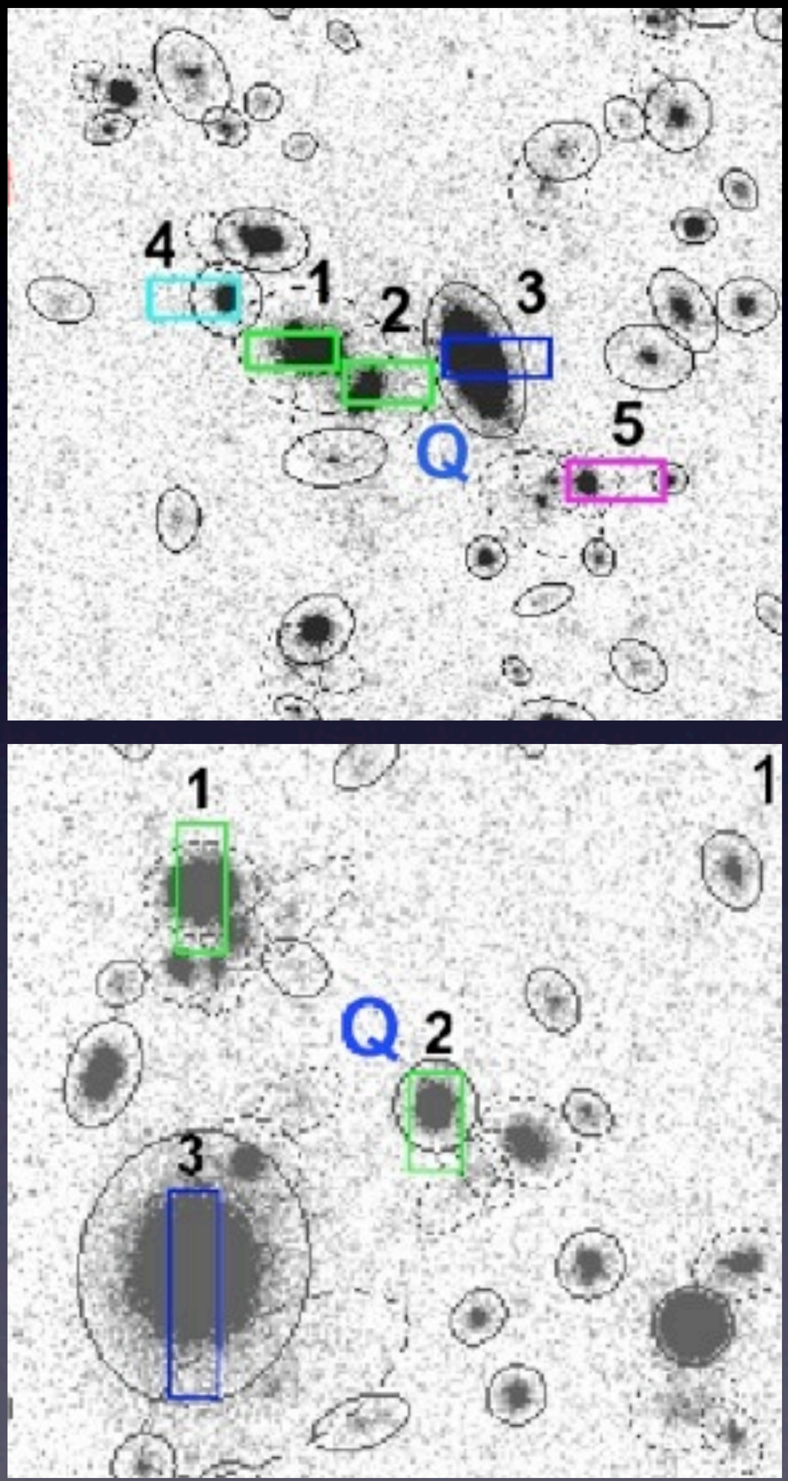
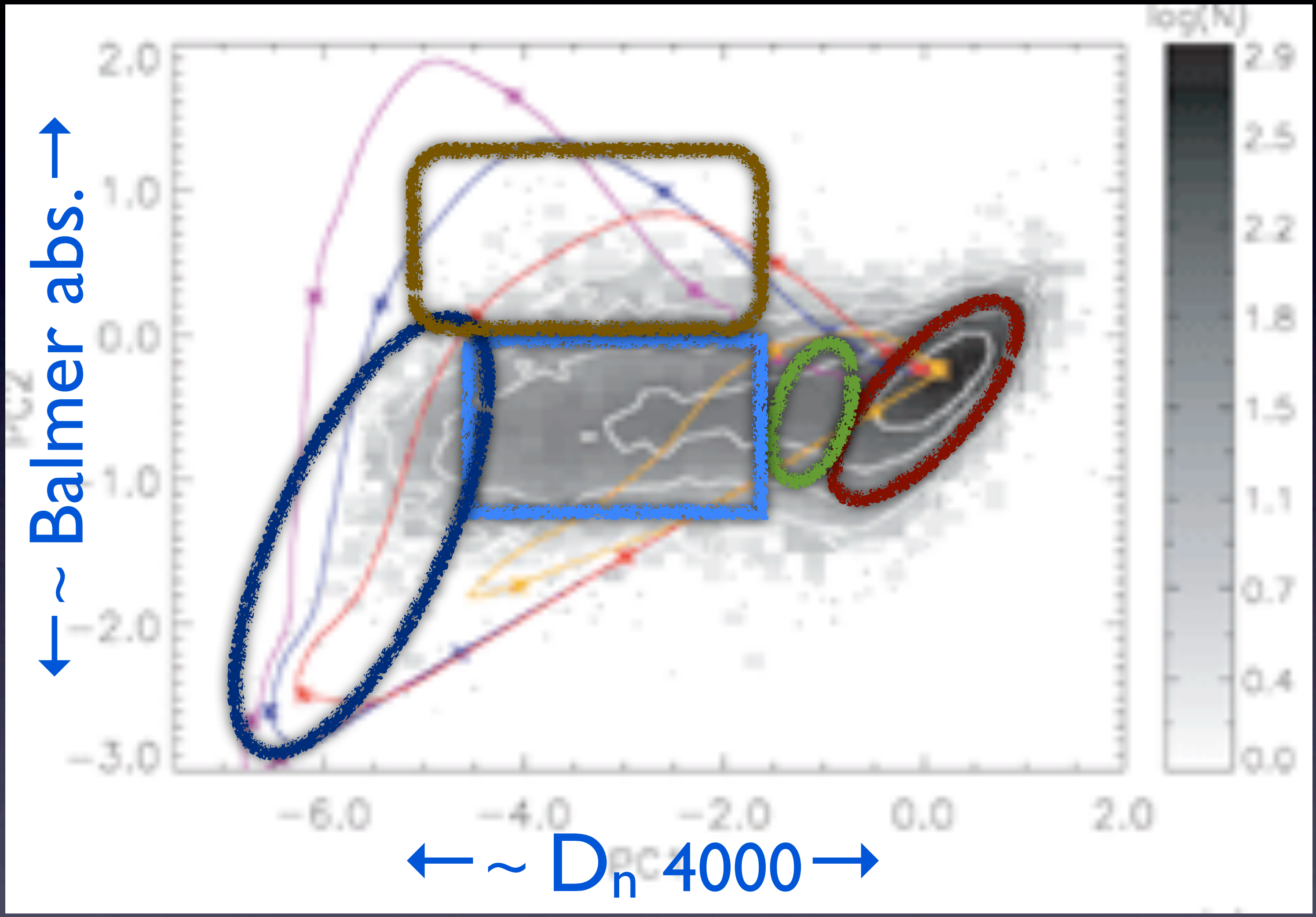




Wild et al., 2007

Ultra-strong MgII absorber – GW connection





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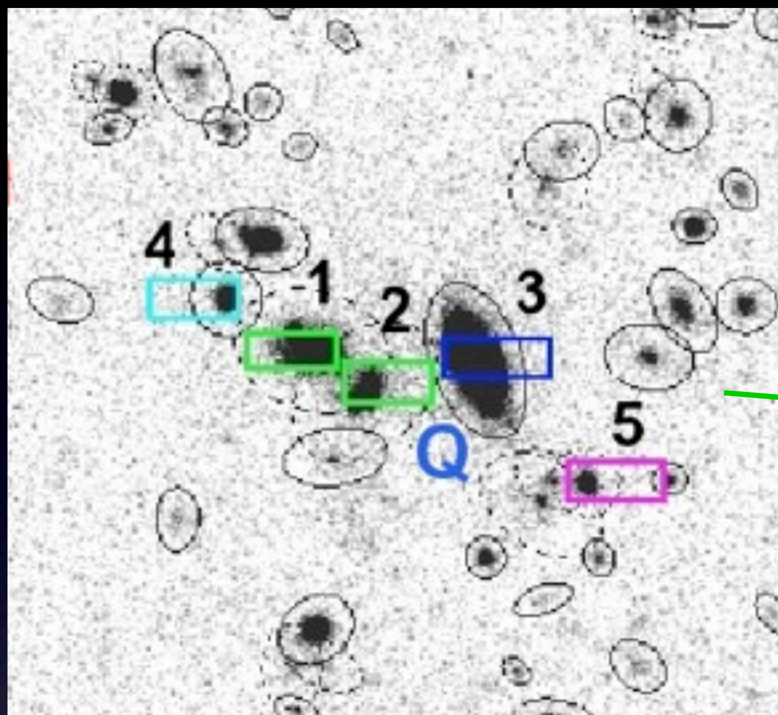
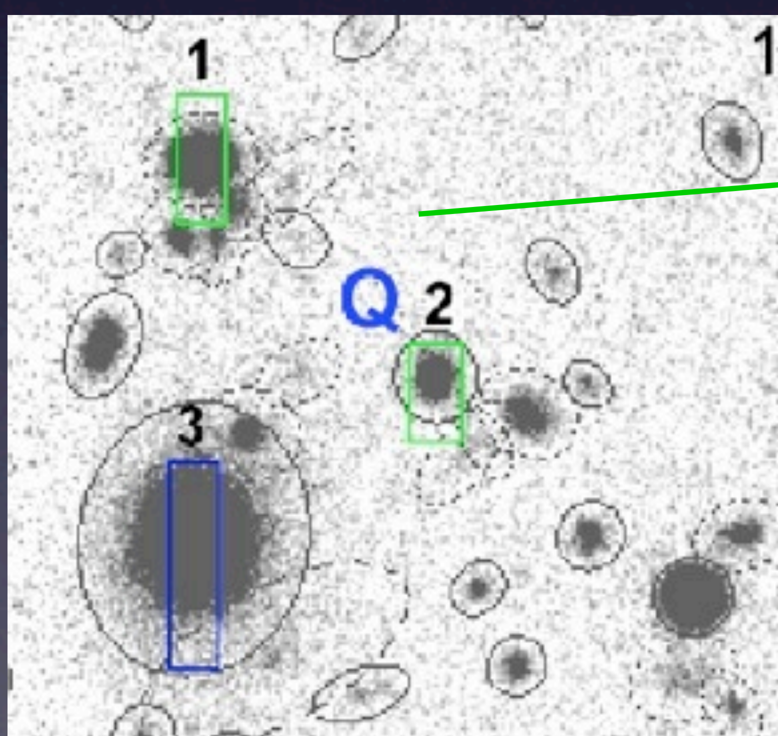
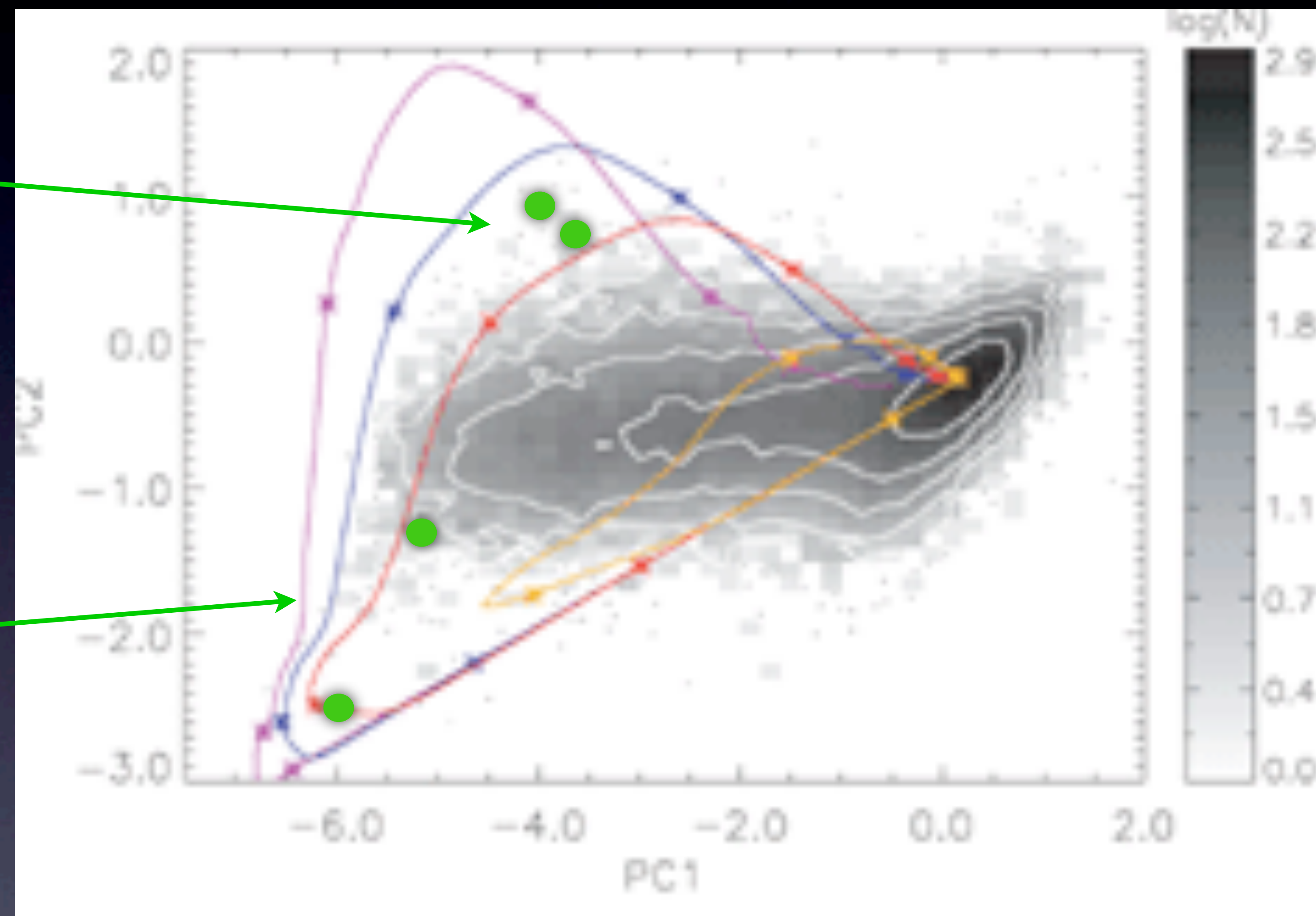




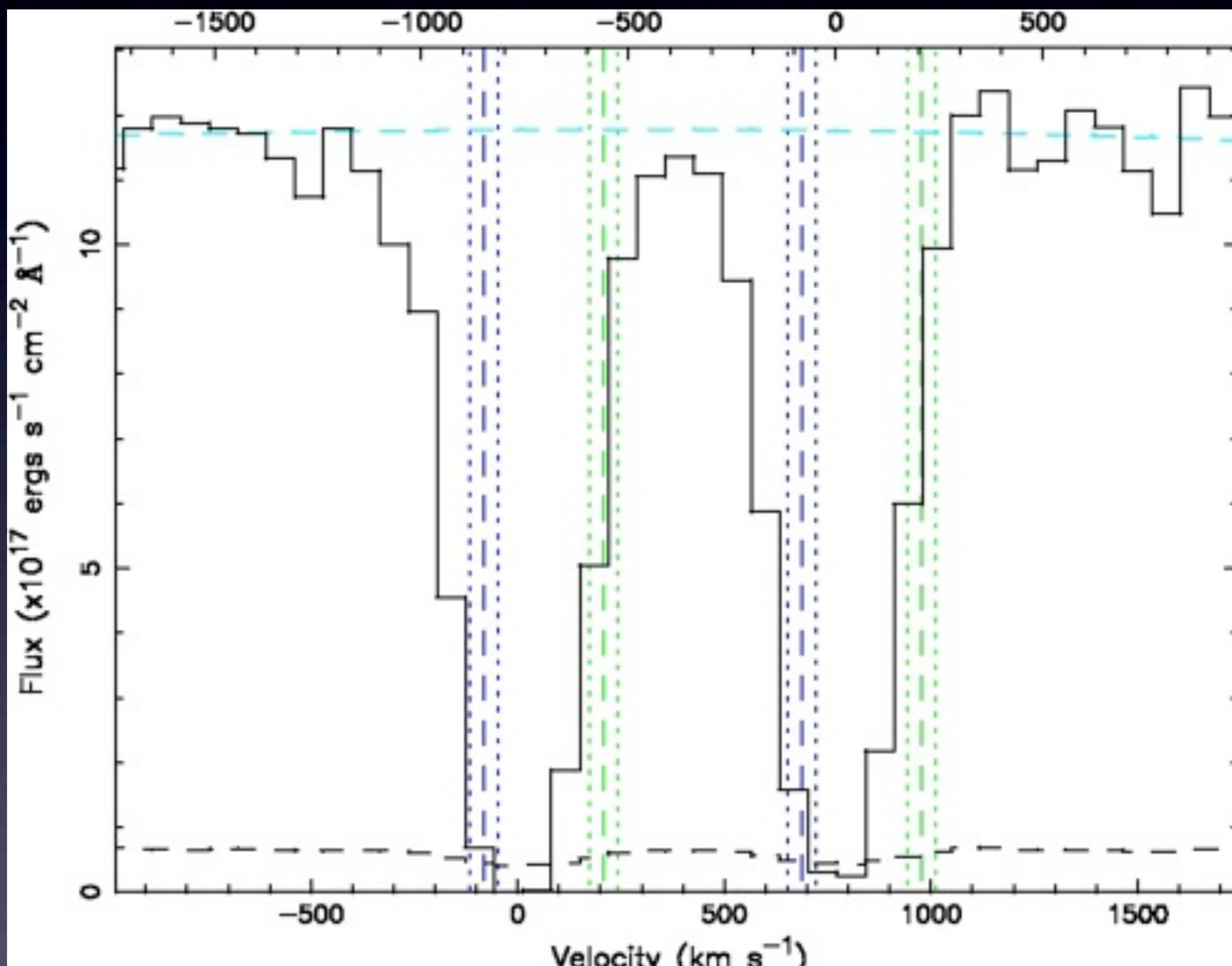


Wild et al., 2007

Ultra-strong MgII absorber – GW connection

Are the age, velocity numbers reasonable?

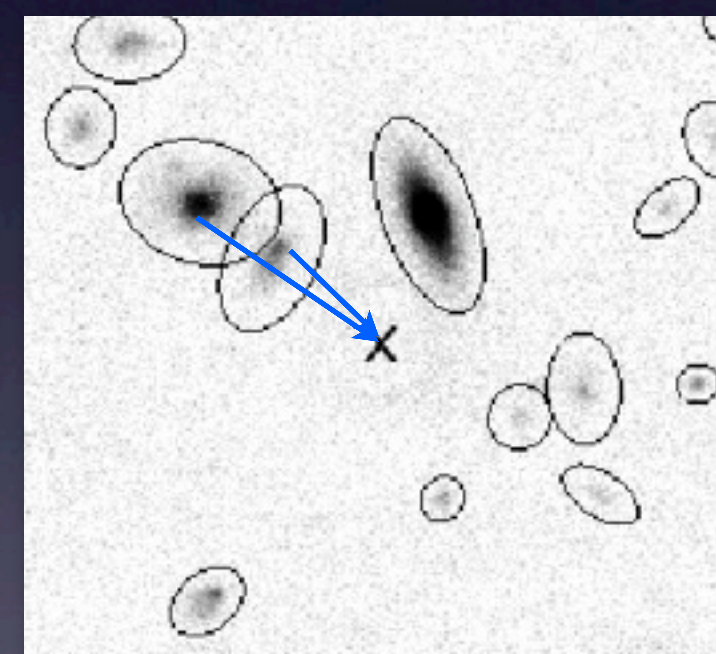
Post-starburst field: Δv ≈ 385 km/s



if T≈200 Myr

b = 38 kpc
v > 185 km/s

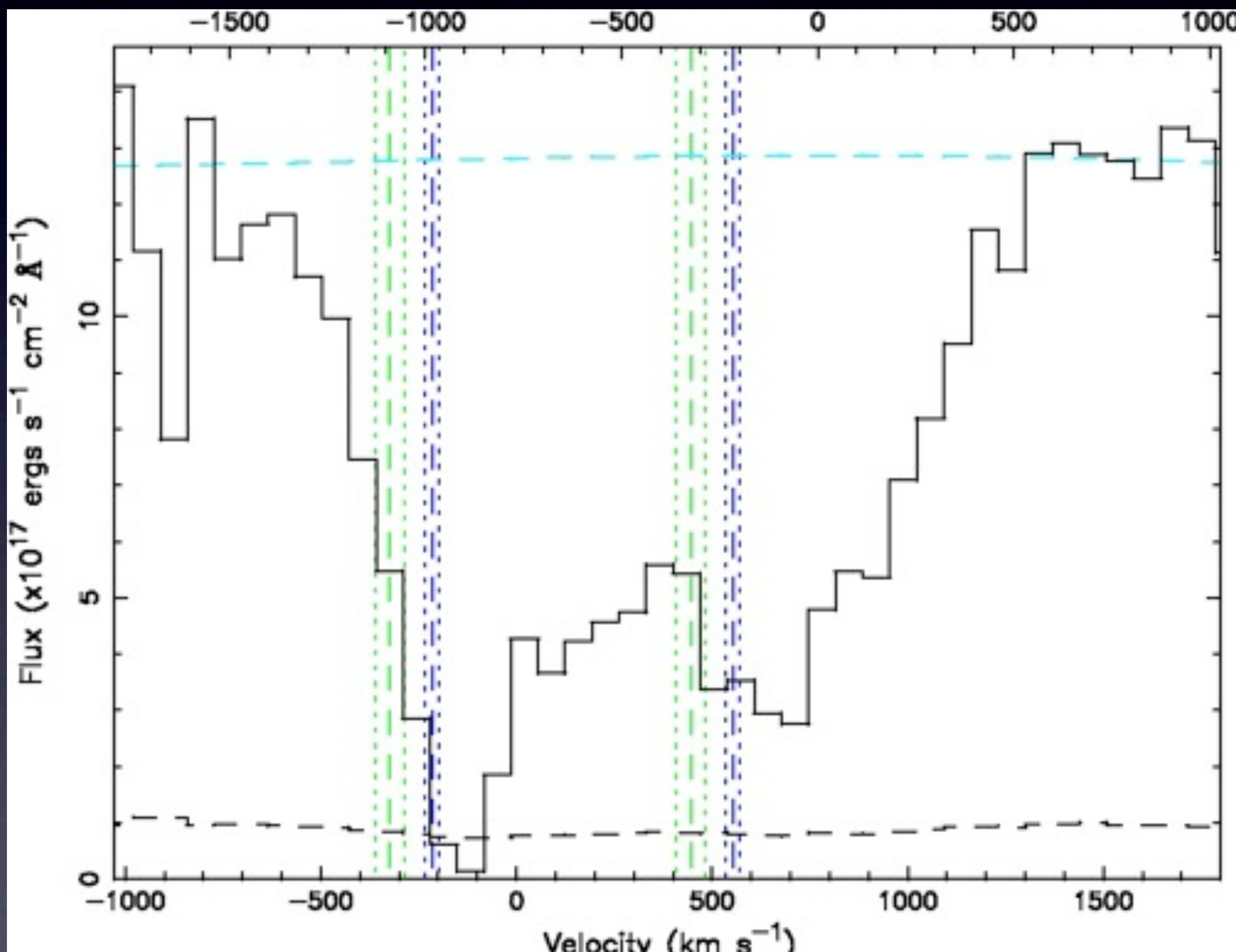
b = 63 kpc
v > 300 km/s



Ultra-strong MgII absorber – GW connection

Are the age, velocity numbers reasonable?

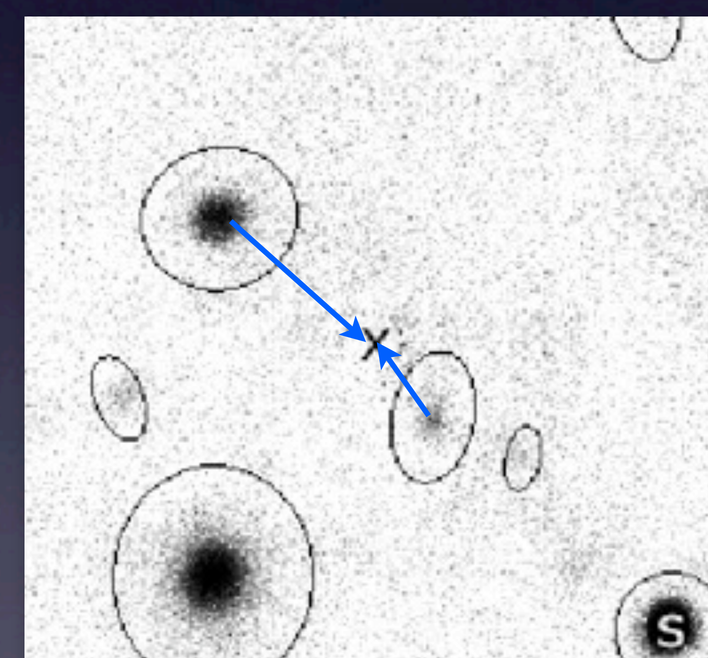
Starburst field: Δv ≈ 850 km/s



if T≈ 60 Myrs
b = 60 kpc

if T≈ 30 Myrs
b = 29 kpc

v ≈1000 km/s



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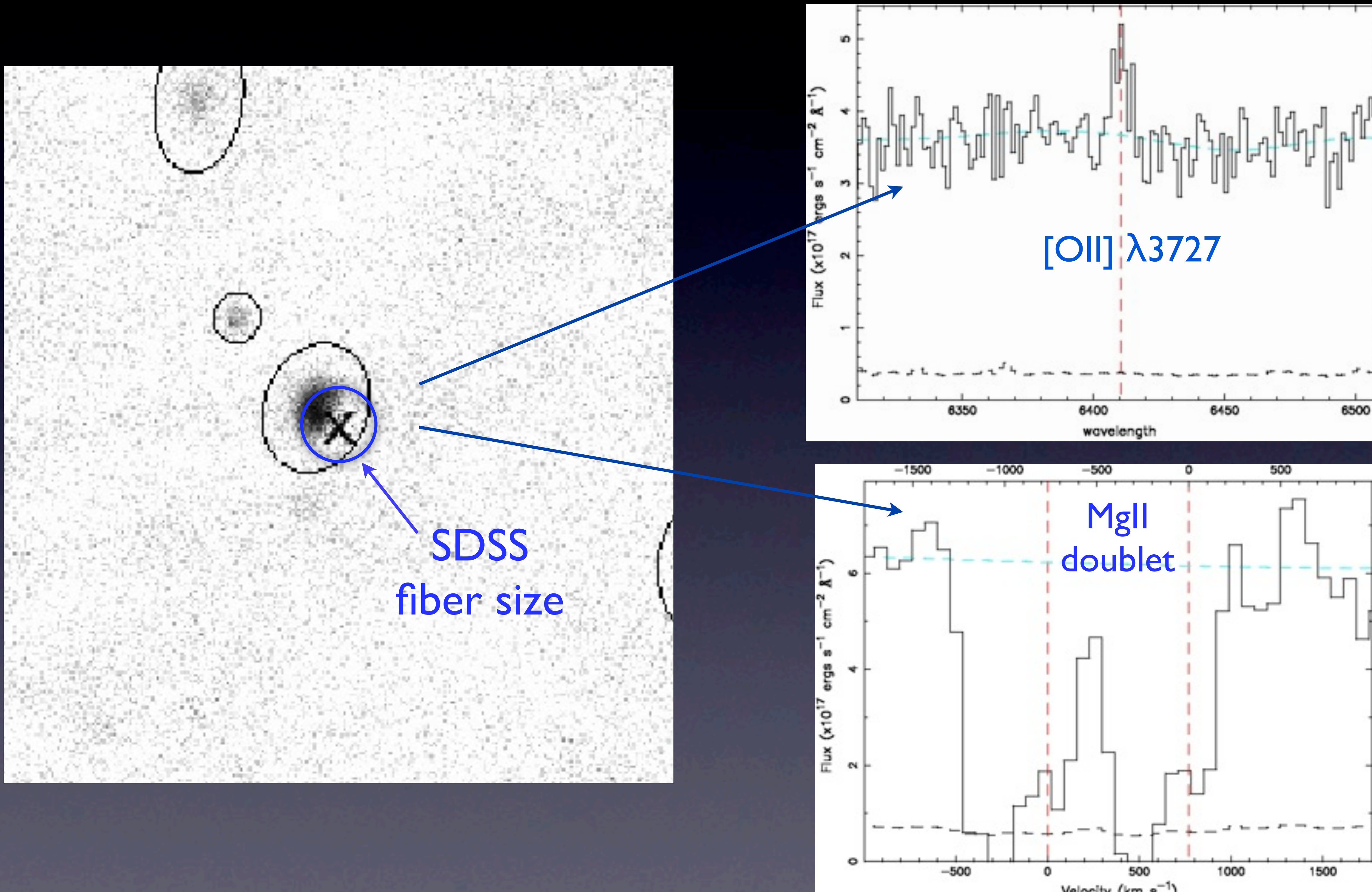
Another approach:
stacking spectra in abs. rest-frame



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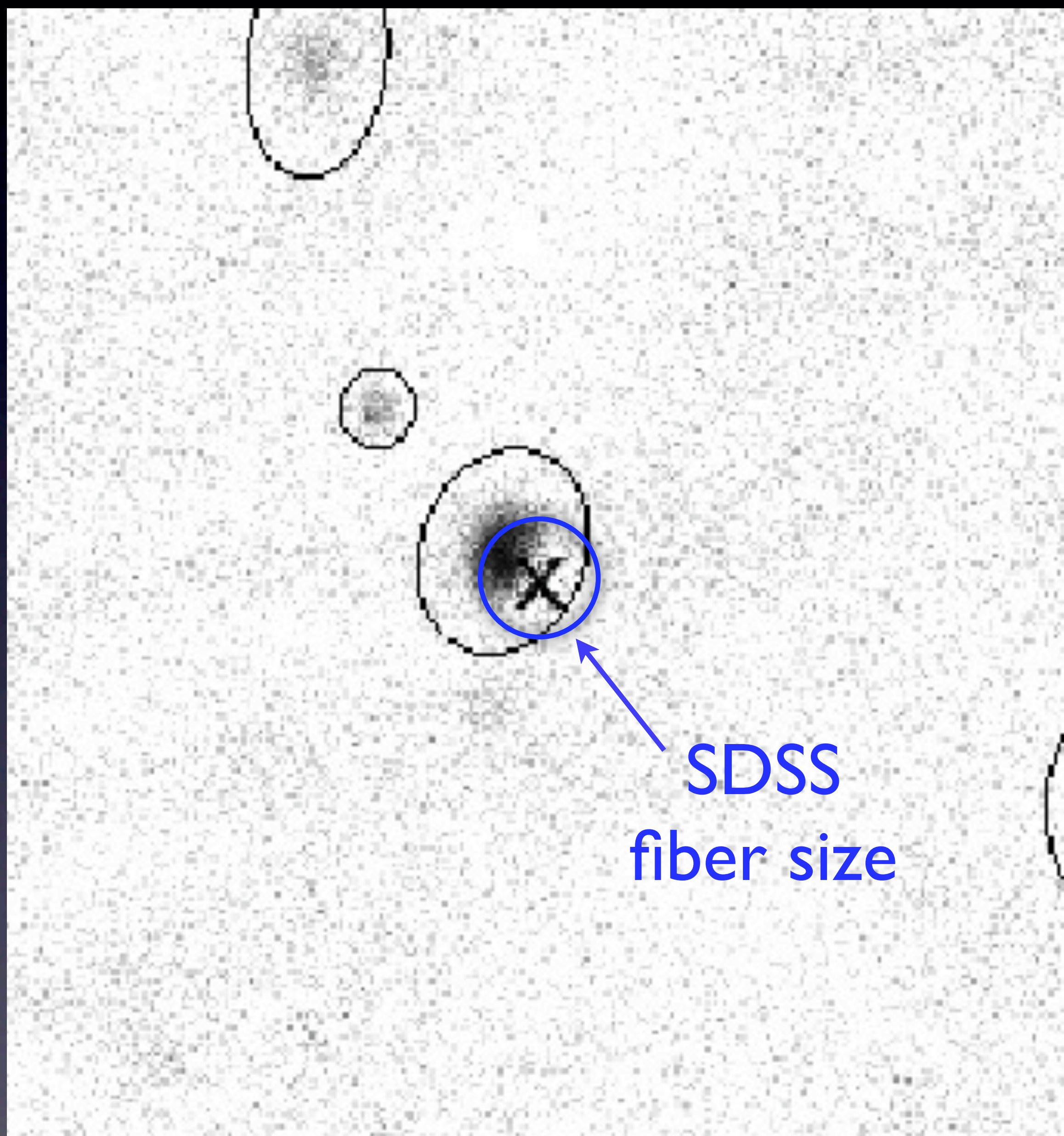

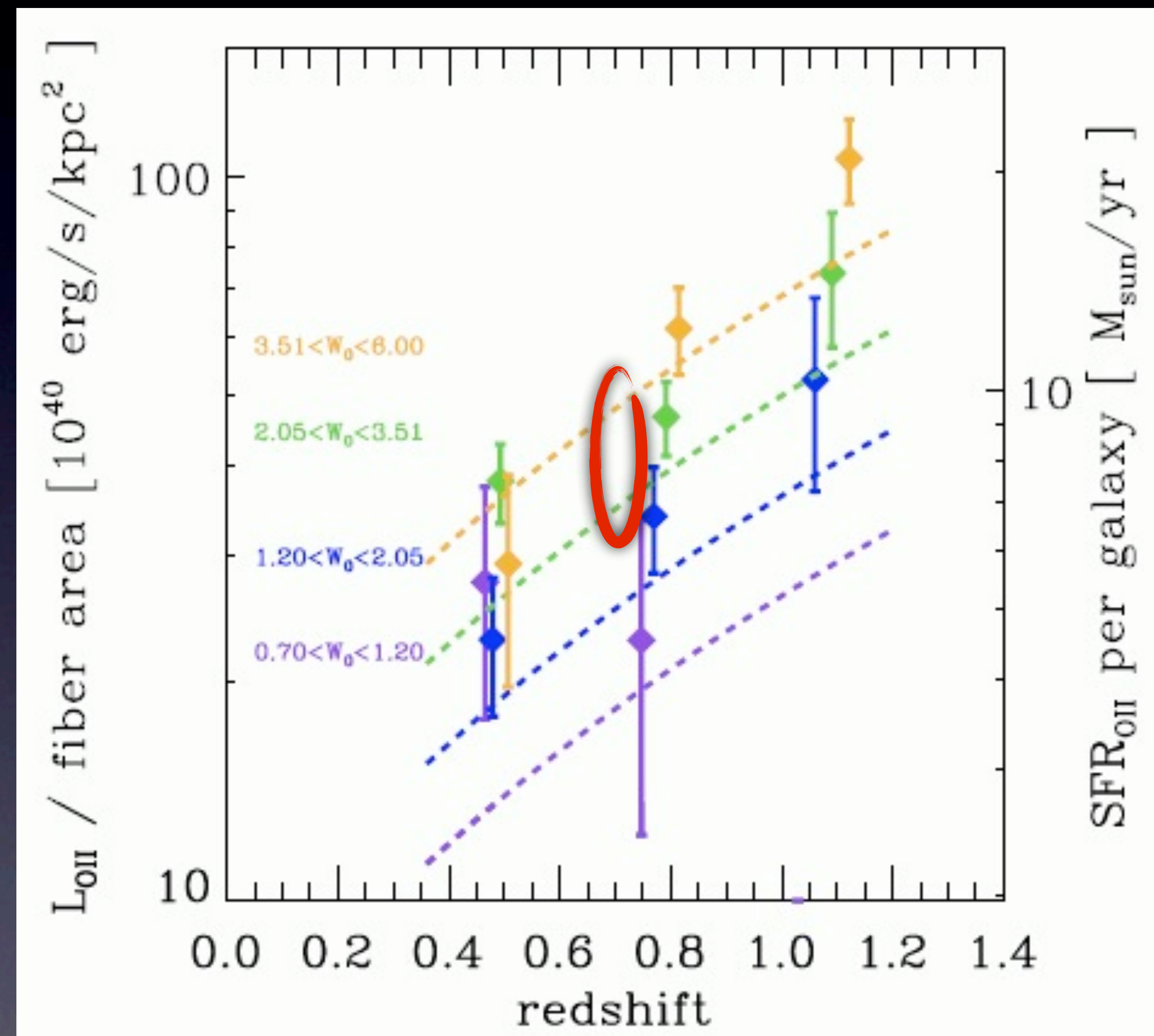

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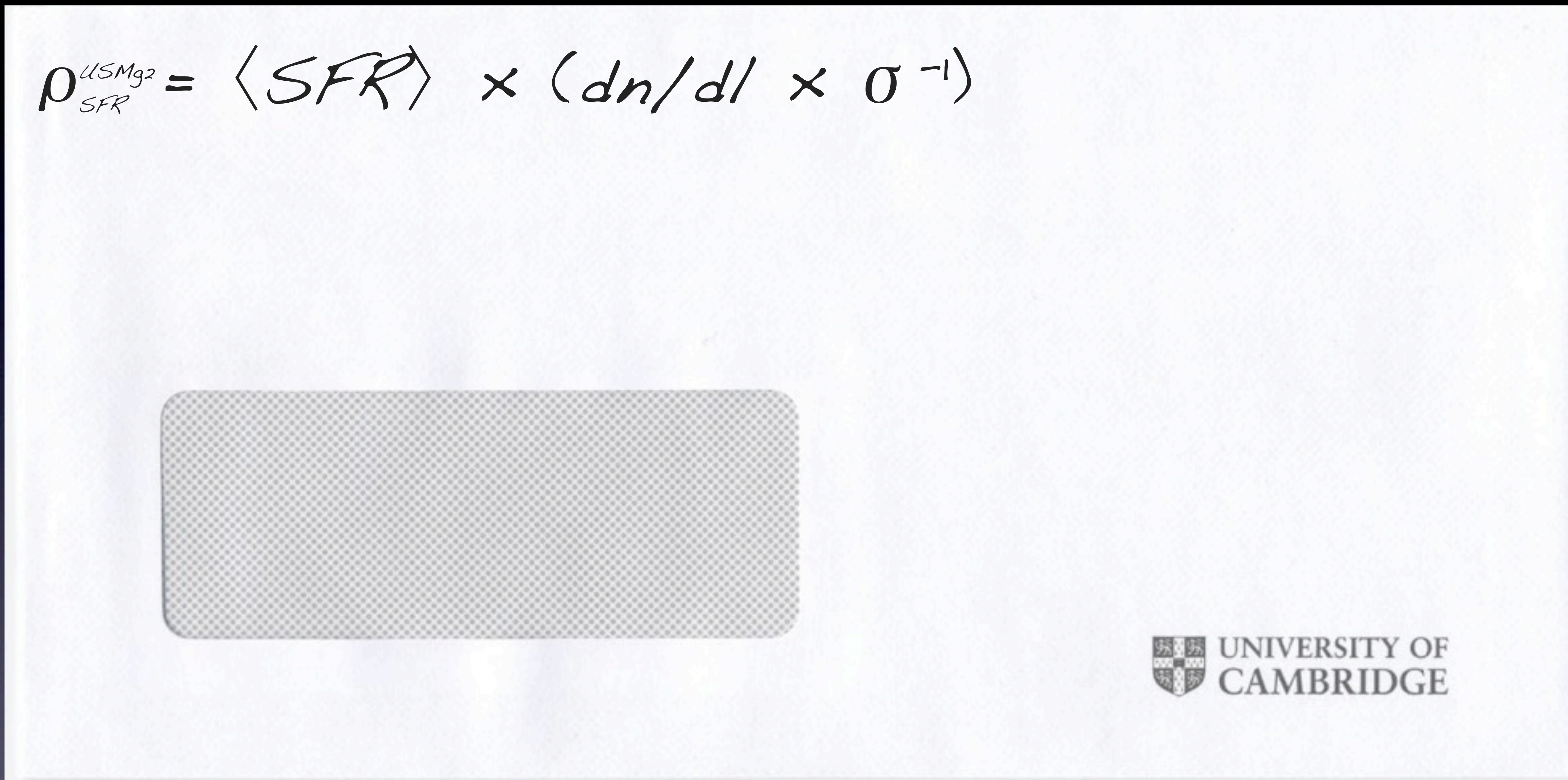

What fraction of the global SF density is traced by USMg2 absorbers?

$$\rho_{SFR}^{USMg2} = \langle SFR \rangle \times (dn/dl \times \sigma^{-1})$$

$$\log \langle SFR \rangle = 0.65 \pm 0.35$$

(i.e., 2 to 10 M_{sol}/yr)

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(i.e., 400 to 1,000 kpc^2)

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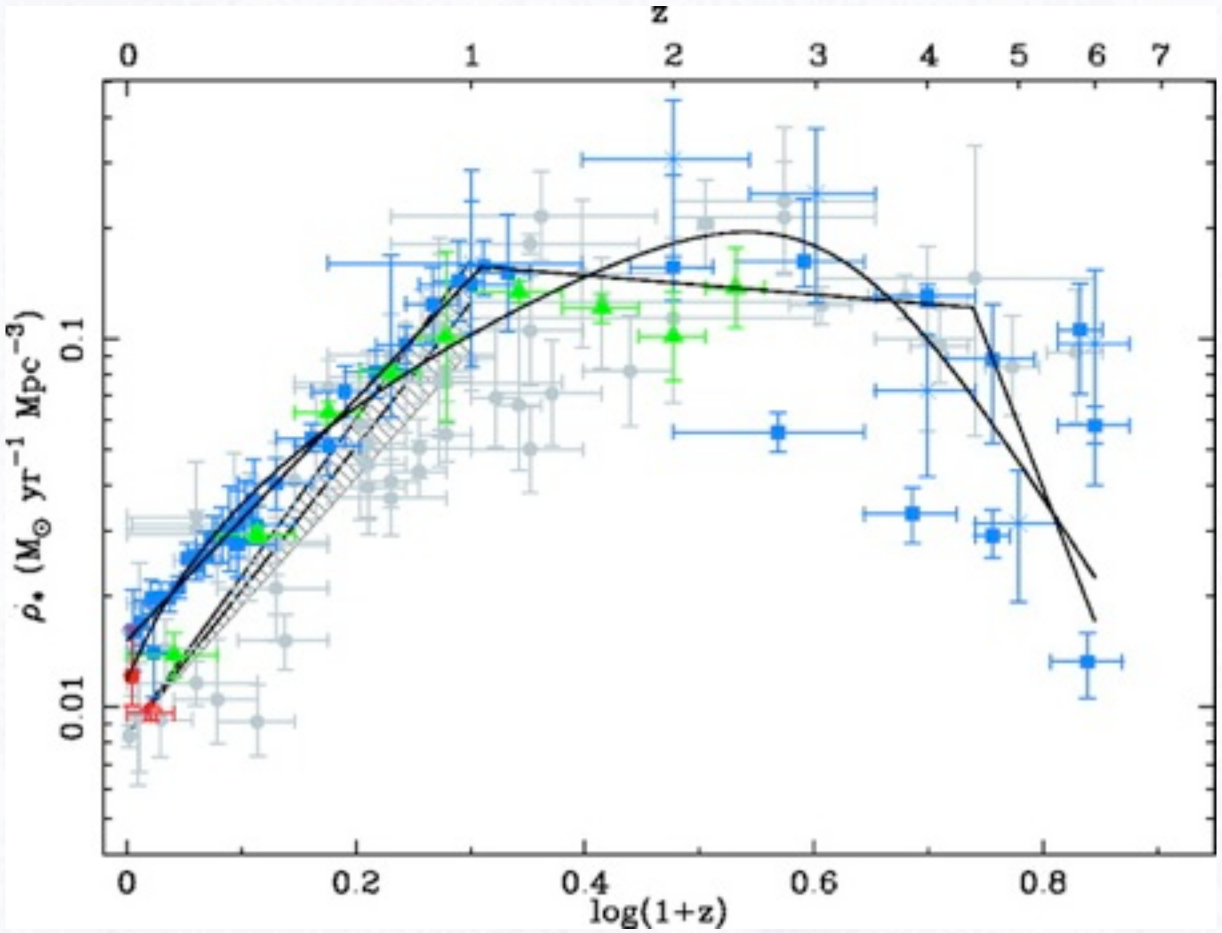

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(i.e., 2 to 10 M_{sol}/yr)

$$\log \langle dn/dl \rangle = -5.0 \pm 0.08$$

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(i.e., 400 to 1,000 kpc^2)

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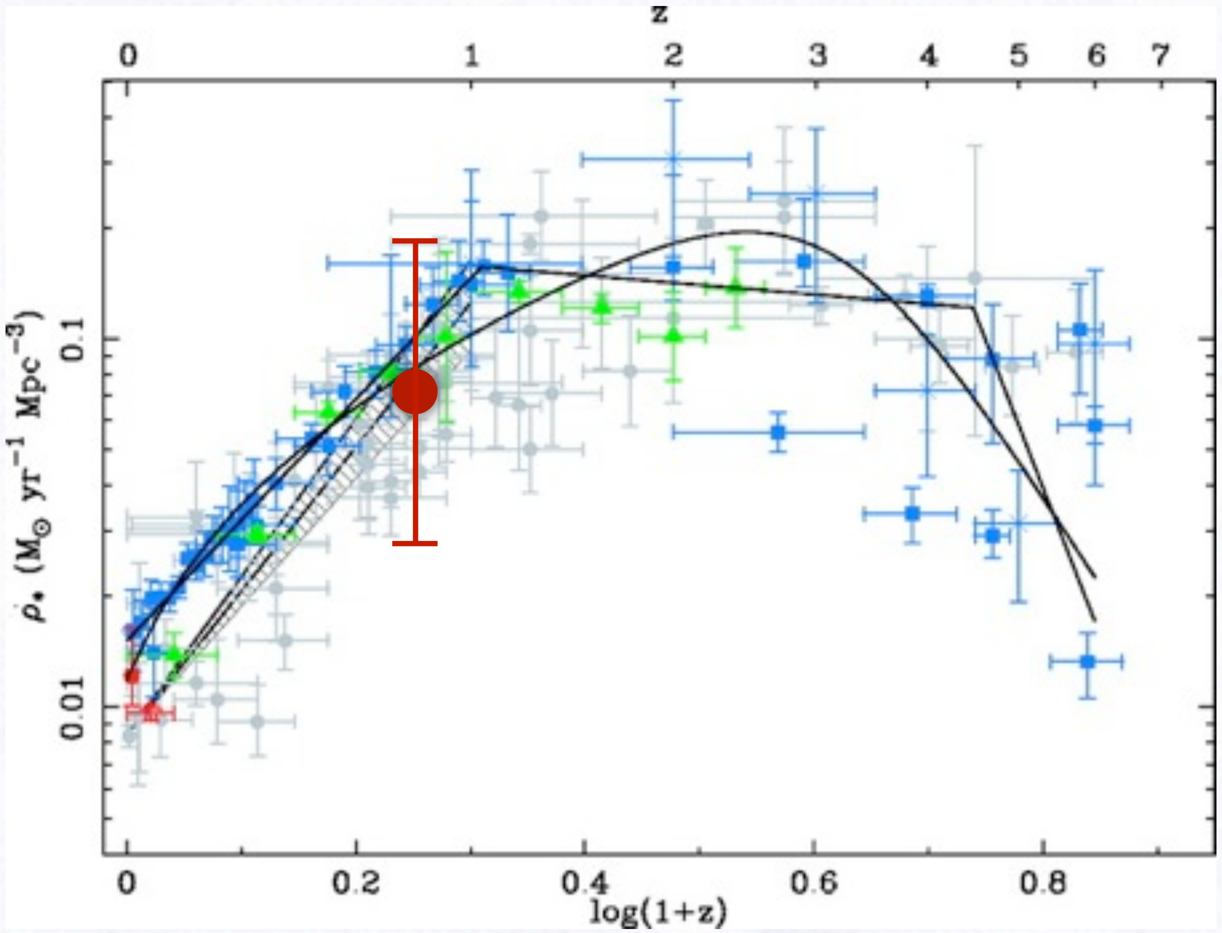

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Conclusions

Quasar absorption lines

are potentially-powerful probes of galaxies that are:

- effective over large span of redshift
- completely independent of galaxy luminosity

Galactic winds

are important for understanding:

- mass-metallicity relation
- IGM enrichment
- galaxy luminosity function
- size of disks, etc.

The strongest MgII absorbers likely select starburst-driven galactic winds, while weaker systems trace the patchily-enriched halos at later epochs.

The total star formation density selected by ultra-strong MgII absorbers seems to be a significant fraction of the total at $z \sim 0.7$.

This implies that the *bulk of the star formation* at this redshift occurs with Σ_{SF} high enough to cause large-scale outflows.