Star Formation in Neutral Gas at High Redshifts

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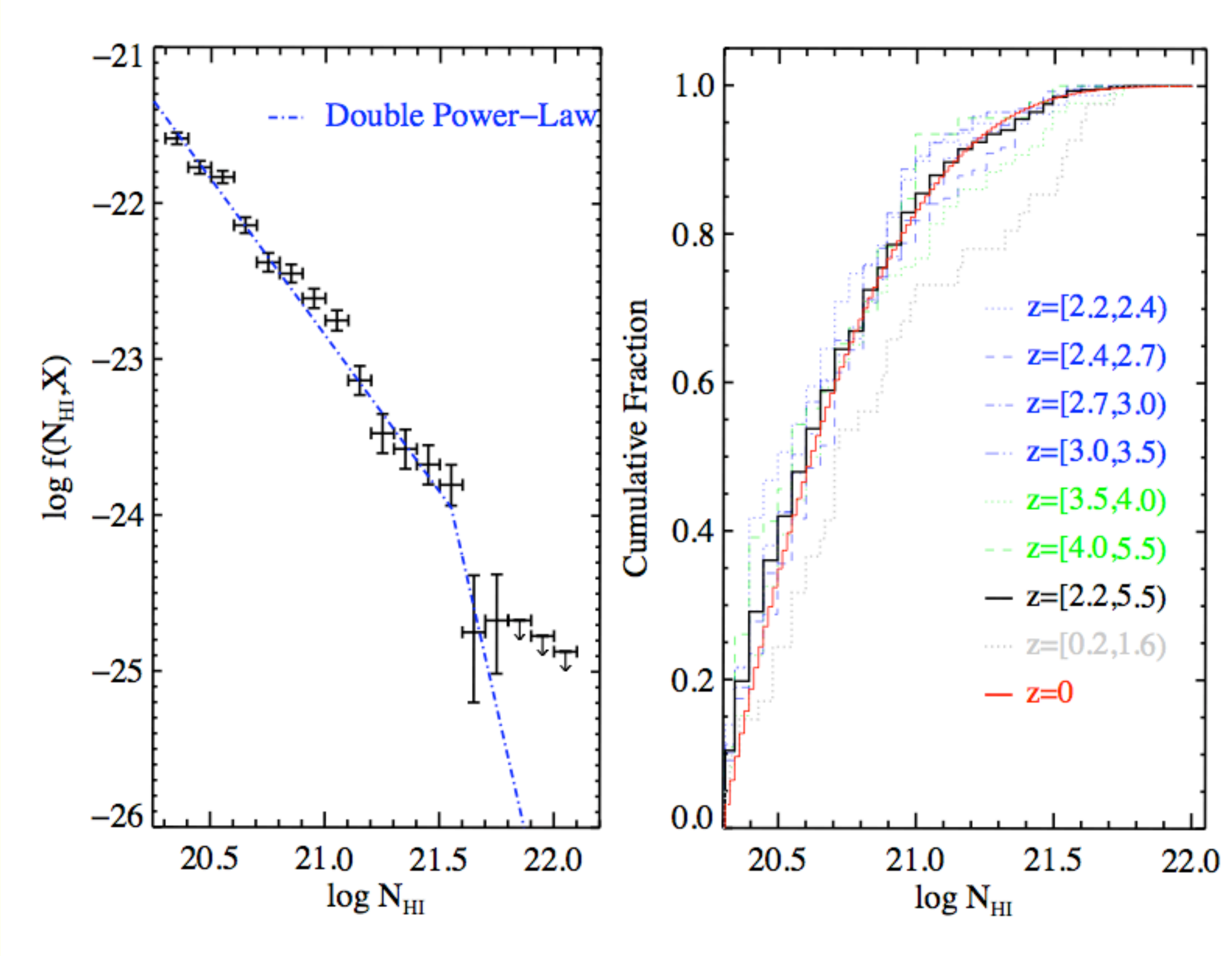
H I Column-Density Distribution Function



Byproducts of f(N,X)

- Covering factor C_A

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- DLAs: z=[2.5,3.5]

$$C_A = 0.33 \text{ for } N_{HI} \geq 2 \times 10^{20} \text{cm}^{-2}$$

- Lyman Break Galaxies (LBGs): z=[2.5,3.5]

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Does Kennicutt-Schmidt law in DLAs light up 1/3 of the sky with *in situ* star formation ?

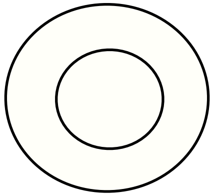
Byproducts of f(N,X)

- SFR per unit comoving volume

Predicted Comoving SFR Density

Comoving SFR Density

$$\dot{\rho}_* = \int dA \dot{\psi}_* n_{co}$$



Product of n_{co} and dA is given by

$$n_{co} dA = (H_0/c) f(N, X) dN$$

where Column-Density Distribution function, $f(N, X)$ is:

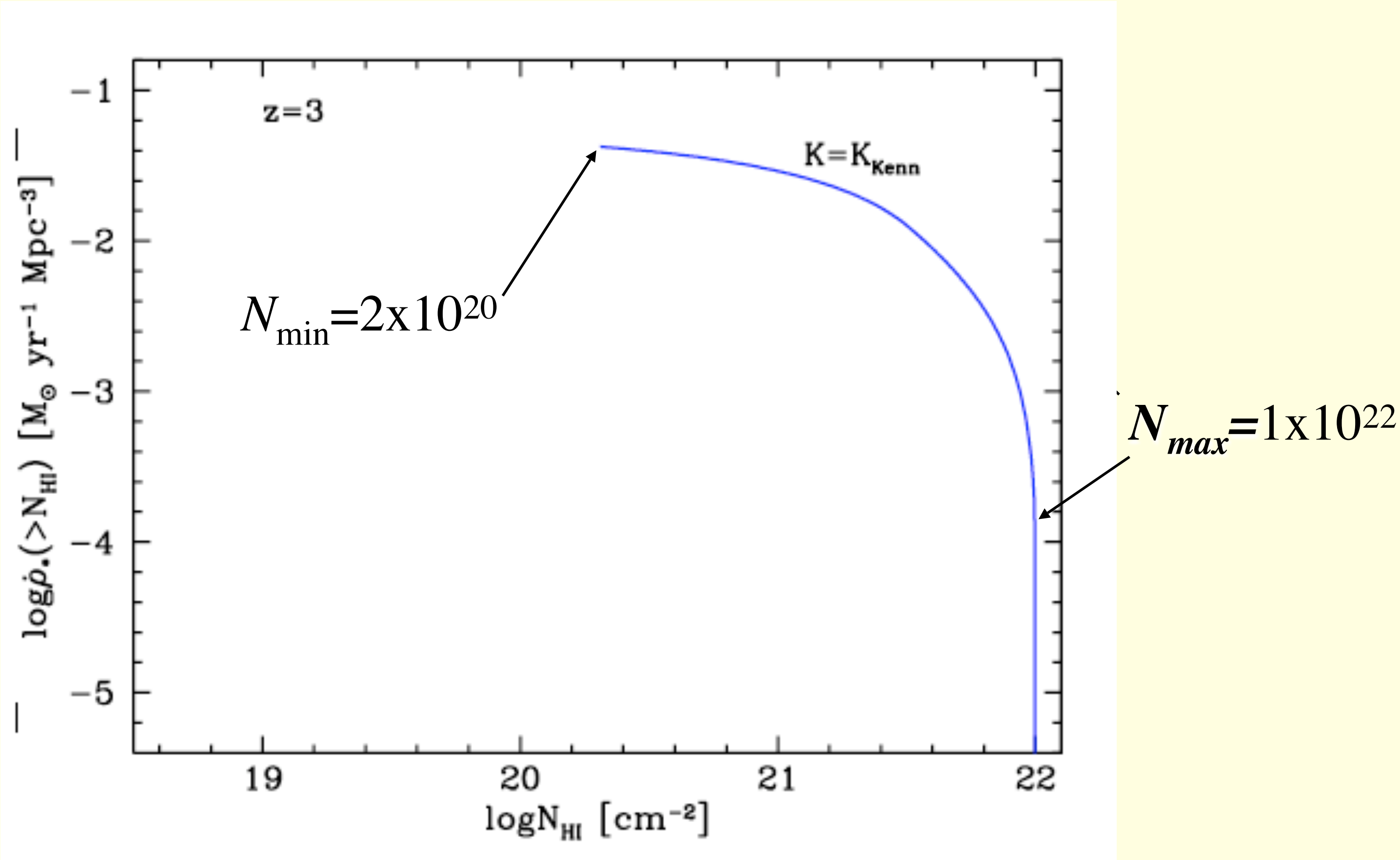
$$d^2\mathcal{N} = f(N, X) dN dX$$

Therefore

$$\dot{\rho}_* = (H_0/c) \int dN f(N, X) \dot{\psi}_*(N)$$

Cumulative Comoving SFR Density Predicted by the Kennicutt-Schmidt Relation for z~3

$$\dot{\rho}_*(> N) = (H_0/c) \int_N^{N_{max}} dN' f(N', X) \dot{\psi}_*(N')$$



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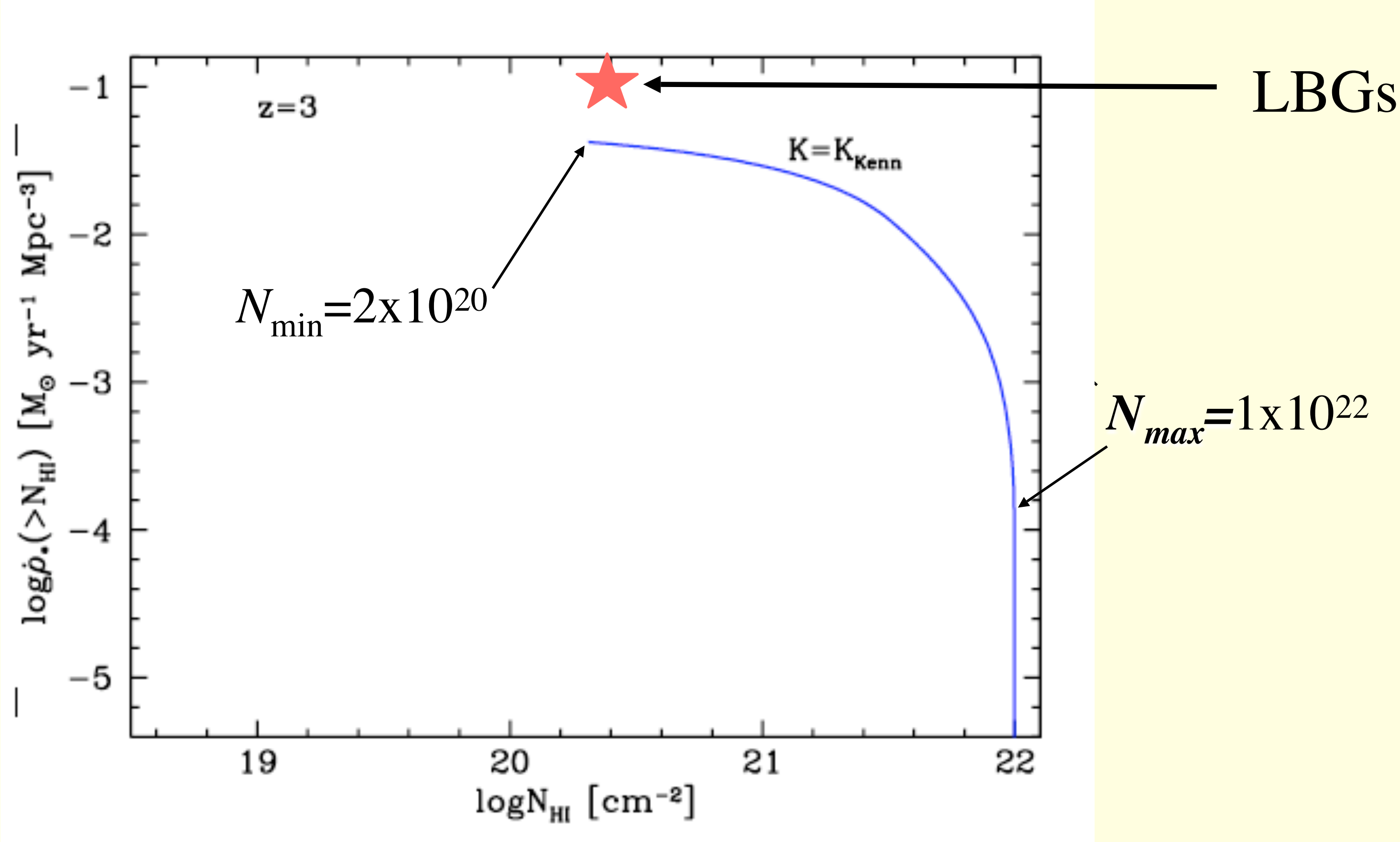


Measurement of SFR density due to DLAs (Wolfe & Chen '06)

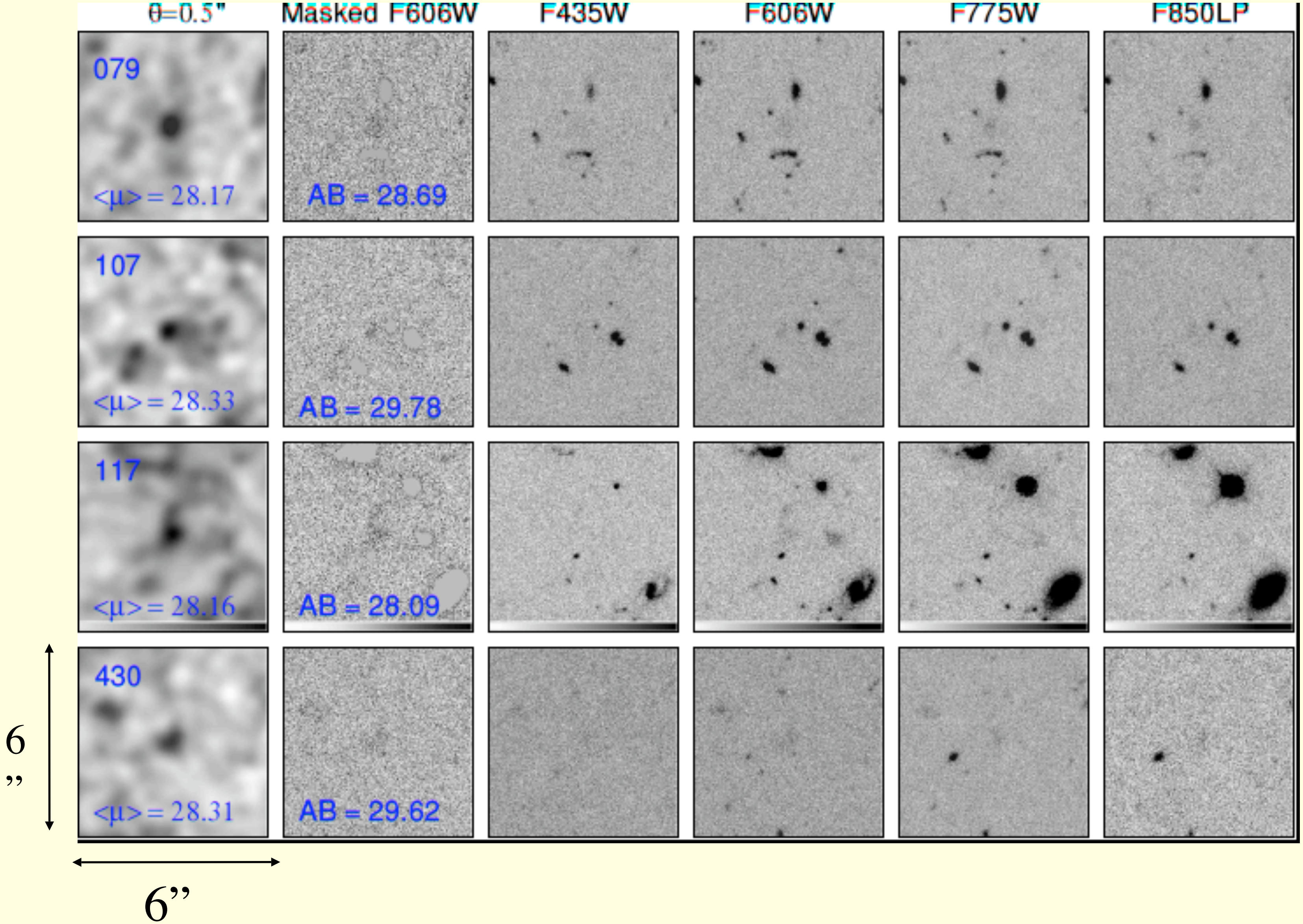
- Search Hubble Ultra Deep Field (UDF) for low surface-brightness galaxies:

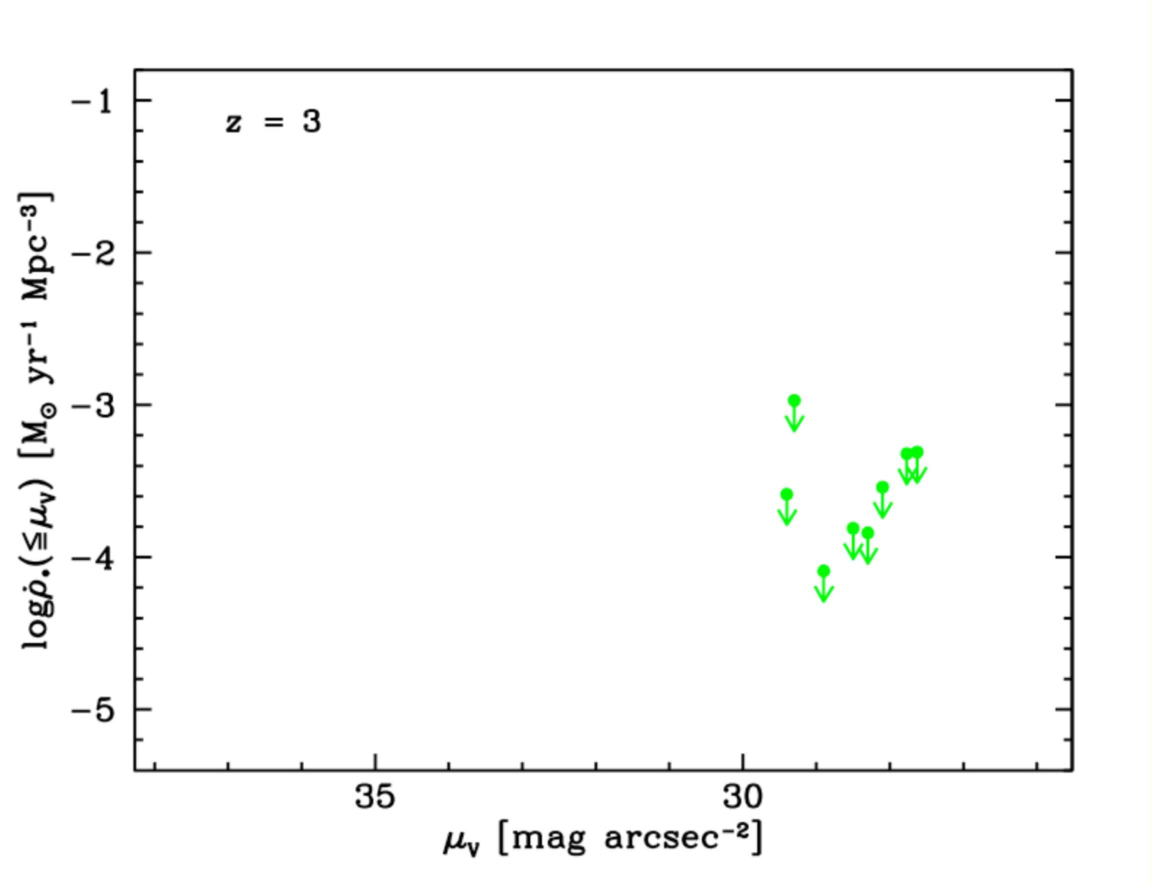
    -- $26 < \mu_V < 30$ mag arcsec^{-2}

    -- at z=[2.5,3.5]

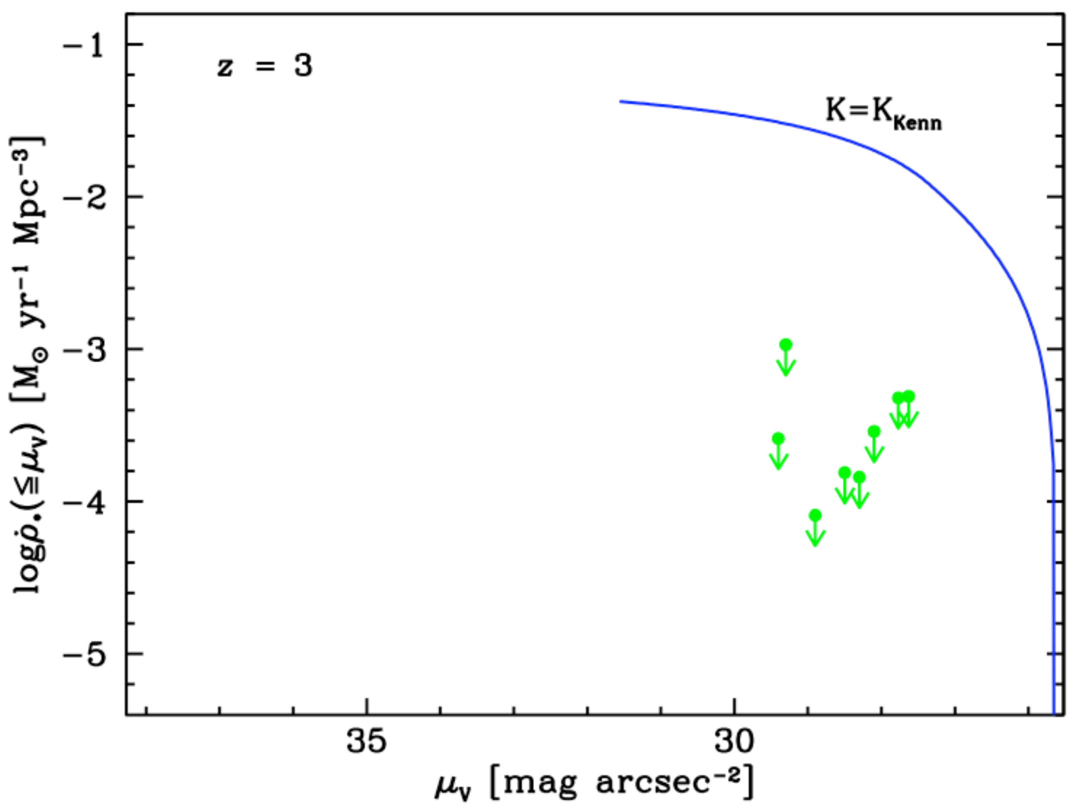
Survey for DLA Emission in the UDF (Wolfe & Chen '06):

Results for θ_{kern} =0.5 arcsec



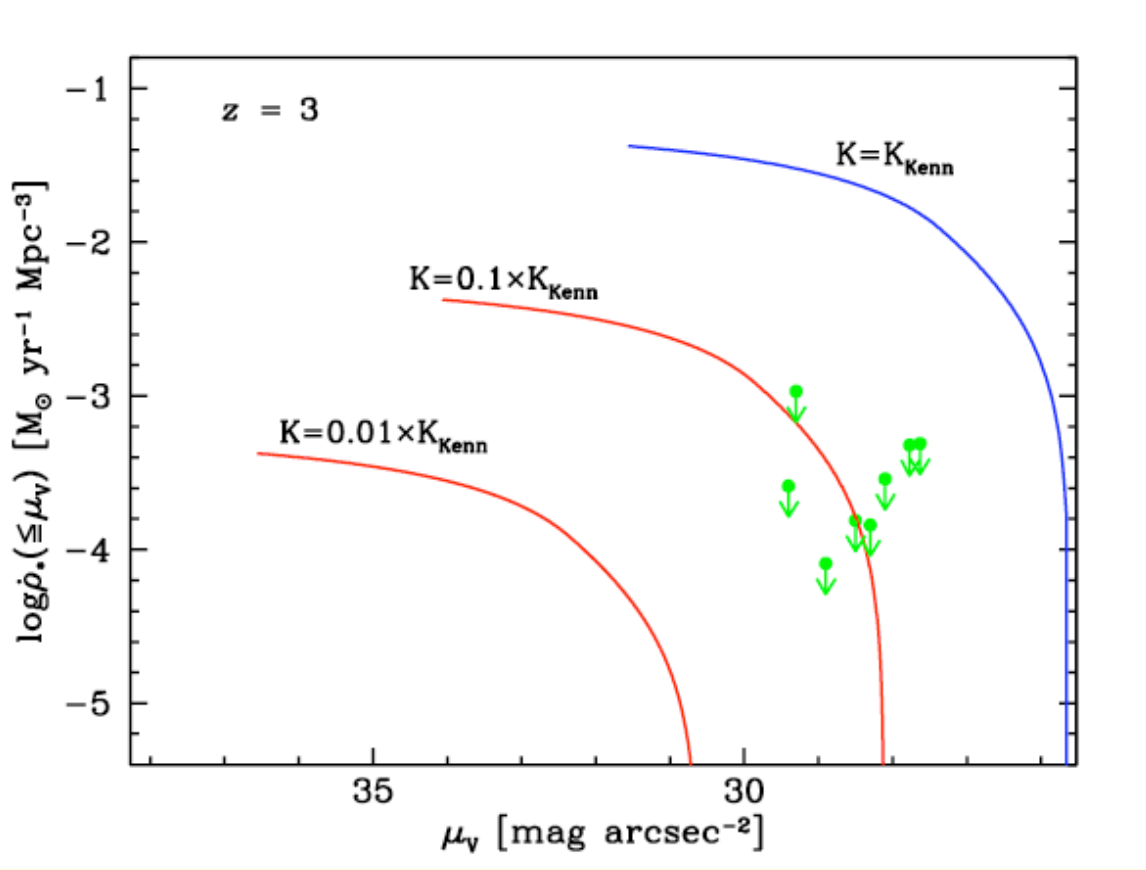


z = 3
−1
−2
−3
−4
−5
35
30
log$\dot{\rho}_*$($\leq\mu_V$) [$M_\odot$ yr^{-1} Mpc^{-3}]
μ_V [mag arcsec^{-2}]



z = 3
K=K_Kenn
−1
−2
−3
−4
−5
35
30
log ρ̇*(≤μ_V) [M_⊙ yr^−1 Mpc^−3]
μ_V [mag arcsec^−2]

Lower SFR Efficiencies: Effect of Decreasing Normalization K



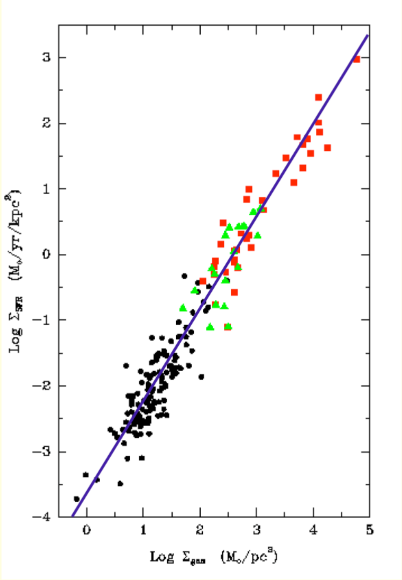
Byproducts of $f(N,X)$

- Evolution of $f(N,X)$

Evolution of f(N,X) predicted by Kennicutt-Schmidt Law

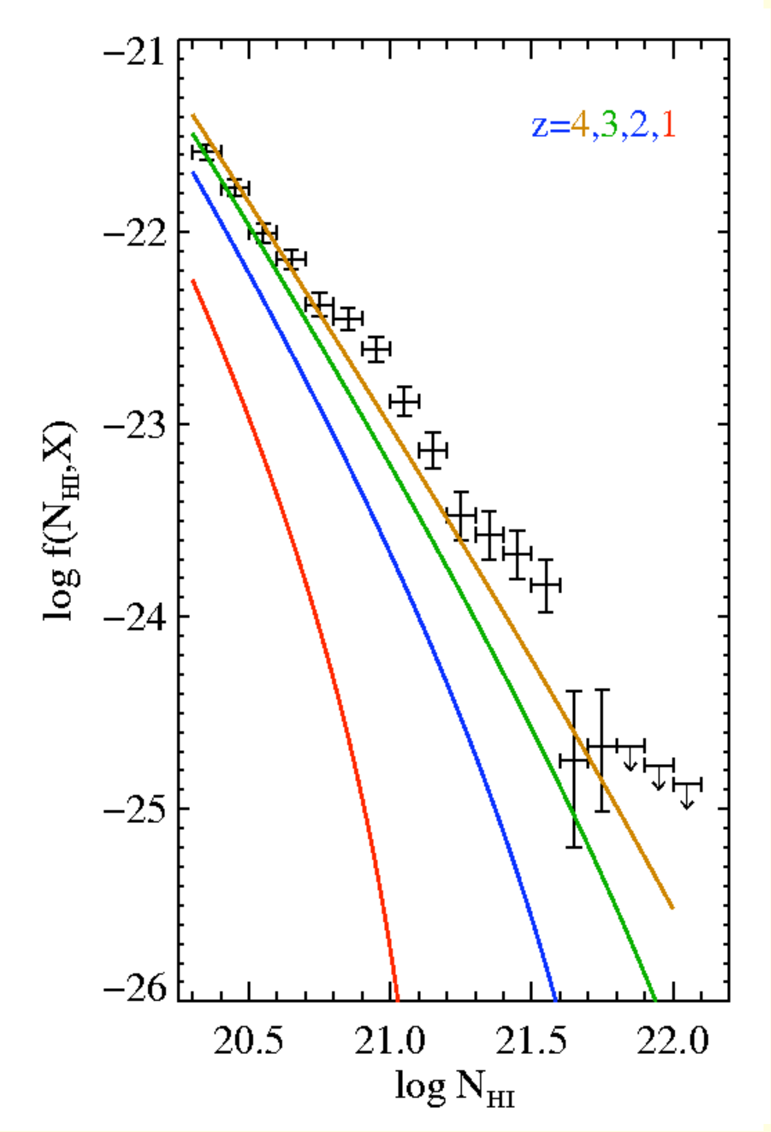
- SFR per unit area

  $\Sigma_{SFR}=K\times\Sigma^{1.4}$



- Gas Consumption

  $dN_{HI}/dt=-K_1\times N_{HI}^{1.4}$



Implications of invariant shape of f(N,X)

- SFR Efficiency ≤ 1/10 local value

or

- Accretion rate onto high-column density systems balances SFR

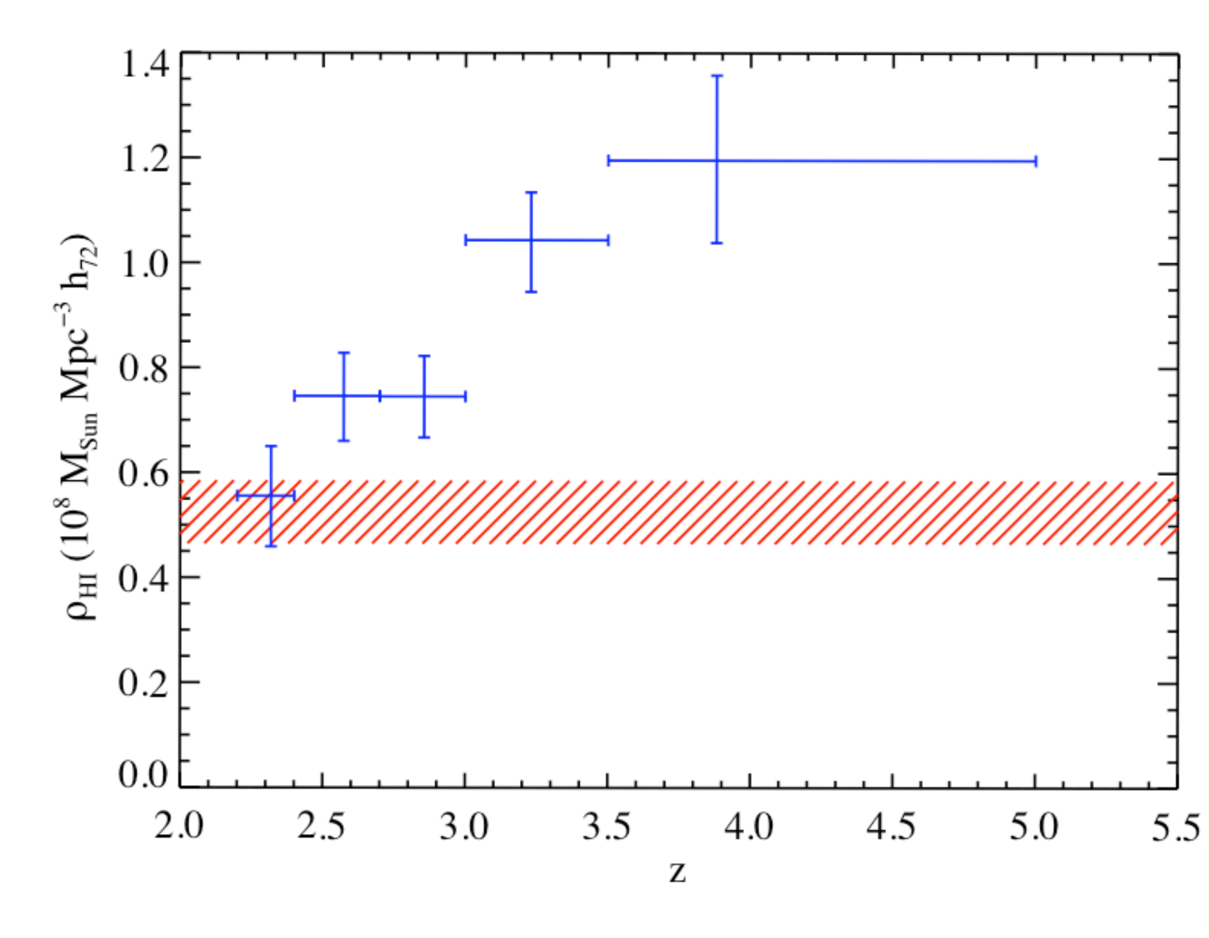
Byproducts of $f(N,X)$

- Mass per unit comoving volume

Mass per unit comoving volume

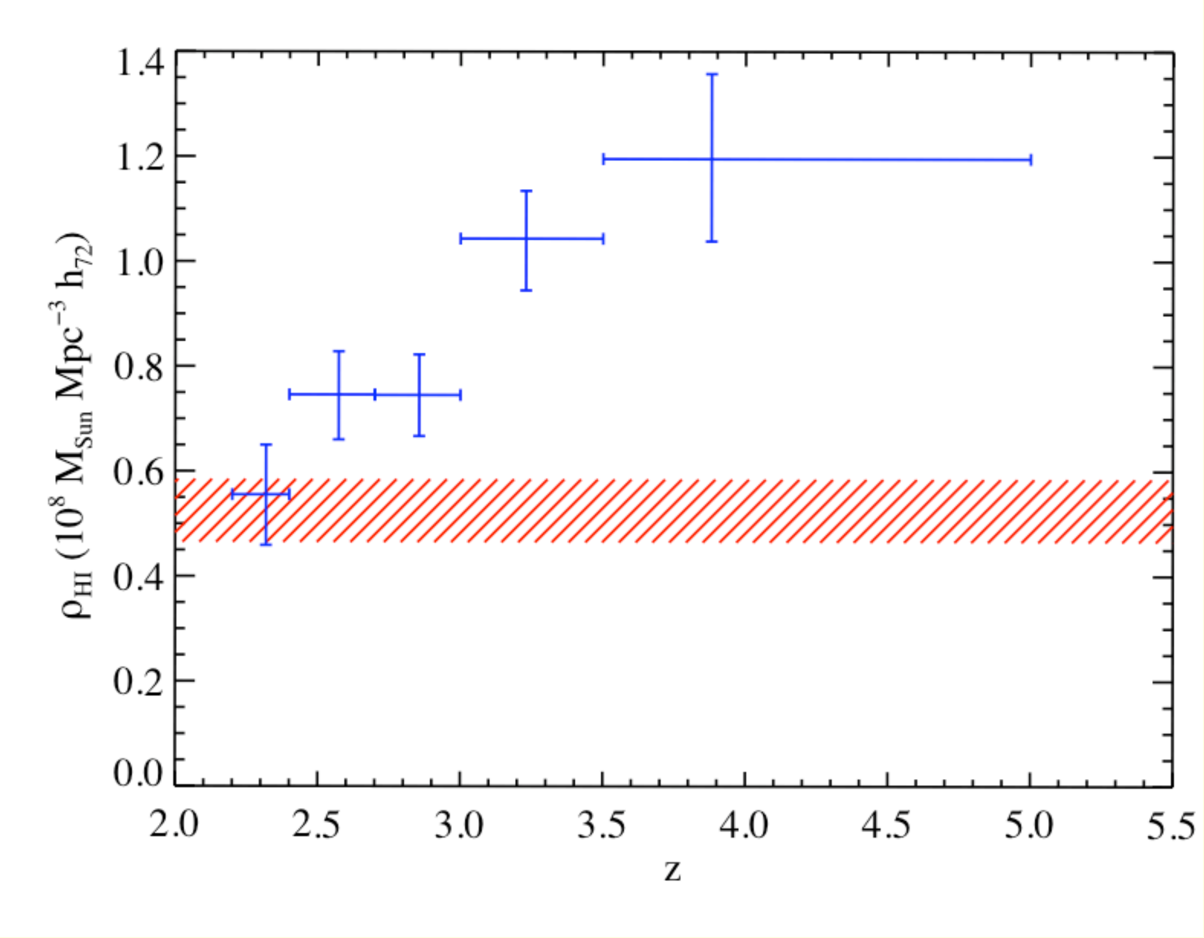
$$\rho_{\rm HI}(z) = \frac{\mu m_H}{(c/H_0)} \int N f(N, X) dN$$

Comoving Density of Neutral Gas

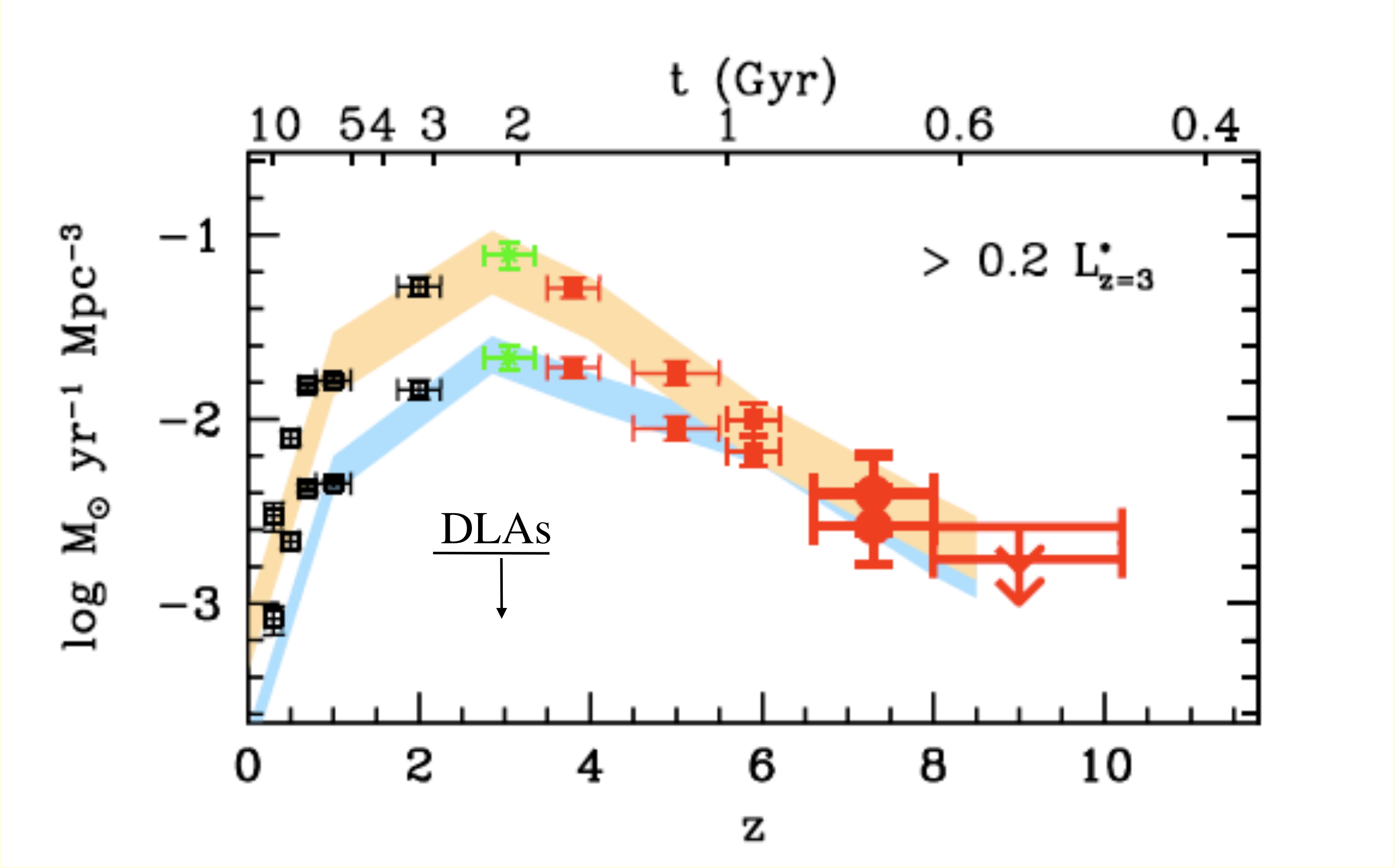


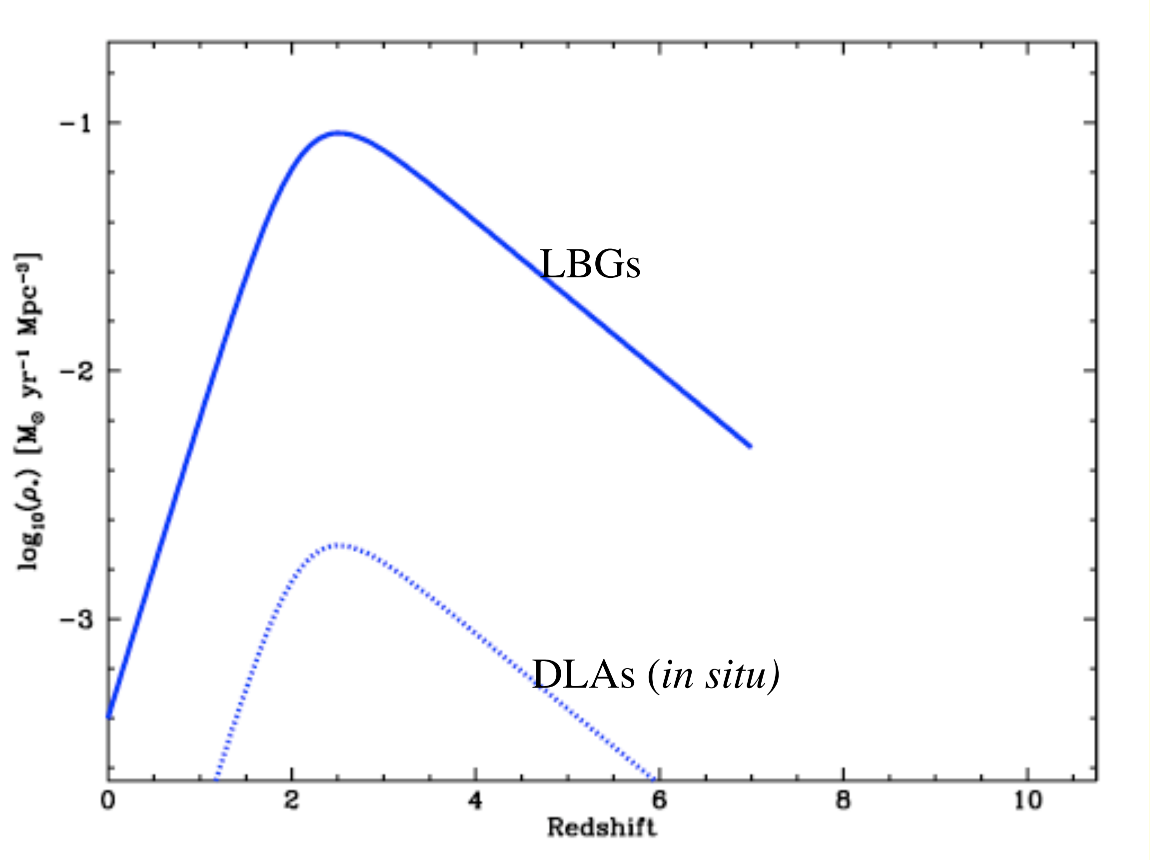
Comoving Density of Neutral Gas

Implication:
is evolution of ρ_{HI} due to gas consumption by star formation?



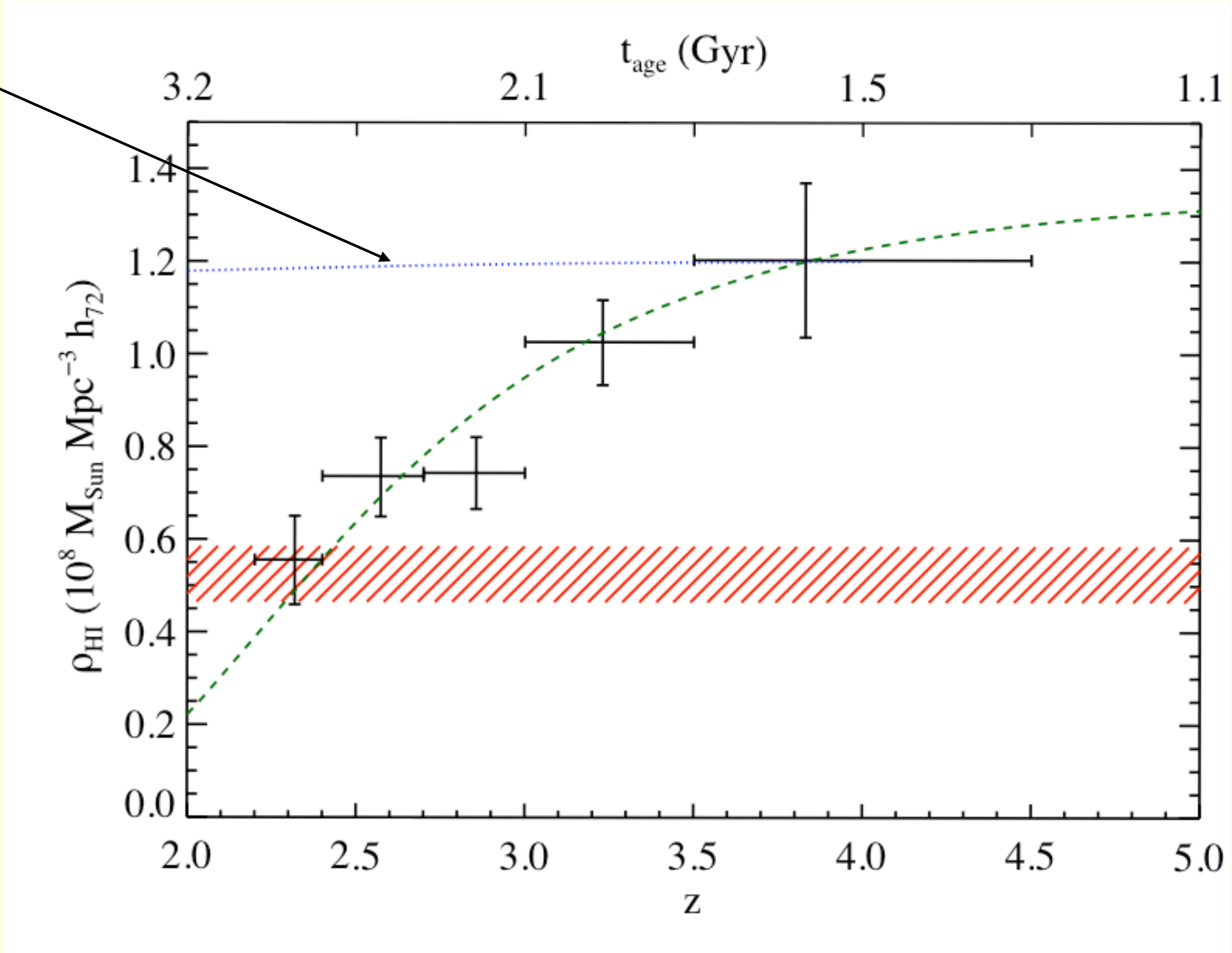
Comparison between Comoving SFR densities of DLAs and LBGs



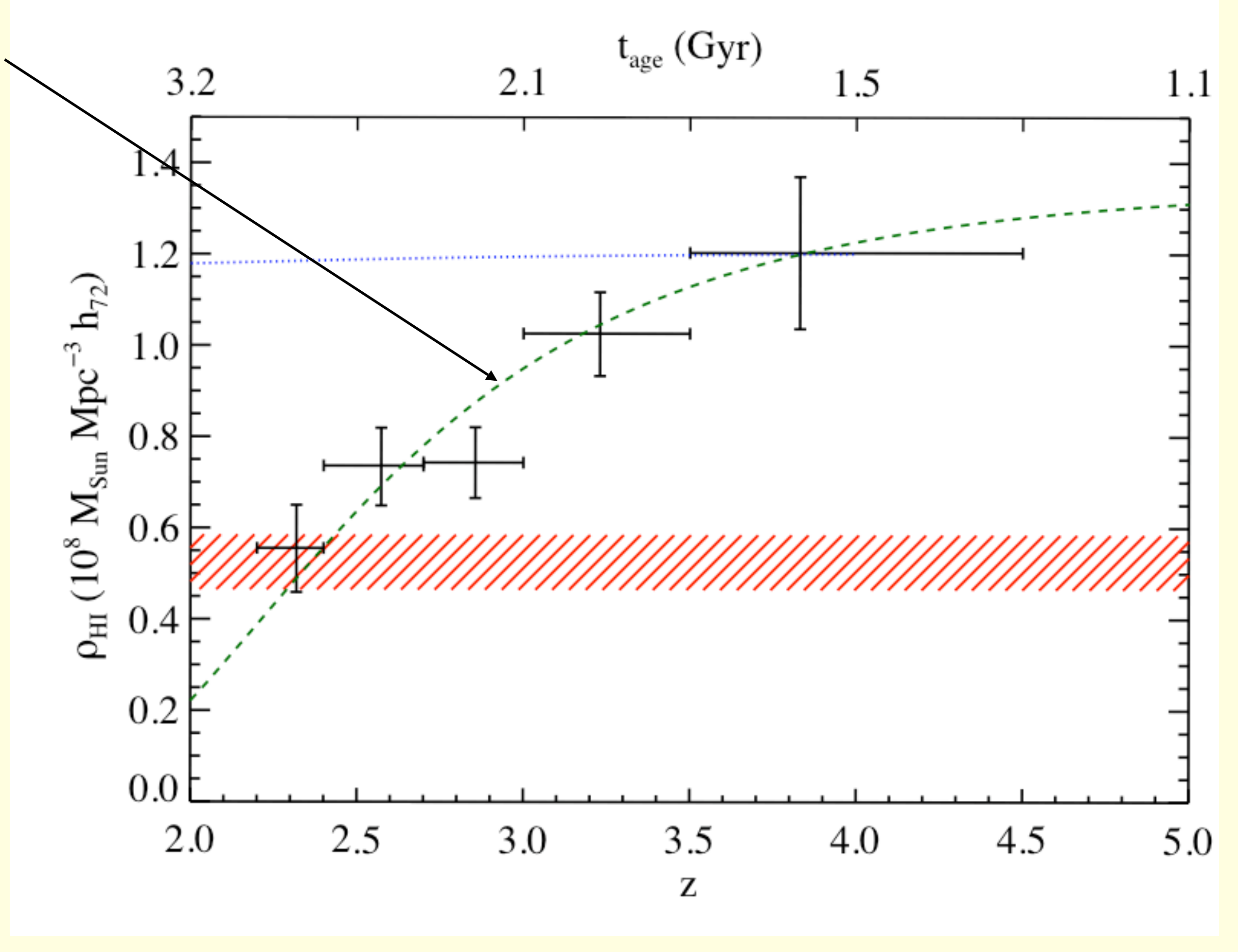


LBGs
DLAs (*in situ)*
Redshift
$\log_{10}(\rho_*)$ [$M_\odot$ yr^{-1} Mpc^{-3}]
0
2
4
6
8
10
−1
−2
−3

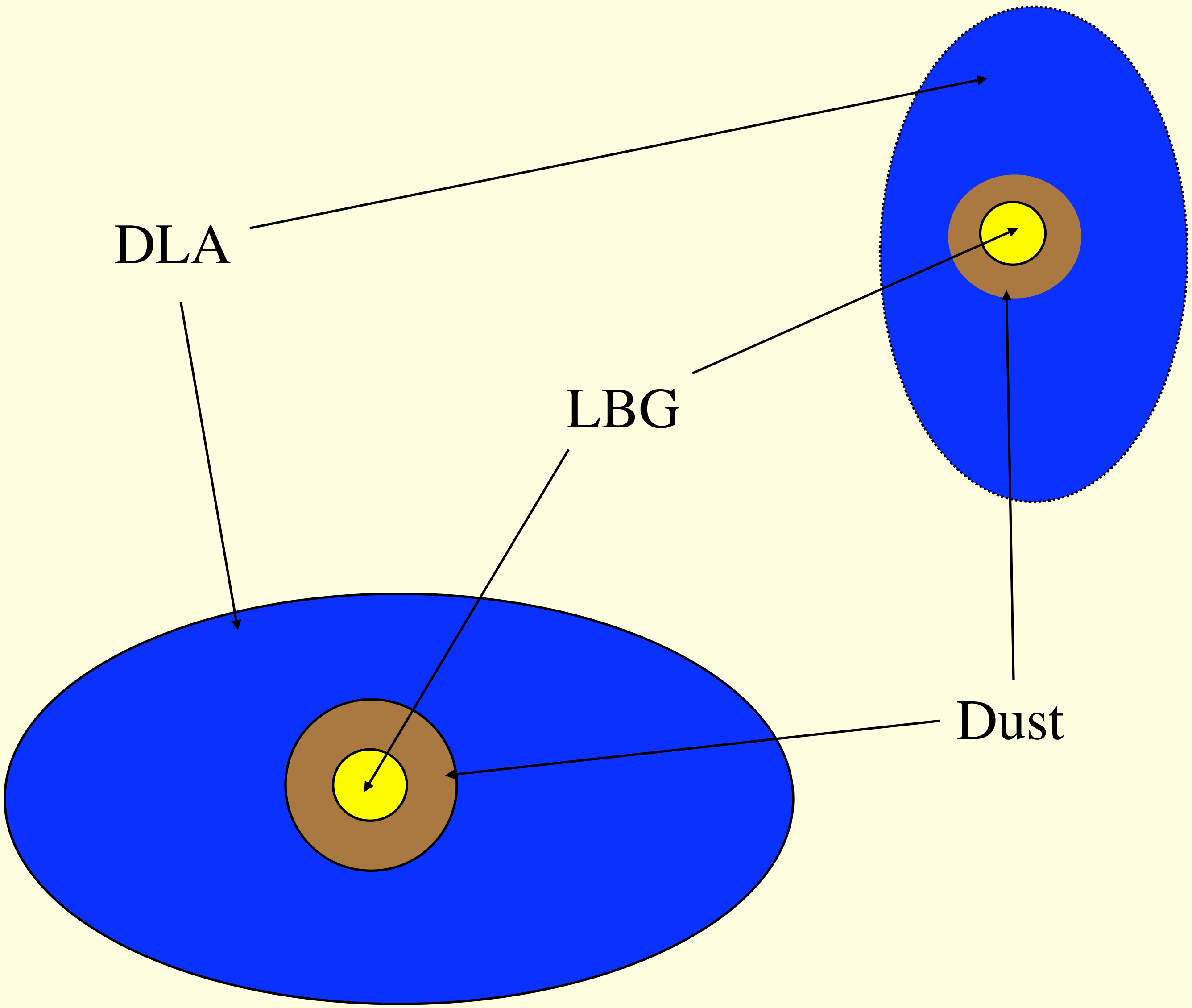
Decrease in ρ_{HI} by *in situ* Star formation In DLAs



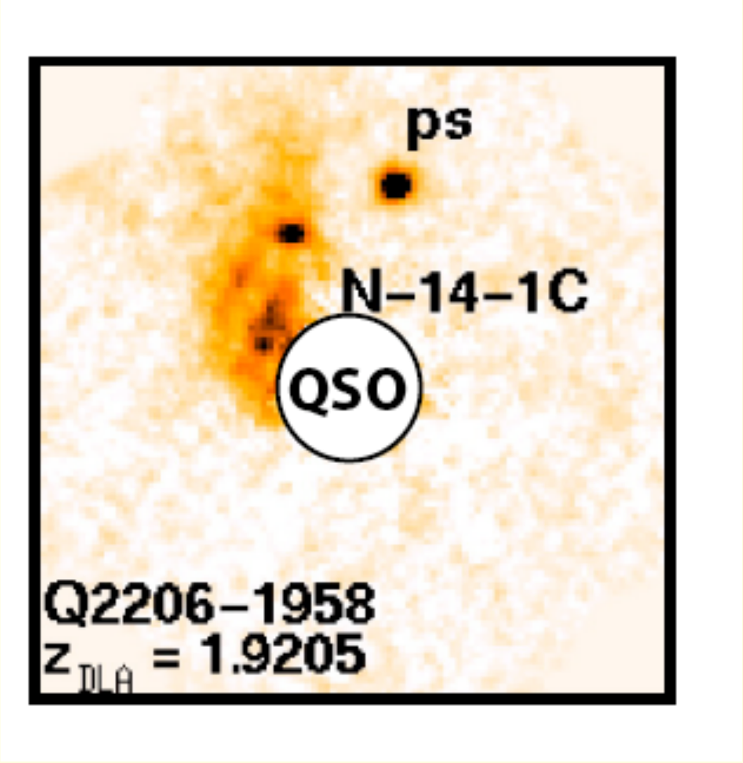
Decrease in ρ_{HI} by star formation in LBGs



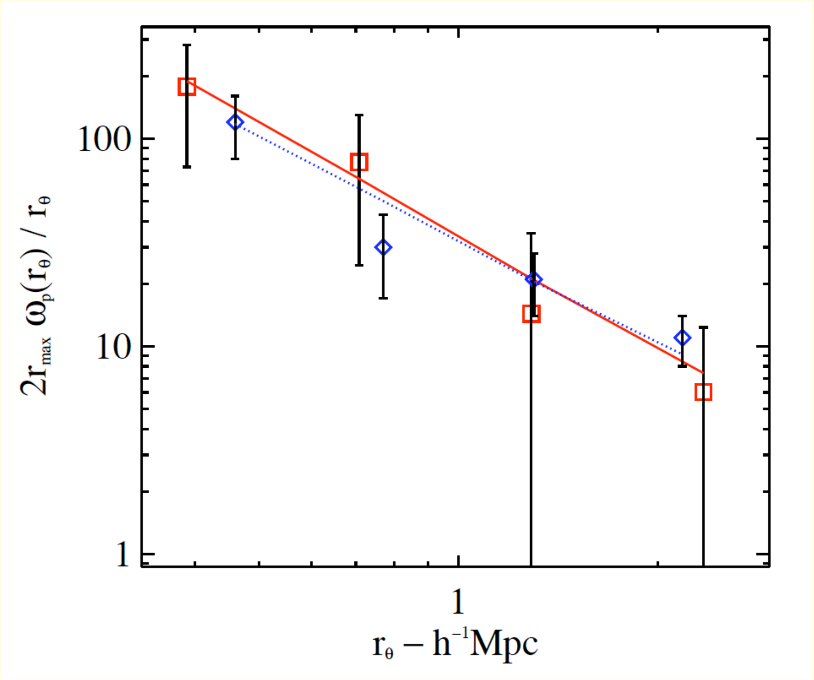
DLAs as Neutral-Gas Reservoirs for star-forming LBGs



DLA-LBG Connection

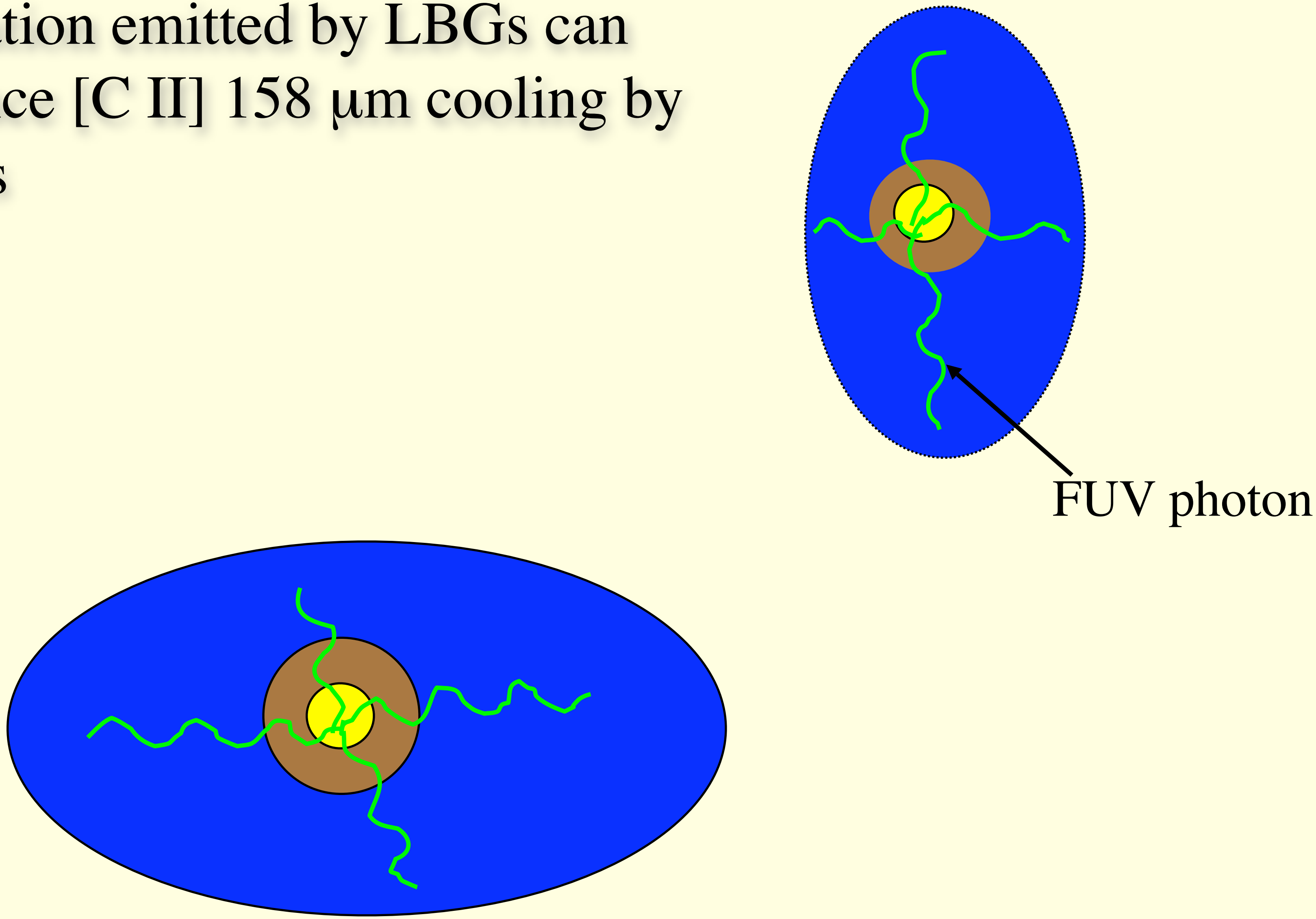


Physical Association

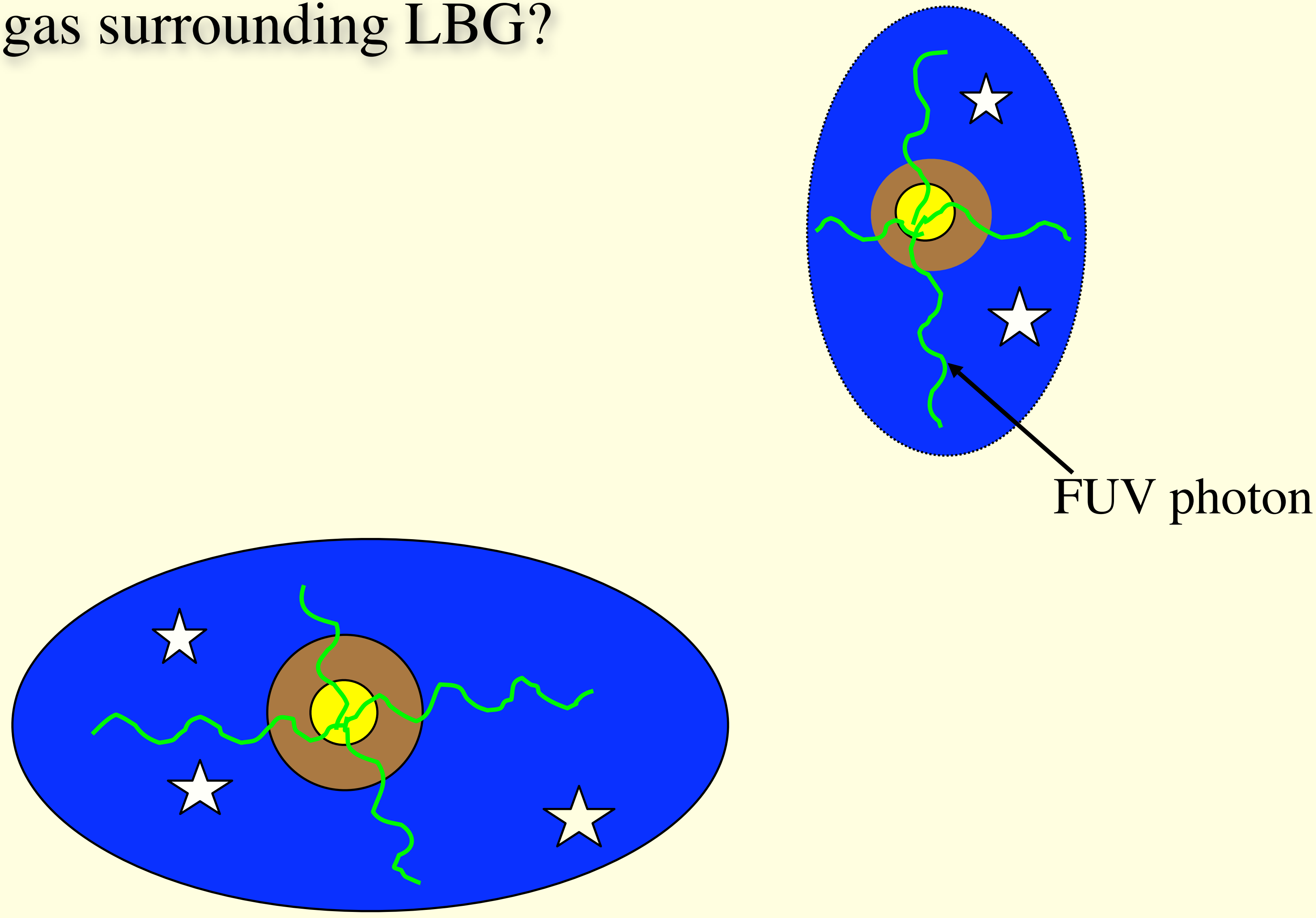


Cross-Correlation

Grain photoelectric heating by FUV Radiation emitted by LBGs can Balance [C II] 158 μm cooling by DLAs



Does *in situ* star formation occur in DLA gas surrounding LBG?



Conclusions: Byproducts of f(N,X)

- DLA gas covers 1/3 of the sky between z=[2.5,3.5]

- $d\rho_*/dt$ predicted by applying K-S law to DLAs ≈ $d\rho_*/dt$ for LBGs

- Search for LSB emission in HUDF shows SFR efficiency in DLAs < 0.05× K-S rate.

- Invariant shape of f(N,X) over z=[0,4.5] also implies low SFR efficiency in DLA gas

- HUDF limits on $d\rho_*/dt$ imply decrease of ρ_{HI} is not due to *in situ* star formation in DLAs.

- But decrease in ρ_{HI} might result from gas consumption in DLAs by centrally located LBGs