Title: Cosmology 6

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Abstract:

The Clustering of Intergalactic Metals

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University of Alberta

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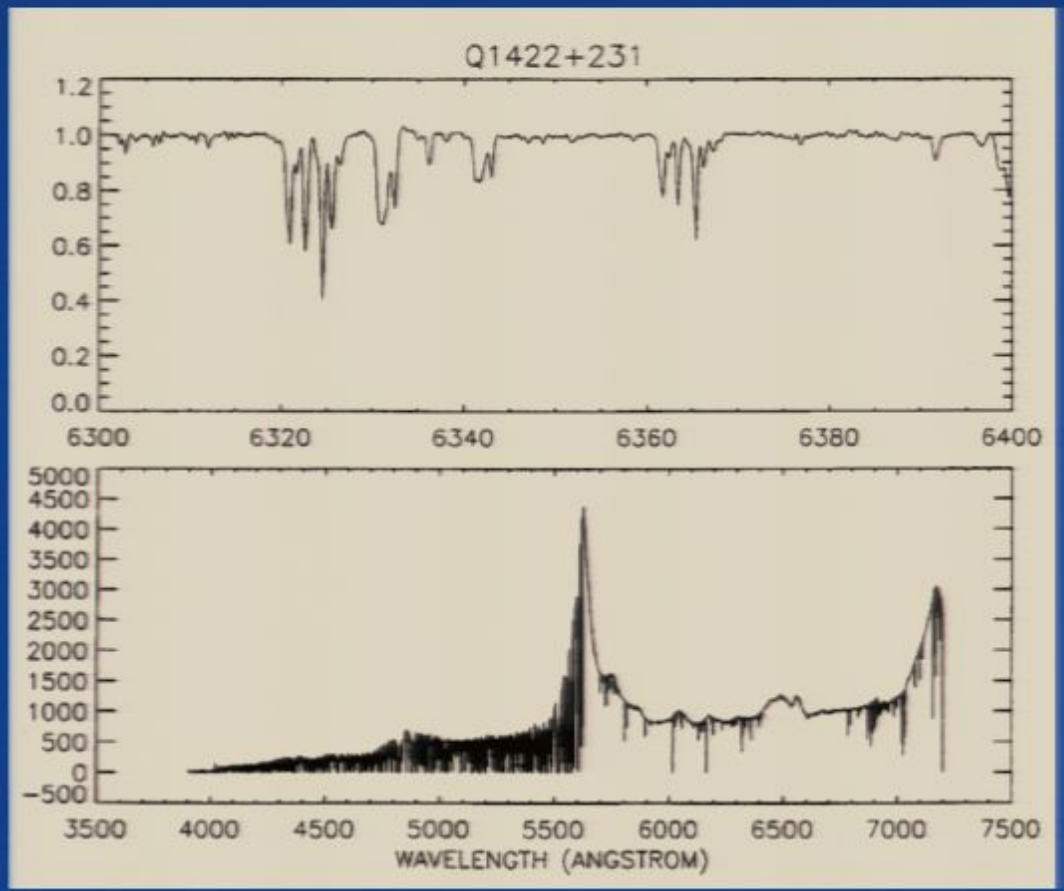
Intergalactic Metals

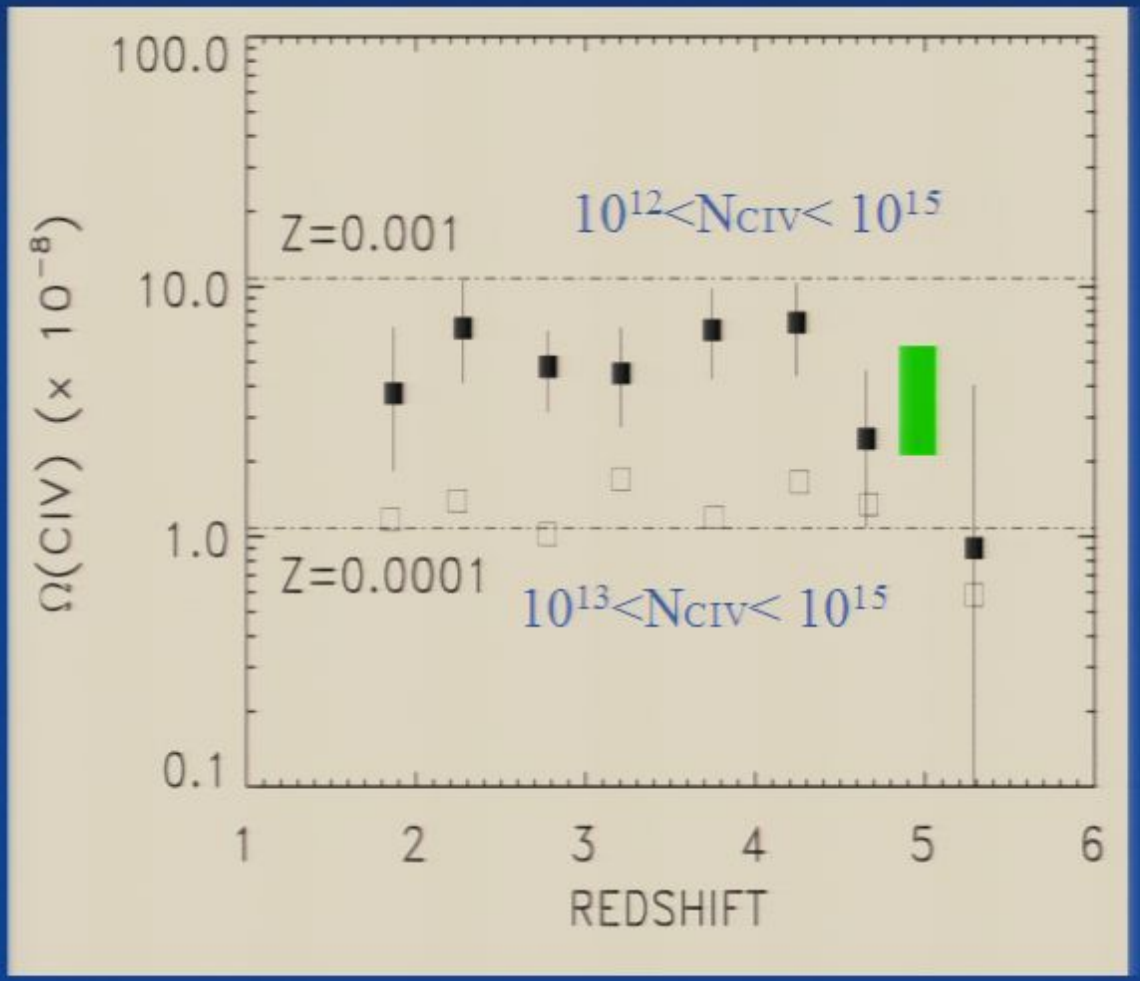


First Discovered outside of galaxies with advent of HIRES spectrograph on KECK:

$N_{HI} = 3 \times 10^{14}\ cm^{-2}$
~10 times mean ρ at $z=3$

(Tytler 1995; Cowie 1996)

Intergalactic Metals



Roughly constant at $z < 5$

Inhomogeneous:

[C/H]~-2.5 at $z=3$

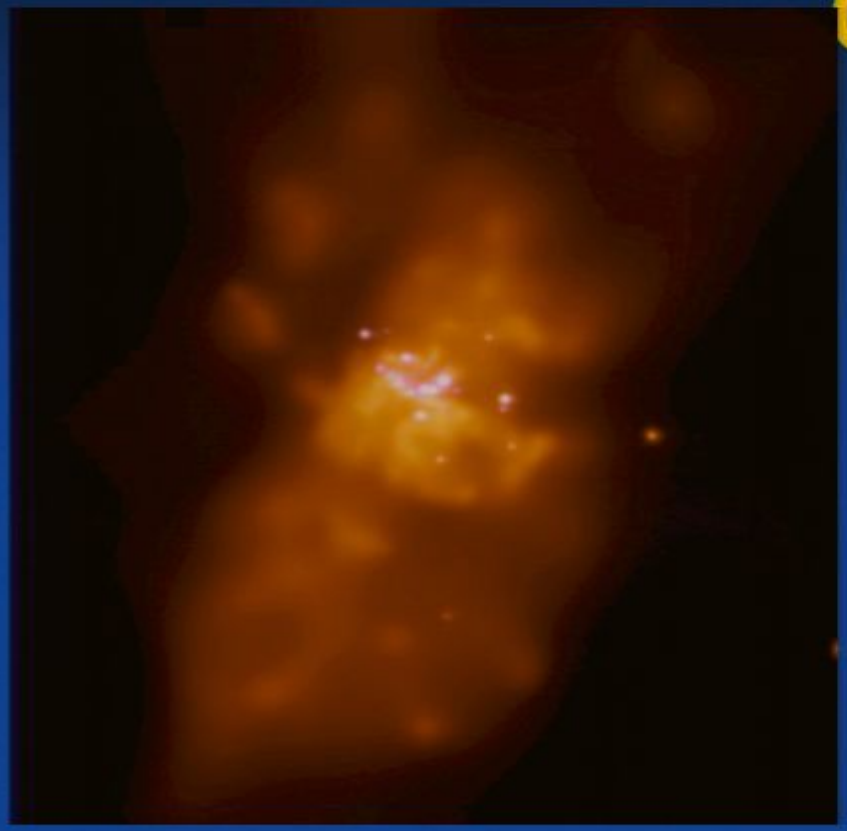
$N_{HI}=10^{14.5}$ order of mag scatter

(Rauch, Haehnelt, & Steinmetz 1997)

(Songaila 2001; Pettini etal 2003)

Competing Scenarios

Competing Scenarios

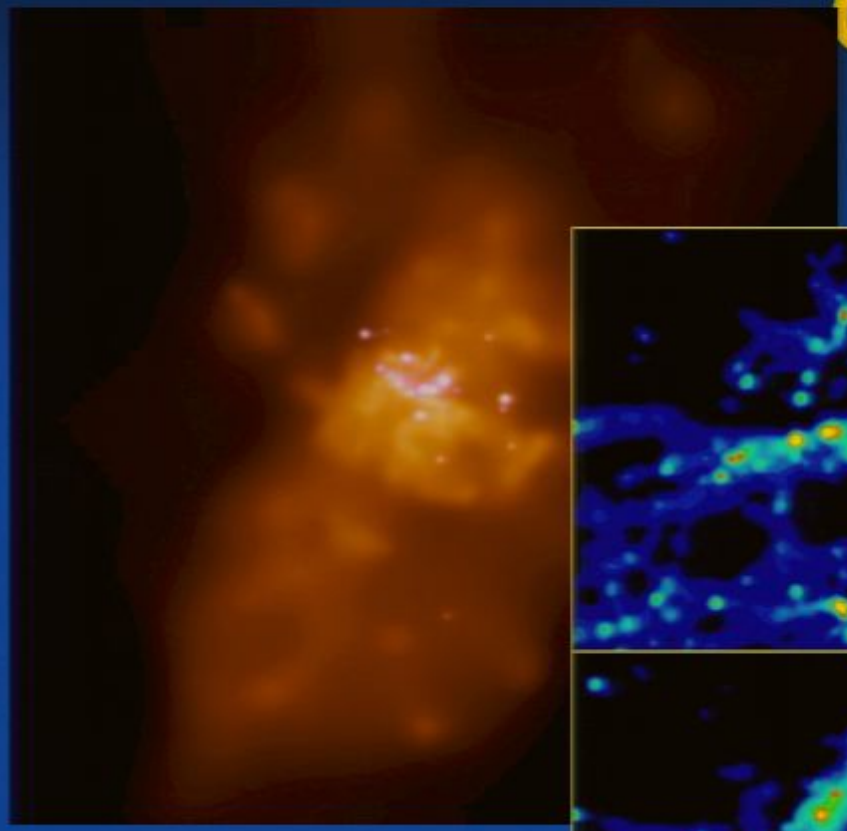


Lyman-Break type z=3-6 starbursting galaxies

Aguirre, Hernquist, Schaye, et al. (01)

Observed by Steidel etal

Competing Scenarios



Lyman-Break type z=3-6 starbursting galaxies

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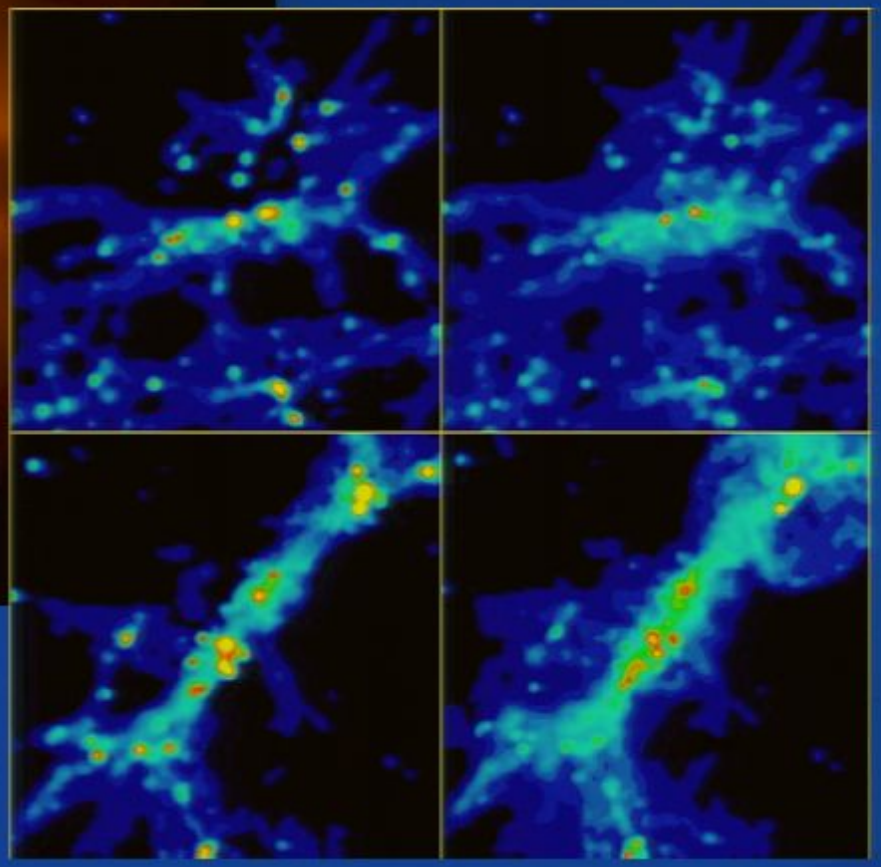
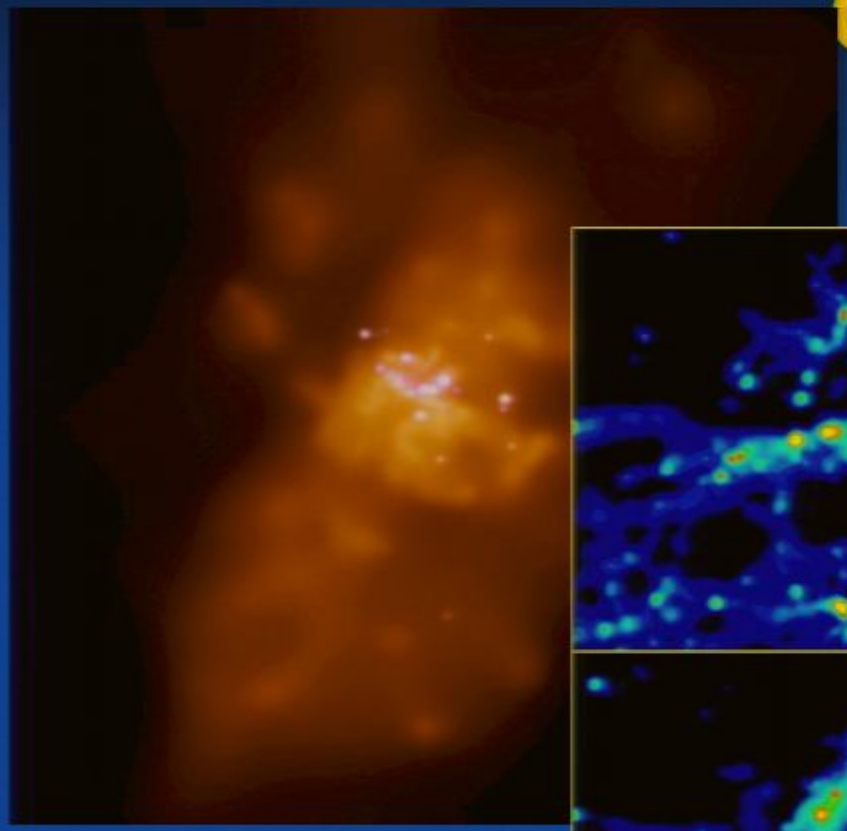


z=>6 protogalaxies

ES, Ferrara, Madau (02)

Thacker, ES, Davis (02)

Competing Scenarios



Lyman-Break type
z=3-6 starbursting
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Schaye, et al. (01)
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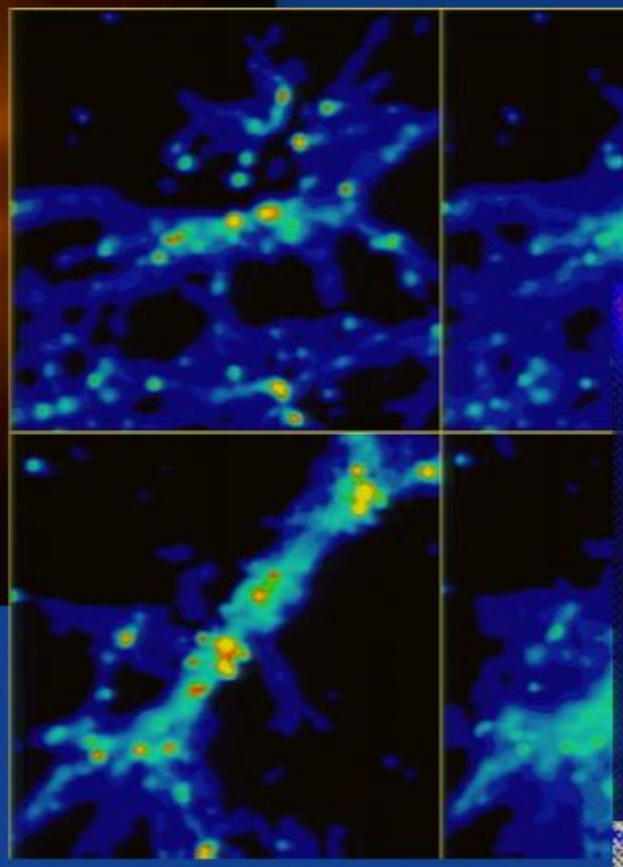
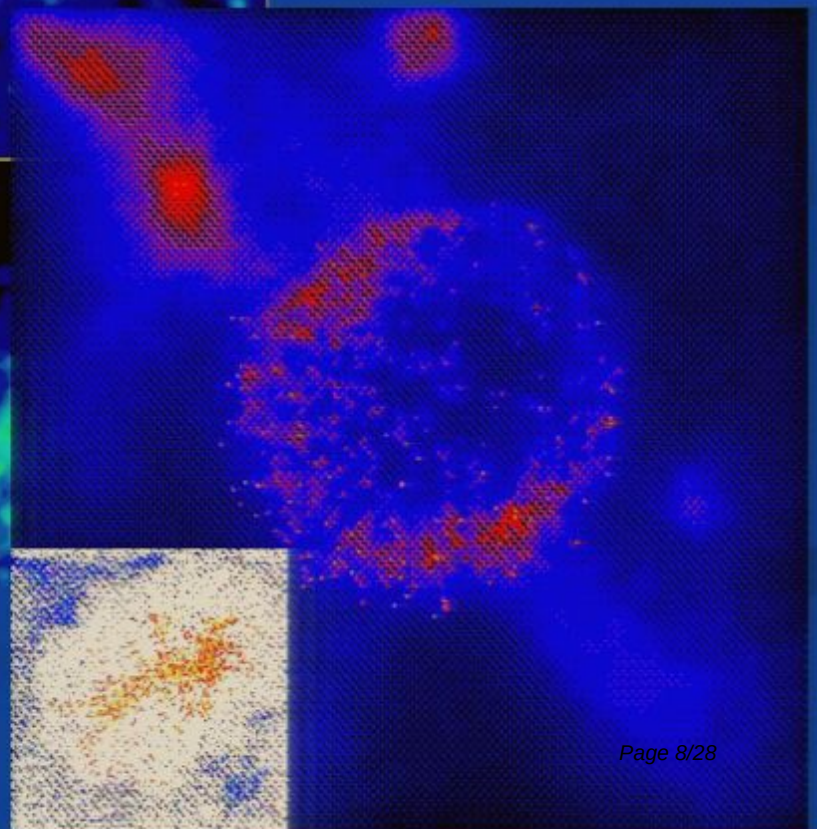


z=>6 protogalaxies
ES, Ferrara, Madau (02)
Thacker, ES, Davis (02)

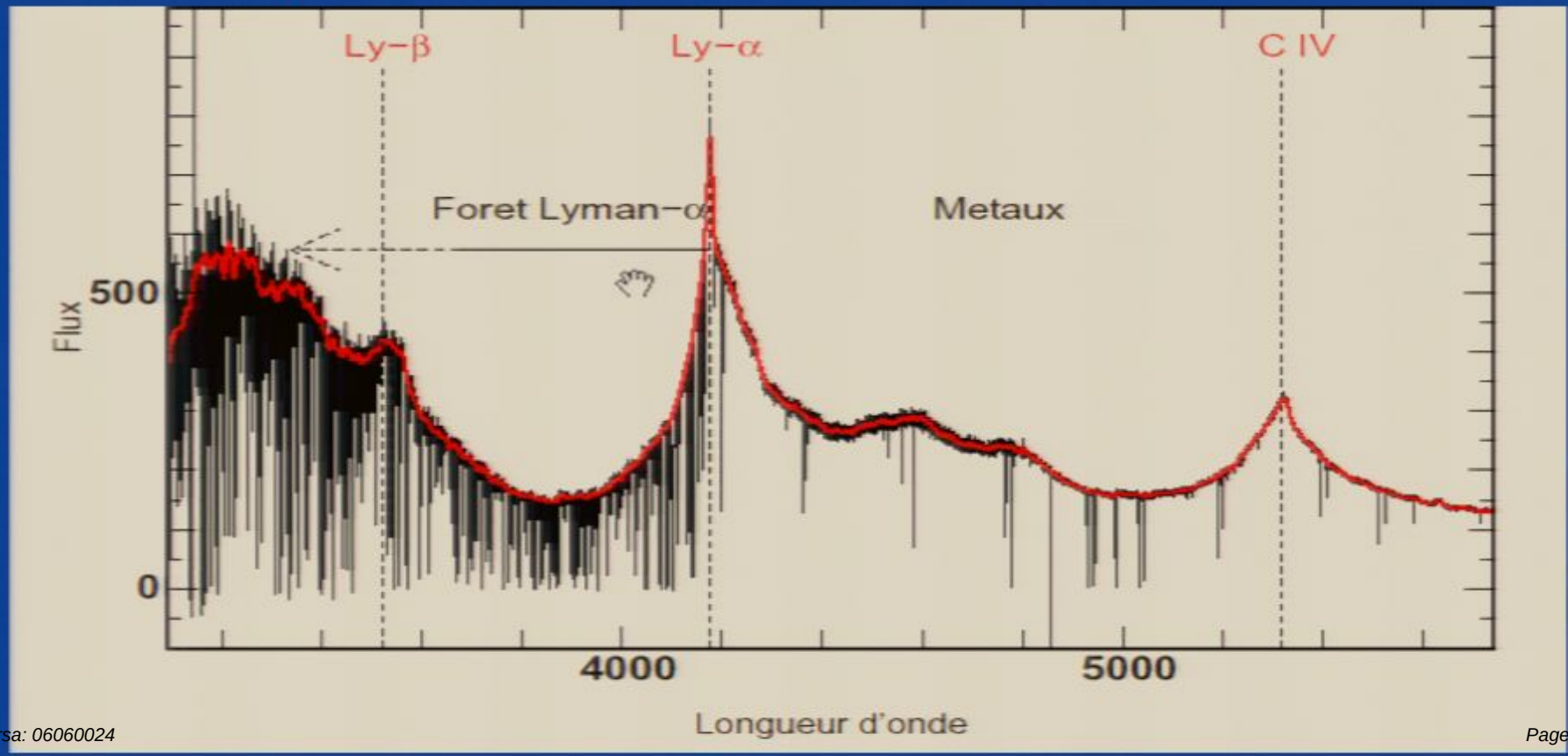
Primordial Stars
Abel Bryan & Norman (01)
Bromm, Yoshida,
Hernquist (03),
ES, Schneider, Ferrara (03)



Observations

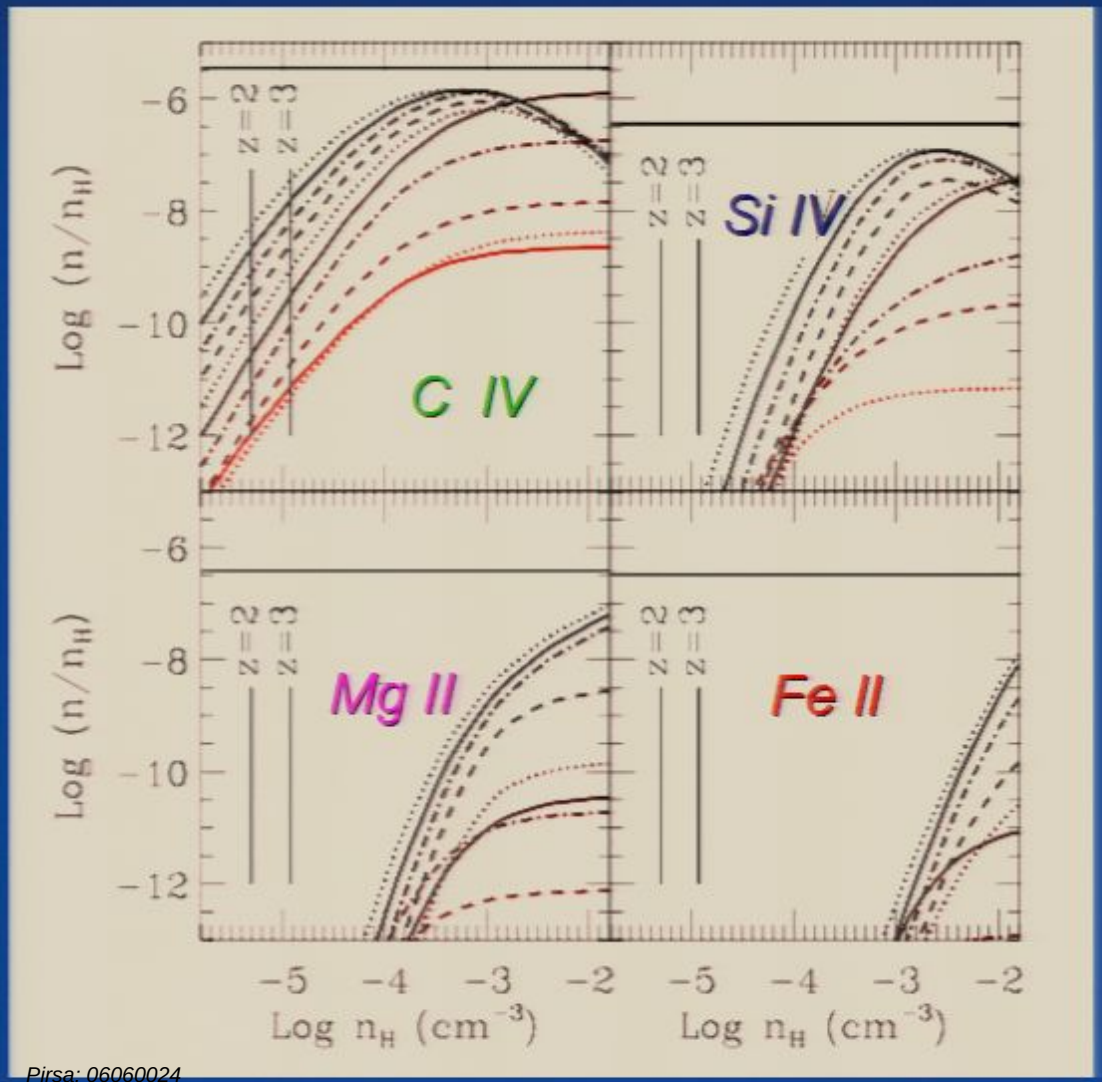
ESO-LP: "Cosmic Evolution of the IGM"

B. Aracil, R. Badde, J. Bergeron, P Boisse, R. Carswell, S. Cristiani, V. d'Odorico, A. Ferrara, A. Fontana, E. Gialolongo, M. Haehnelt, T.-S. Kim, C. Ledoux, S. Lopez, C. Mallouris, P. Moller, P. Petitjean, C. Peroux, C. Pichon, M. Rauch, E Scannapieco, P. Shaver, G. Vladillo



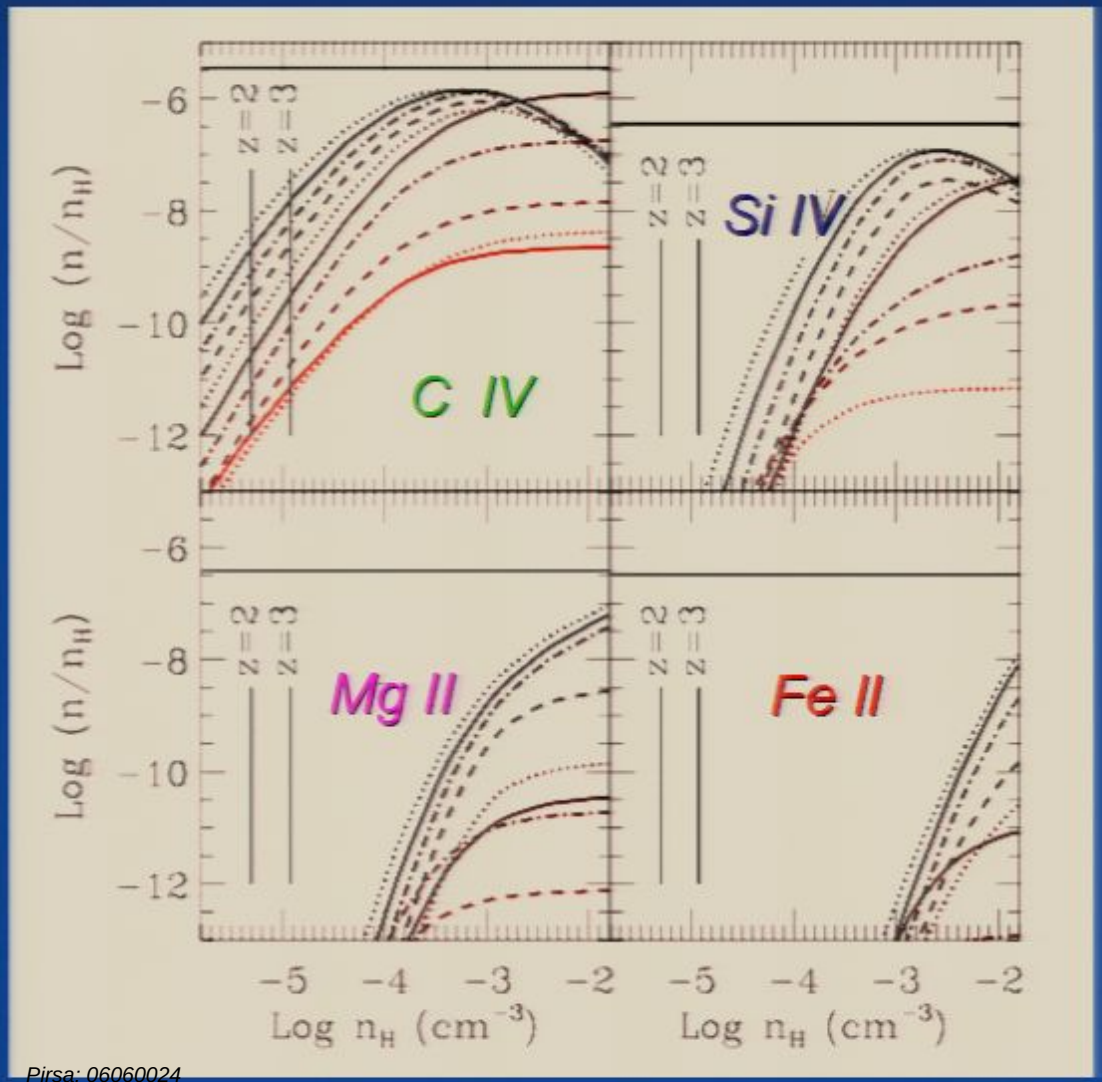
Focus on CIV & SiIV (z=1.5-3.0) & MgII and FeII (z=0.5-2.0)

Our Target Species



After Rauch, Haehnelt, & Steinmetz 1997

Our Target Species

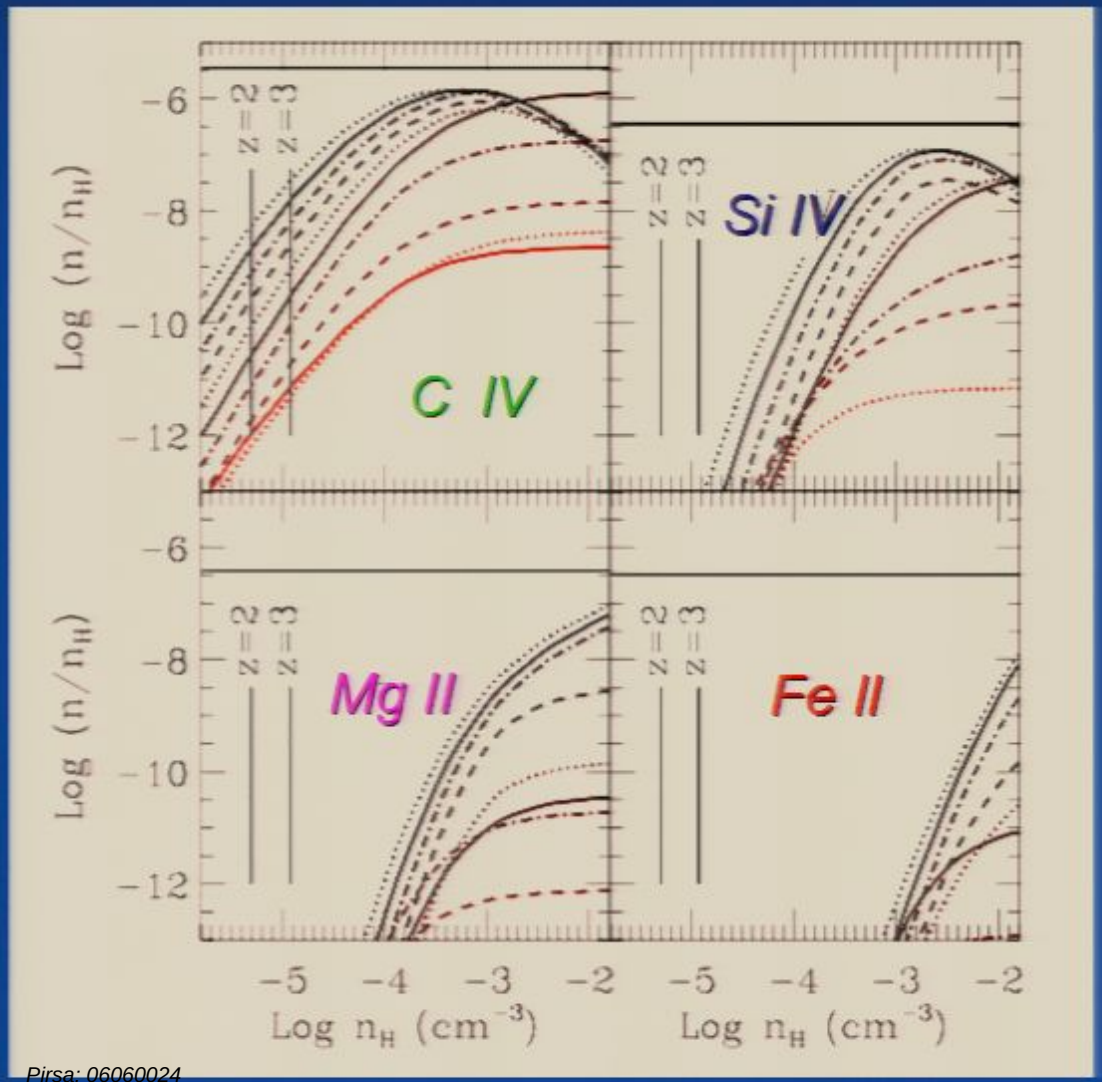


Carbon-IV

λ: (1548,1551)

After Rauch, Haehnelt, & Steinmetz 1997

Our Target Species



Carbon-IV

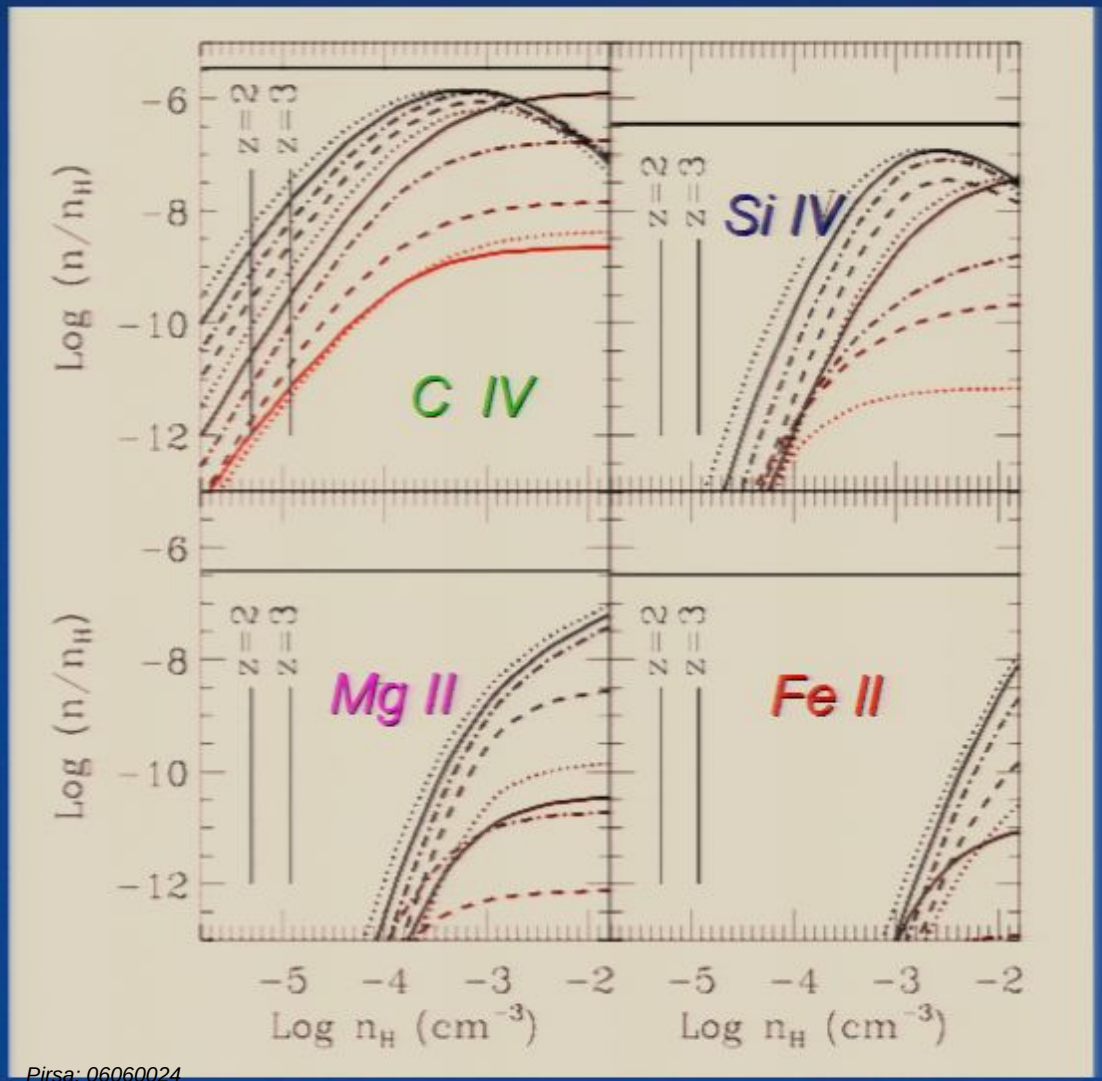
λ: (1548,1551)

Likes: Δ ~ 30

Dislikes: $T>10^5 K$

After Rauch, Haehnelt, & Steinmetz 1997

Our Target Species



After Rauch, Haehnelt, & Steinmetz 1997

Carbon-IV

λ: (1548,1551)

Likes: Δ ~ 30

Dislikes: $T>10^5K$

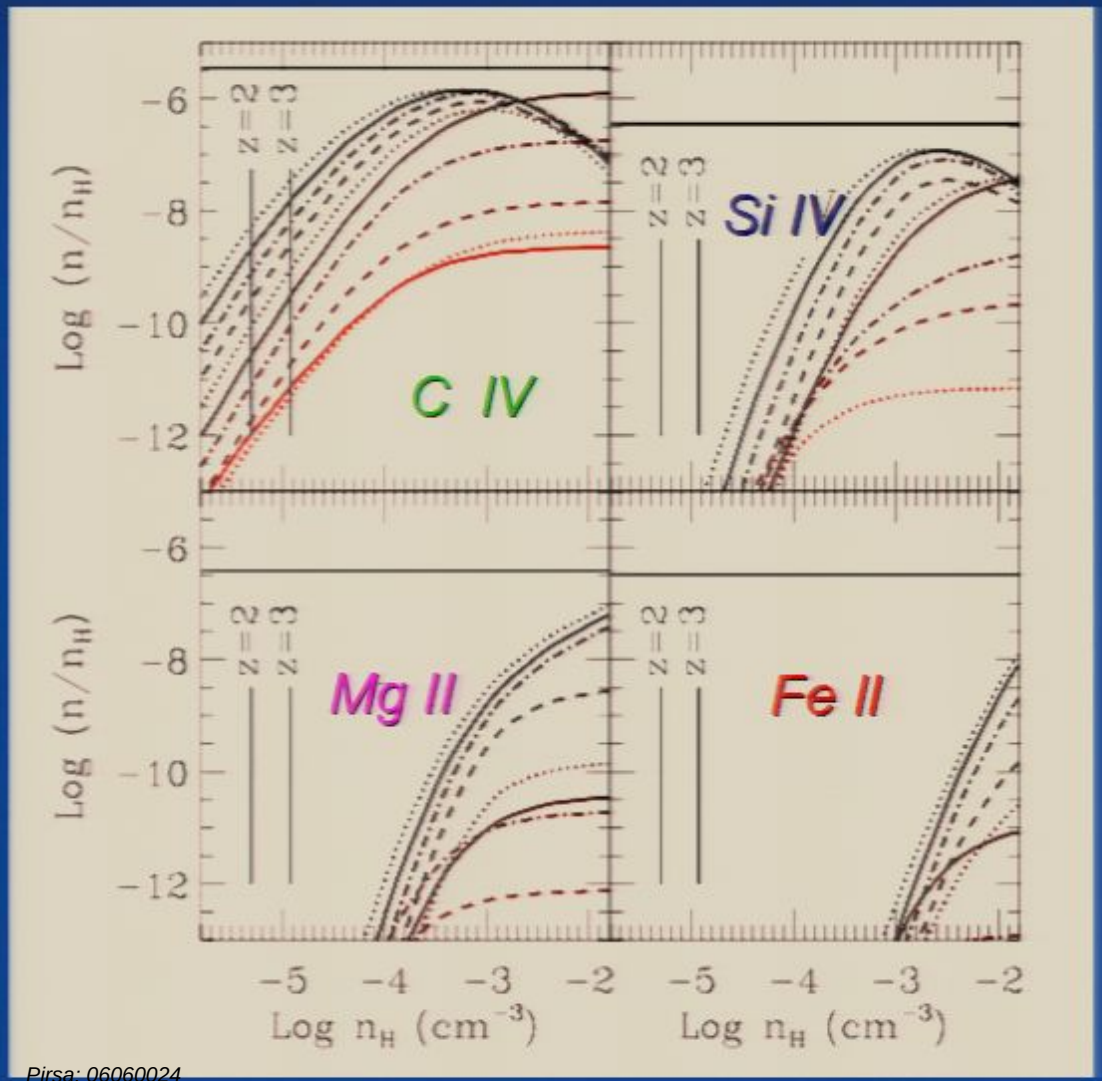
Silicon-IV

λ: (1394,1403)

Likes: Δ ~ 100

Dislikes: $T>10^{4.75}K$

Our Target Species



Magnesium-II

λ: (2796,2803)

Likes: Δ > 300

Dislikes: $T>10^{4.25}K$

Iron-II

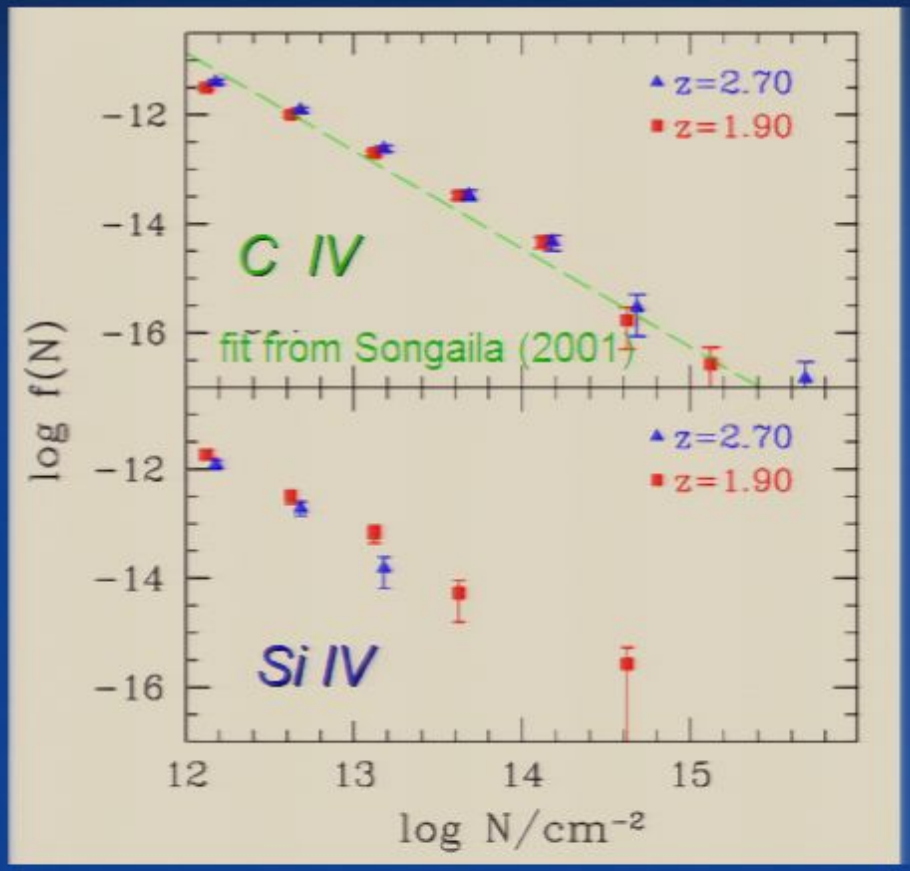
λ: (2344,2382, 2473)

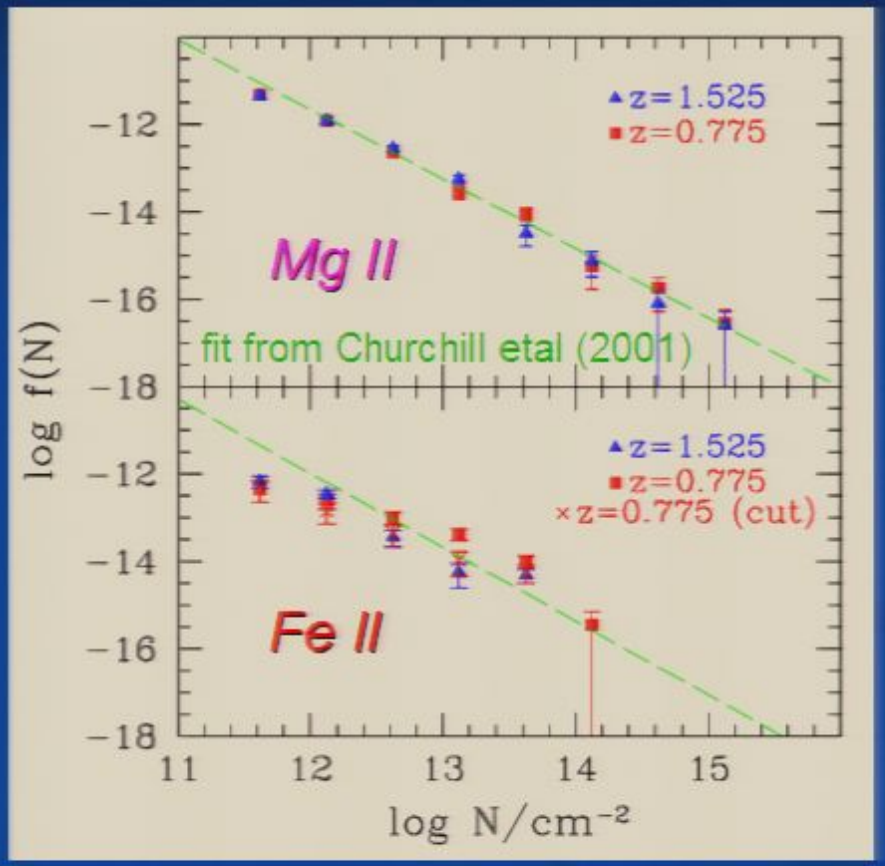
Likes: Δ > 1000

Dislikes: $T>10^{4}K$

After Rauch, Haehnelt, & Steinmetz 1997

2 Number Densities

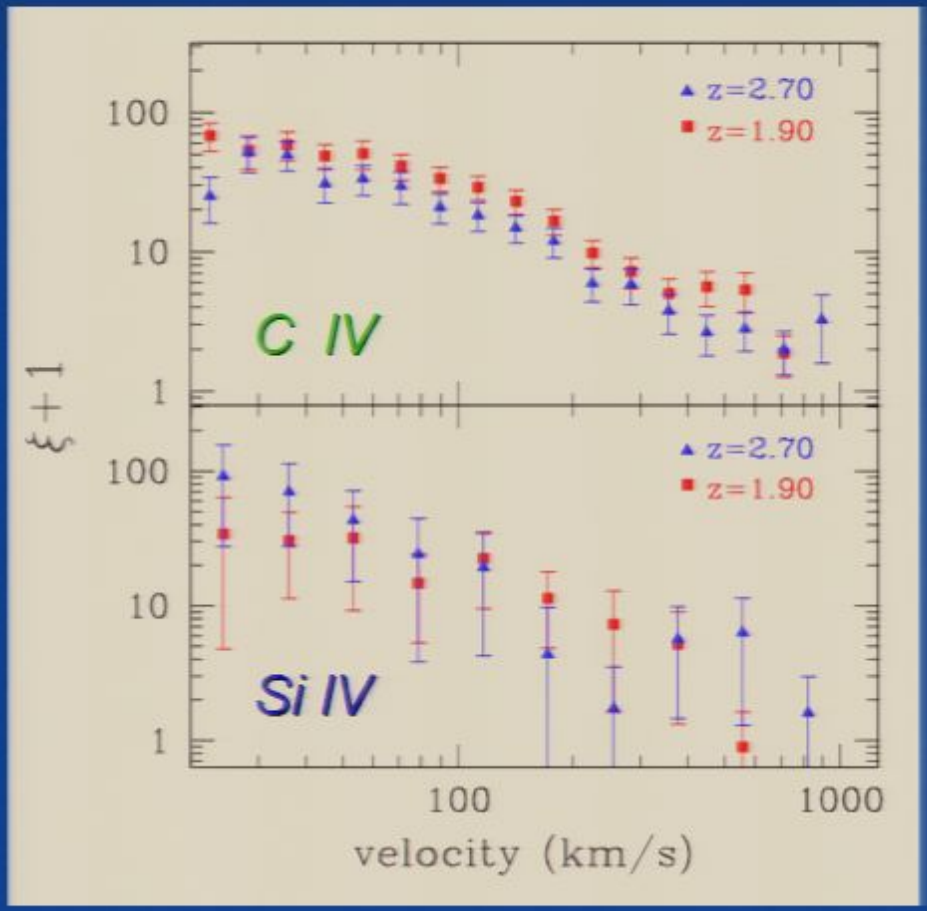




f= d#/dX/dN

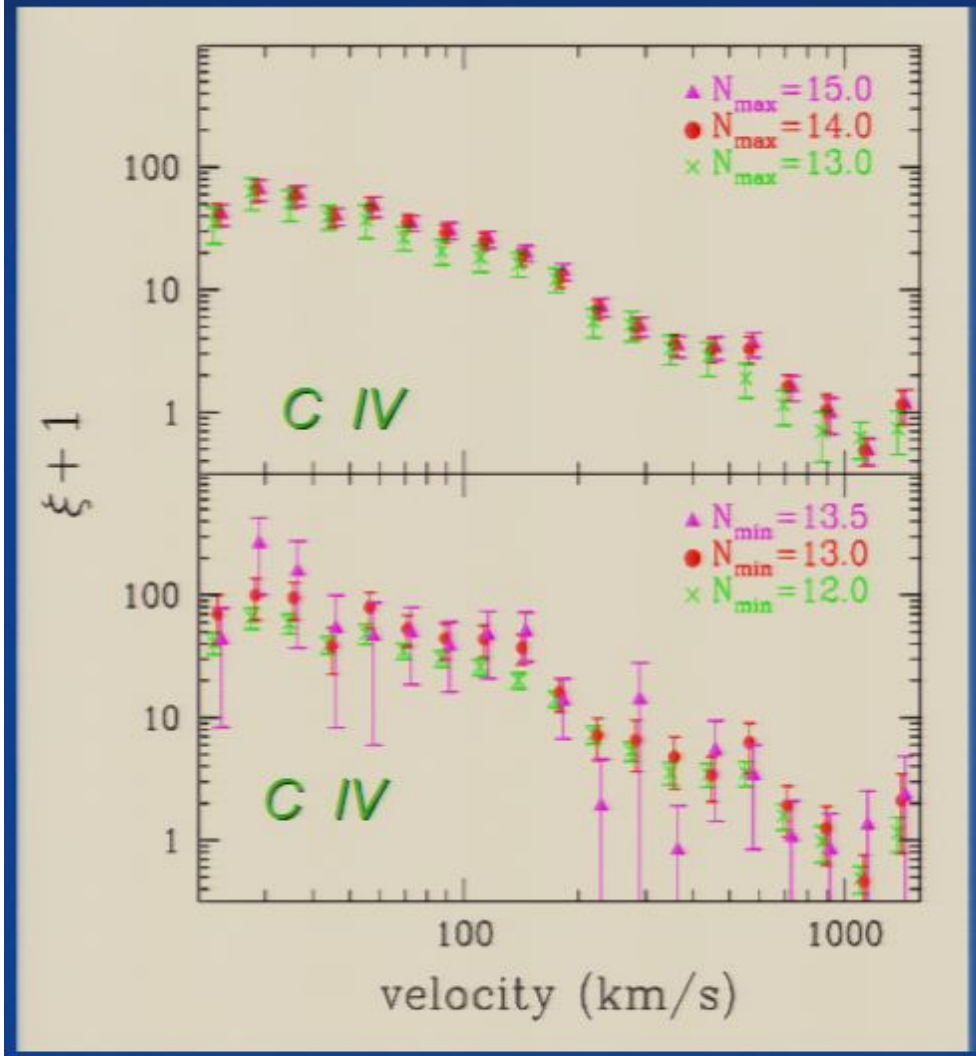
1. No Evolution Detected
2. Number densities consistent with previous estimates:
   619 CIV & 81 Si IV($N>= 10^{12}$)
   316 MgII & 82 FeII ($N>= 10^{11.5}$)

CIV and SiIV Correlation Functions



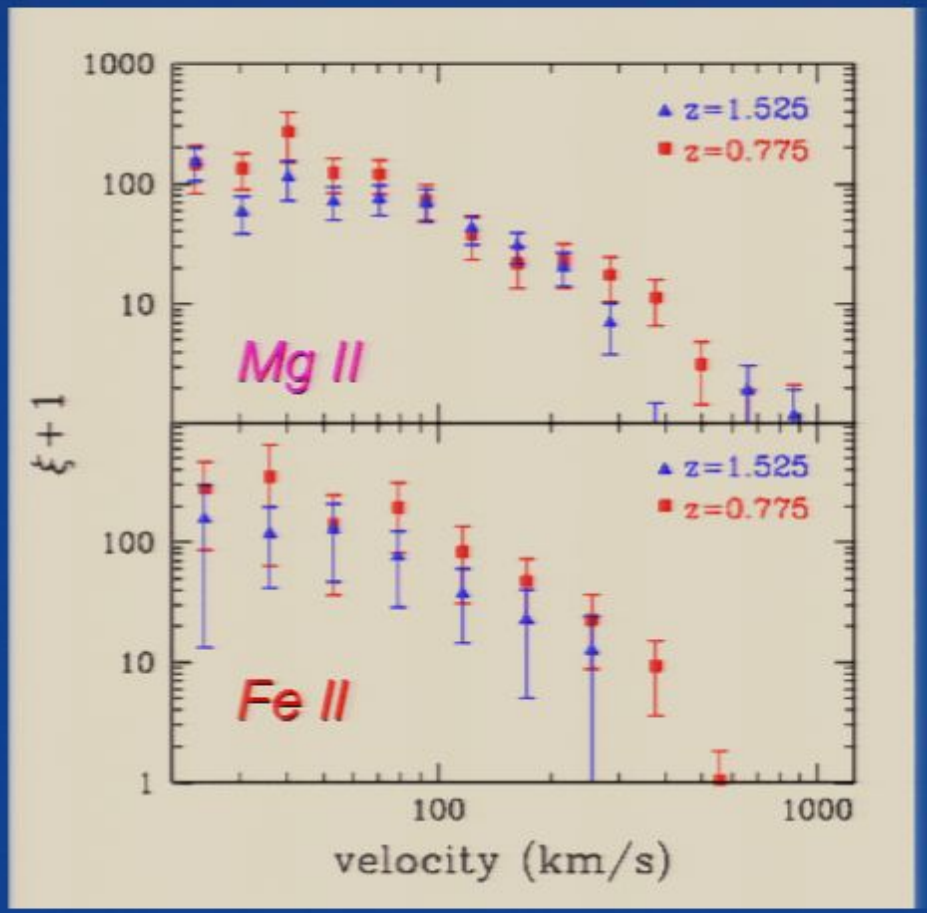
1. Detected CIV and SiIV trace each other closely
2. Two-slope shape with a "knee" at 150 km/s,
3. Weak Evolution, consistent with linear growth

How Robust?

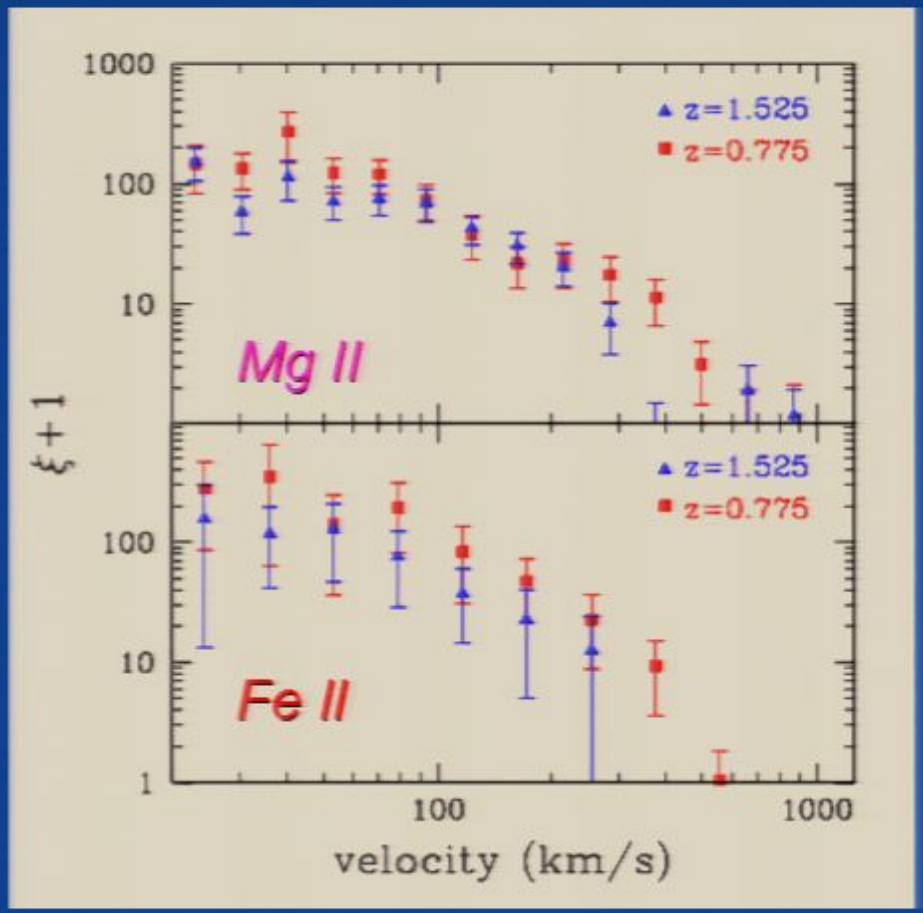


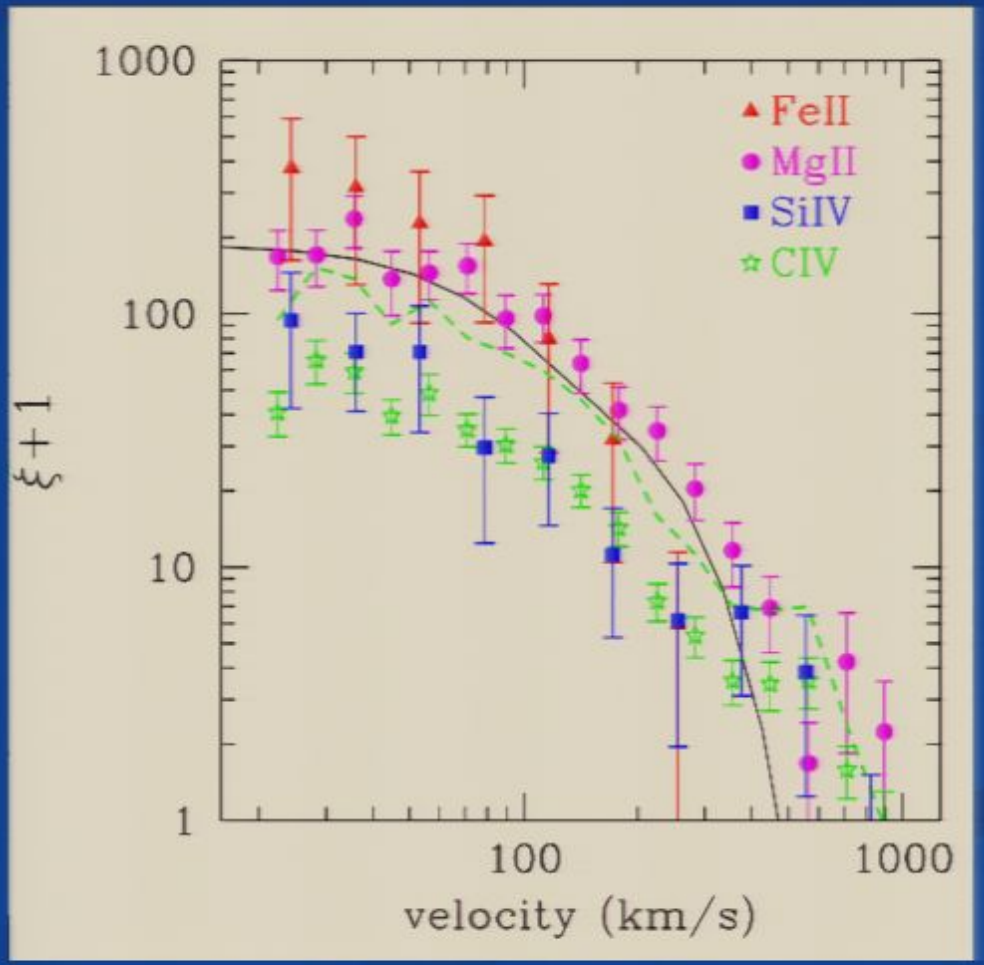
No dependence on Max N
No dependence on Min N

MgII and FeII Correlation Functions

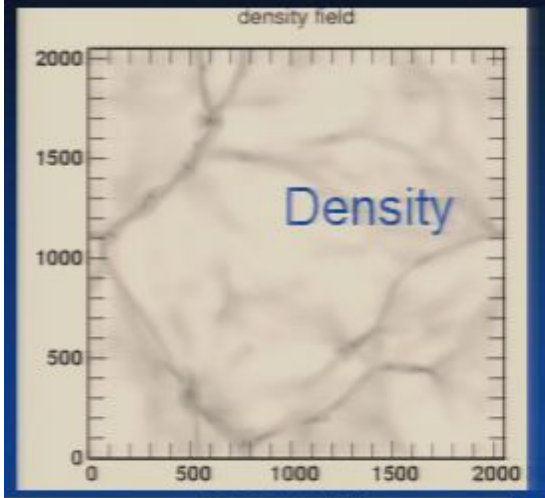


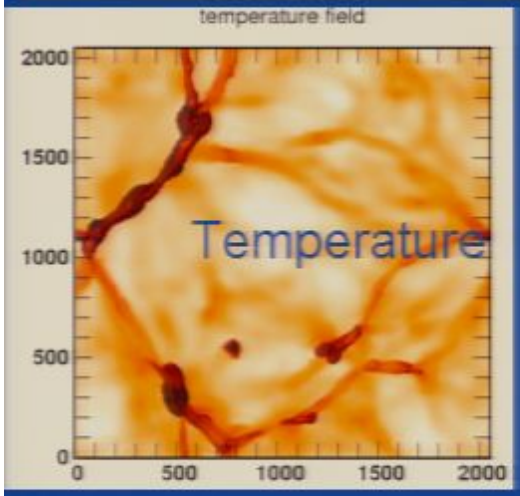
MgII and FeII Correlation Functions

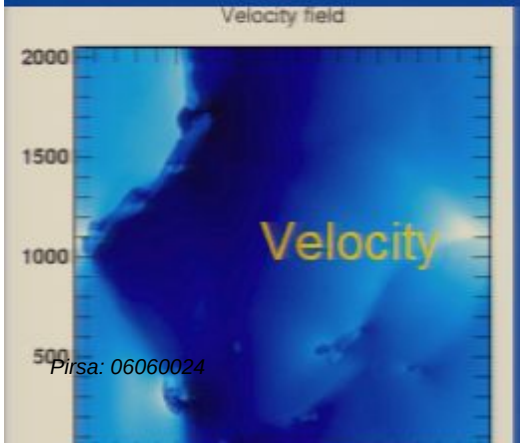




Synthetic Metals







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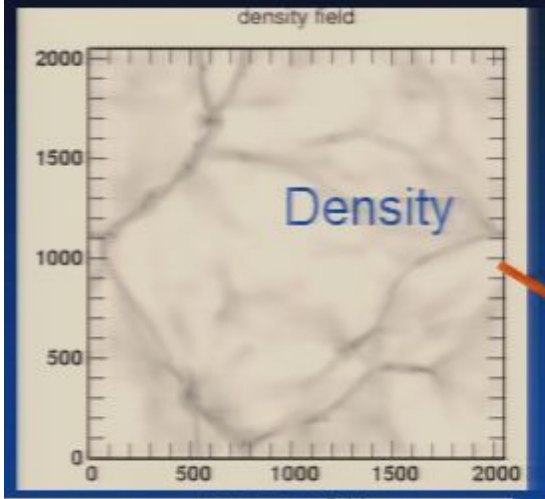
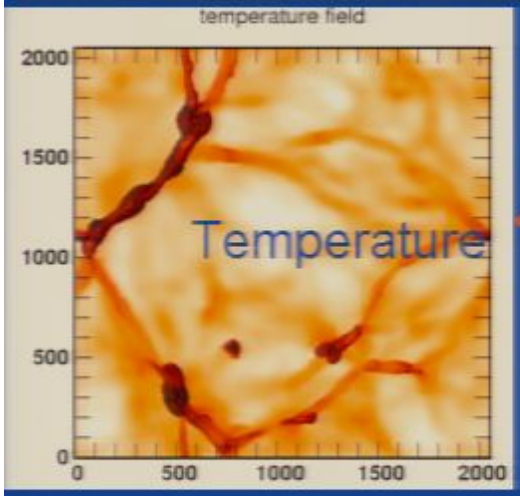
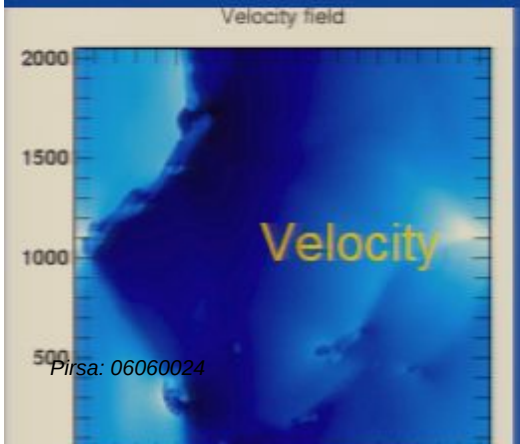
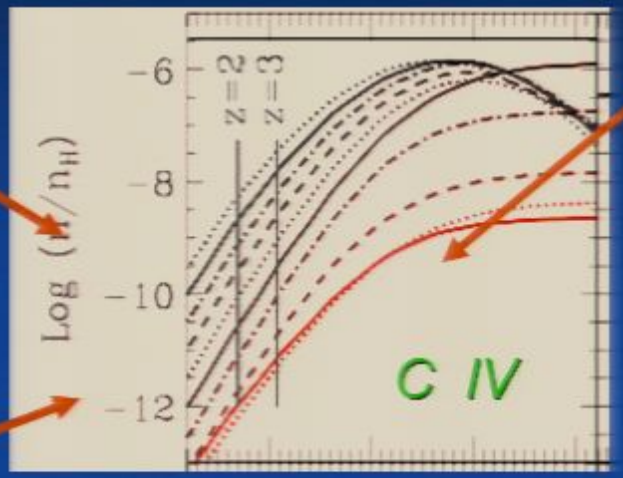


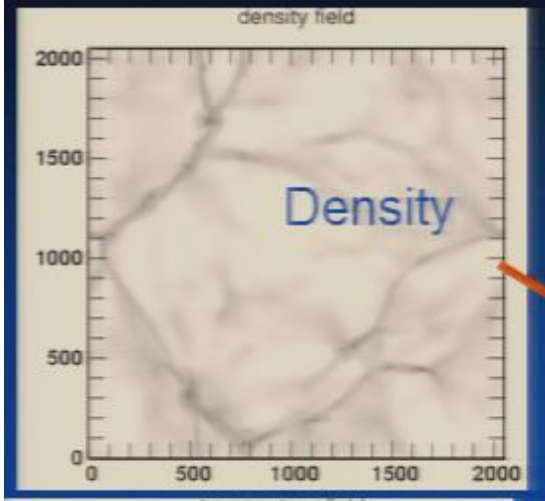


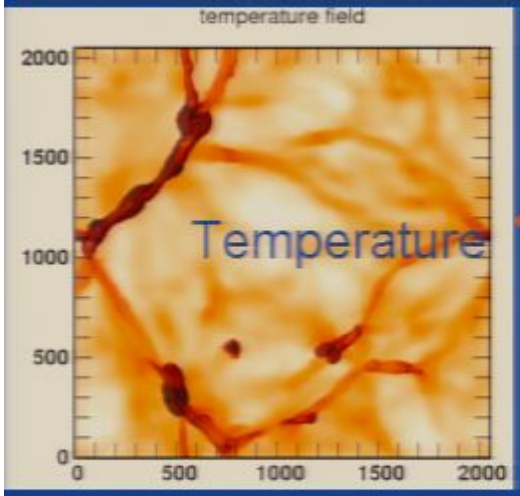


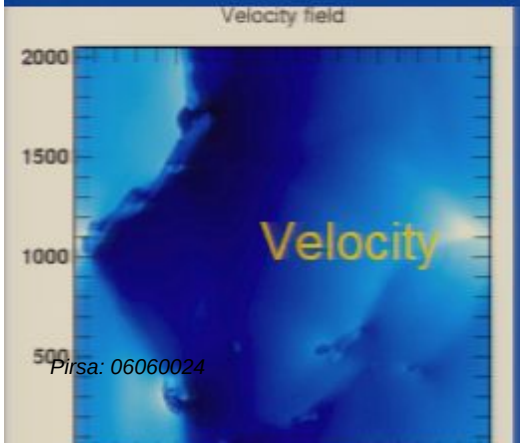


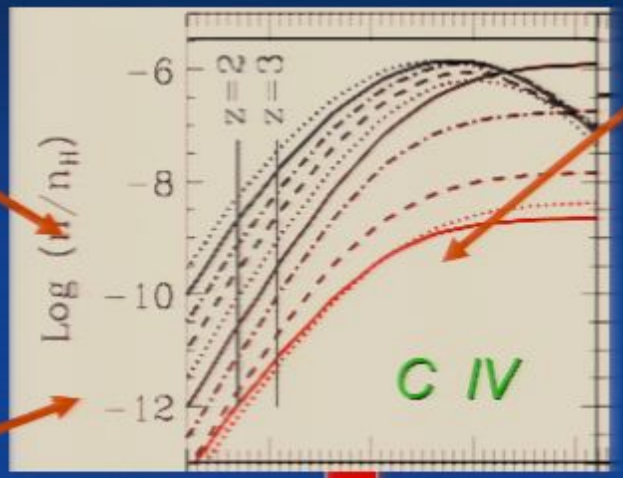
Metallicity

Synthetic Metals









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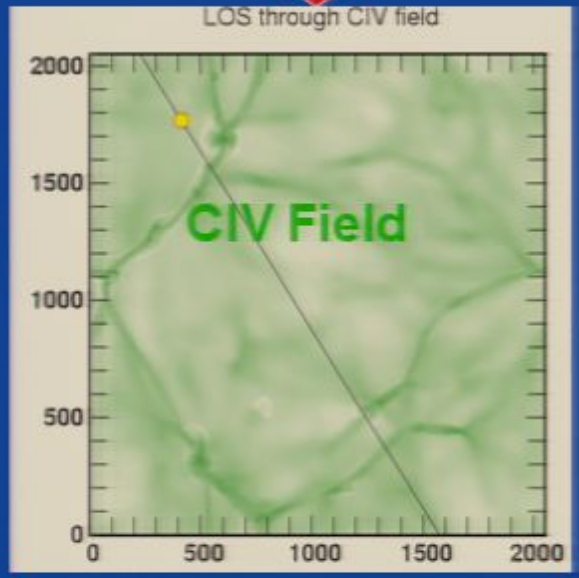

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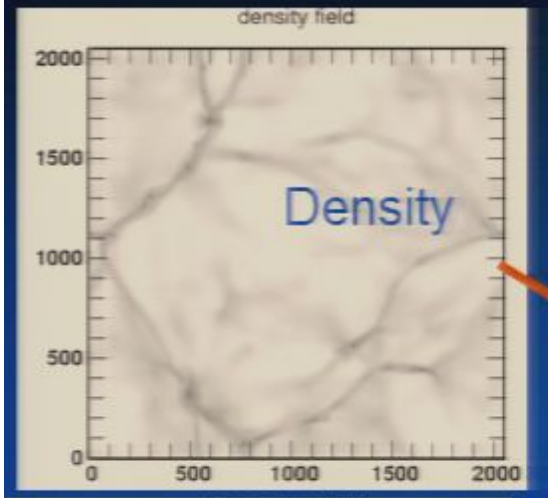

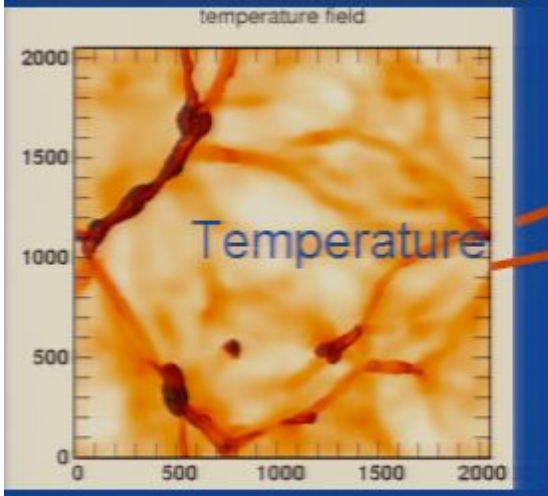

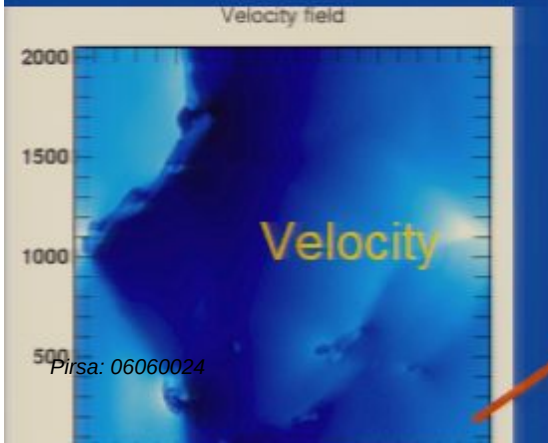

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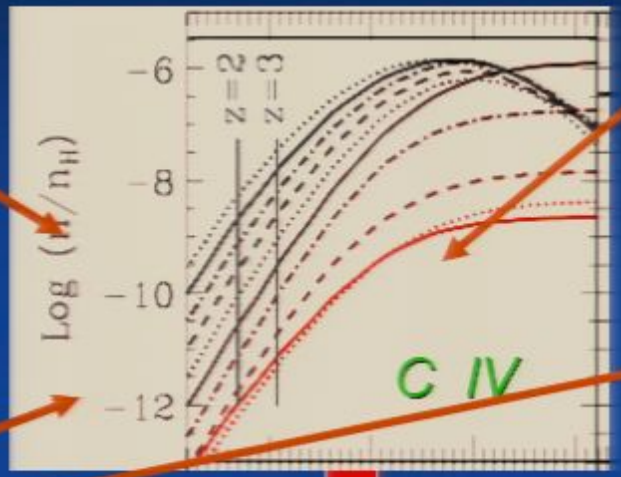
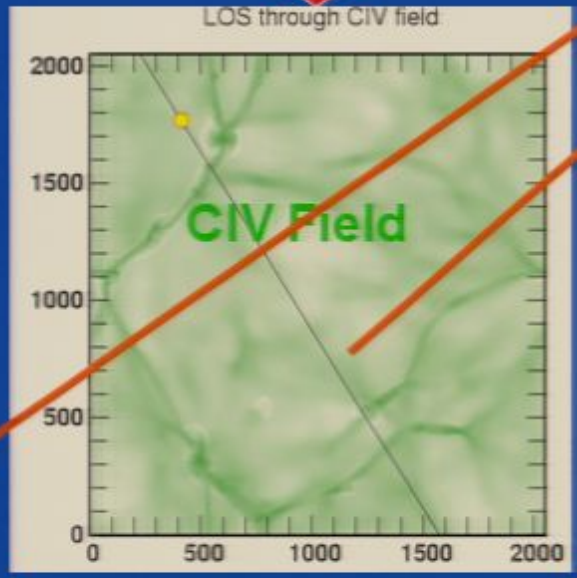
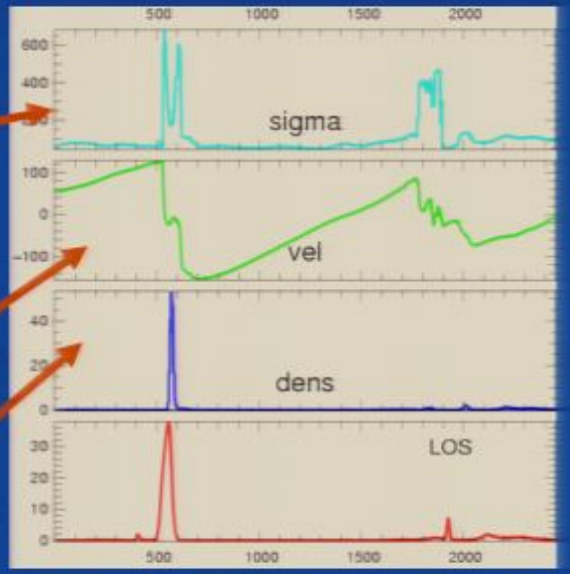
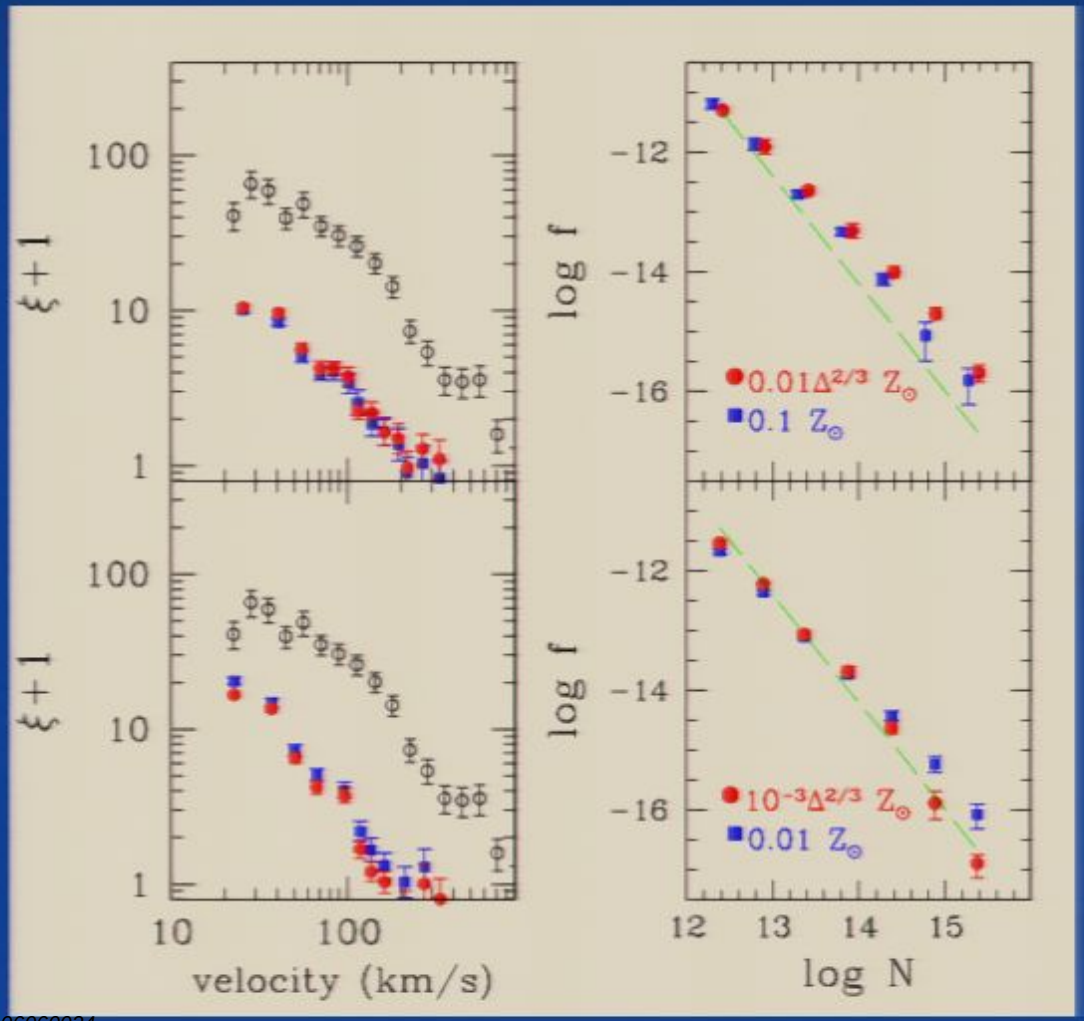






Constant Z / Local Z-Δ Relation



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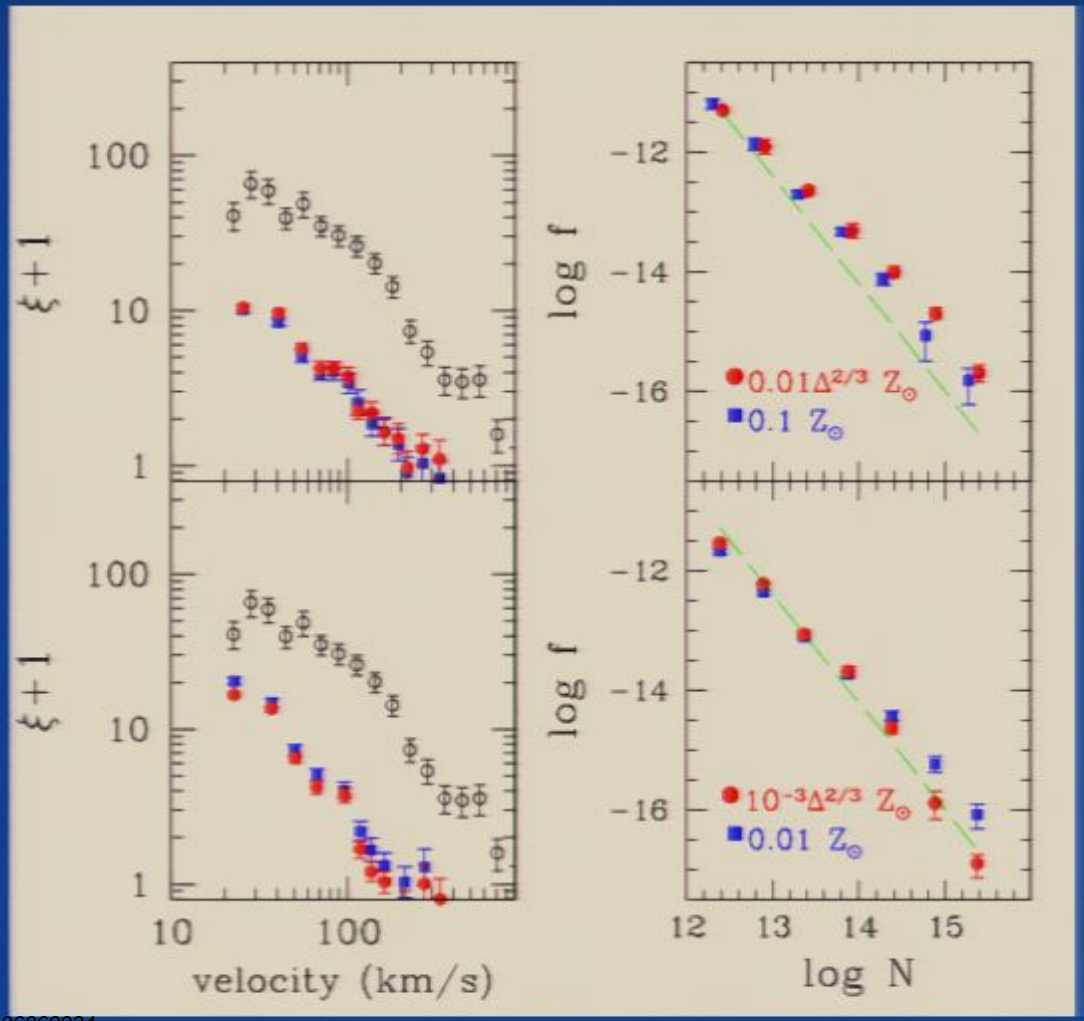
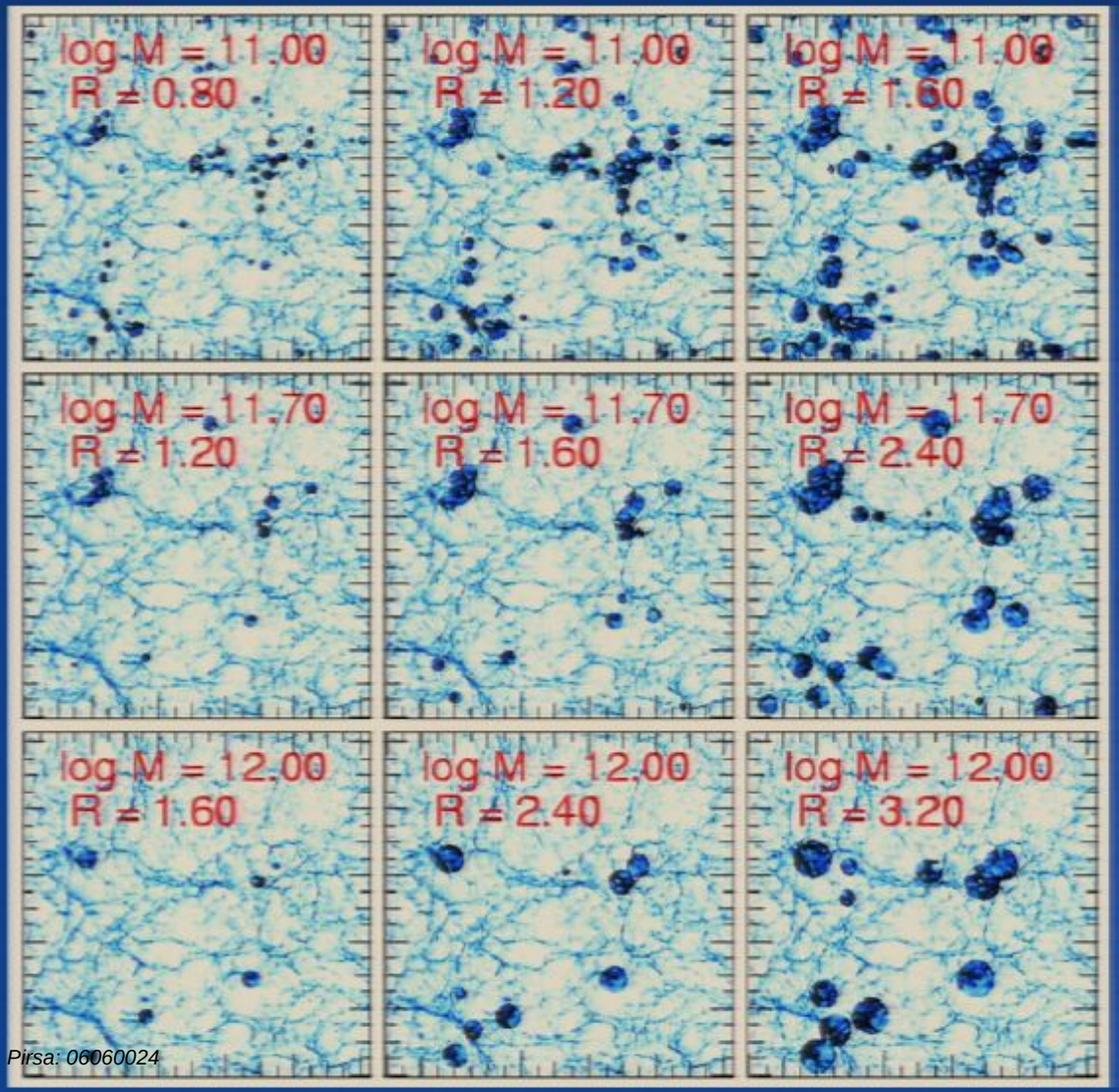


There's a Nonlocal relation!

Bubble Modeling



Paint Spheres of

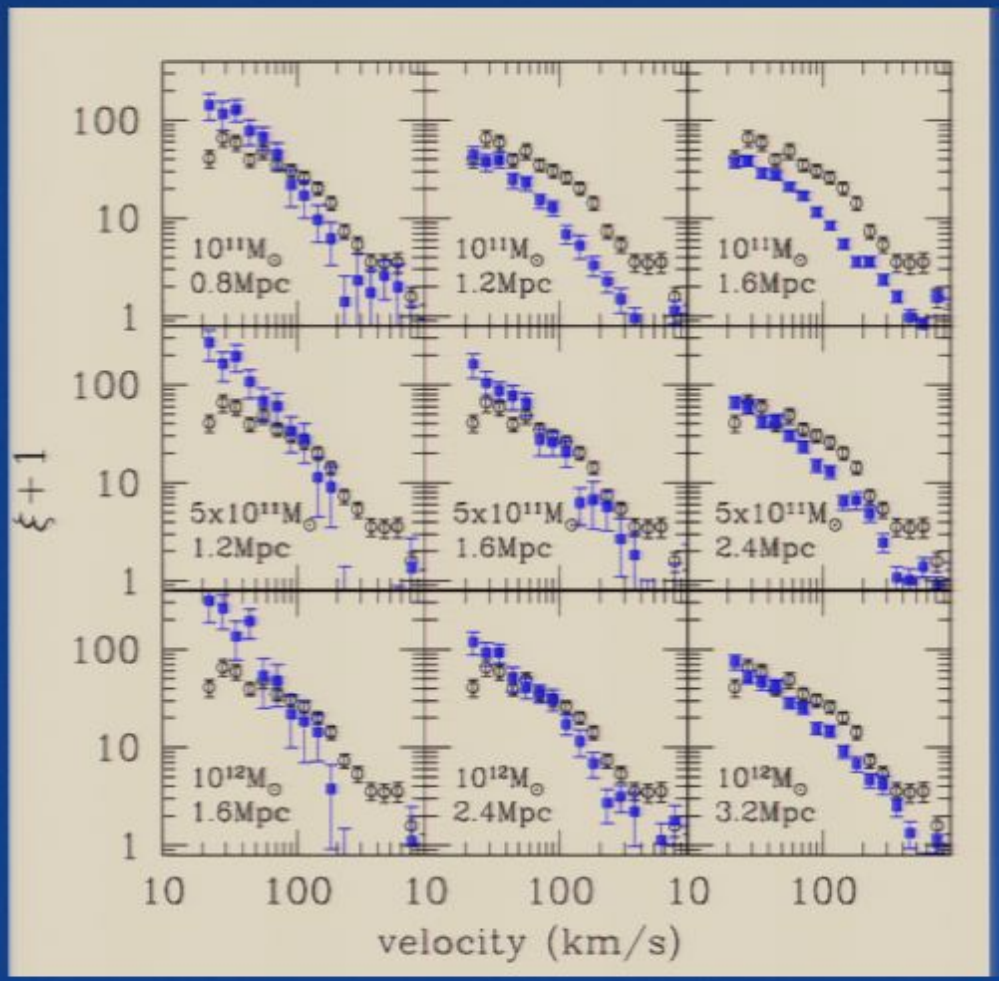
-- a fixed metallicity Z_s

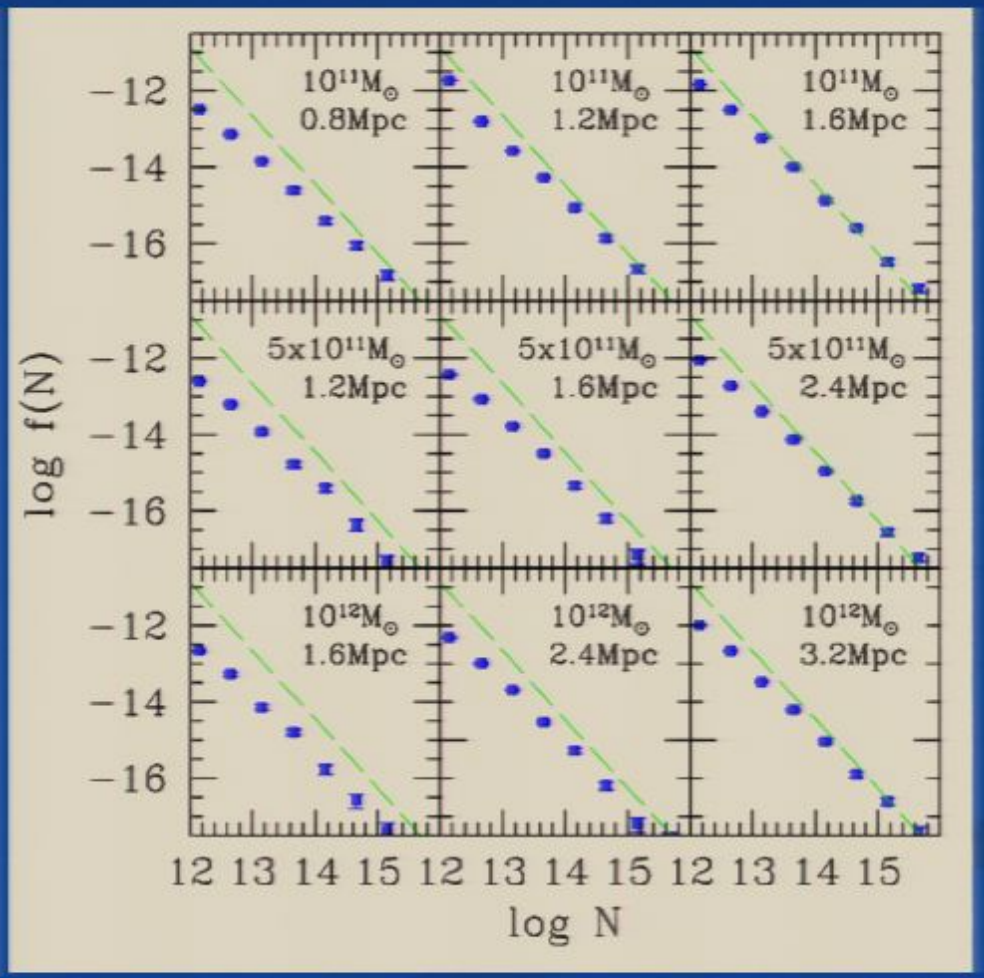
--- with a fixed radius R_s

about z=3 groups of

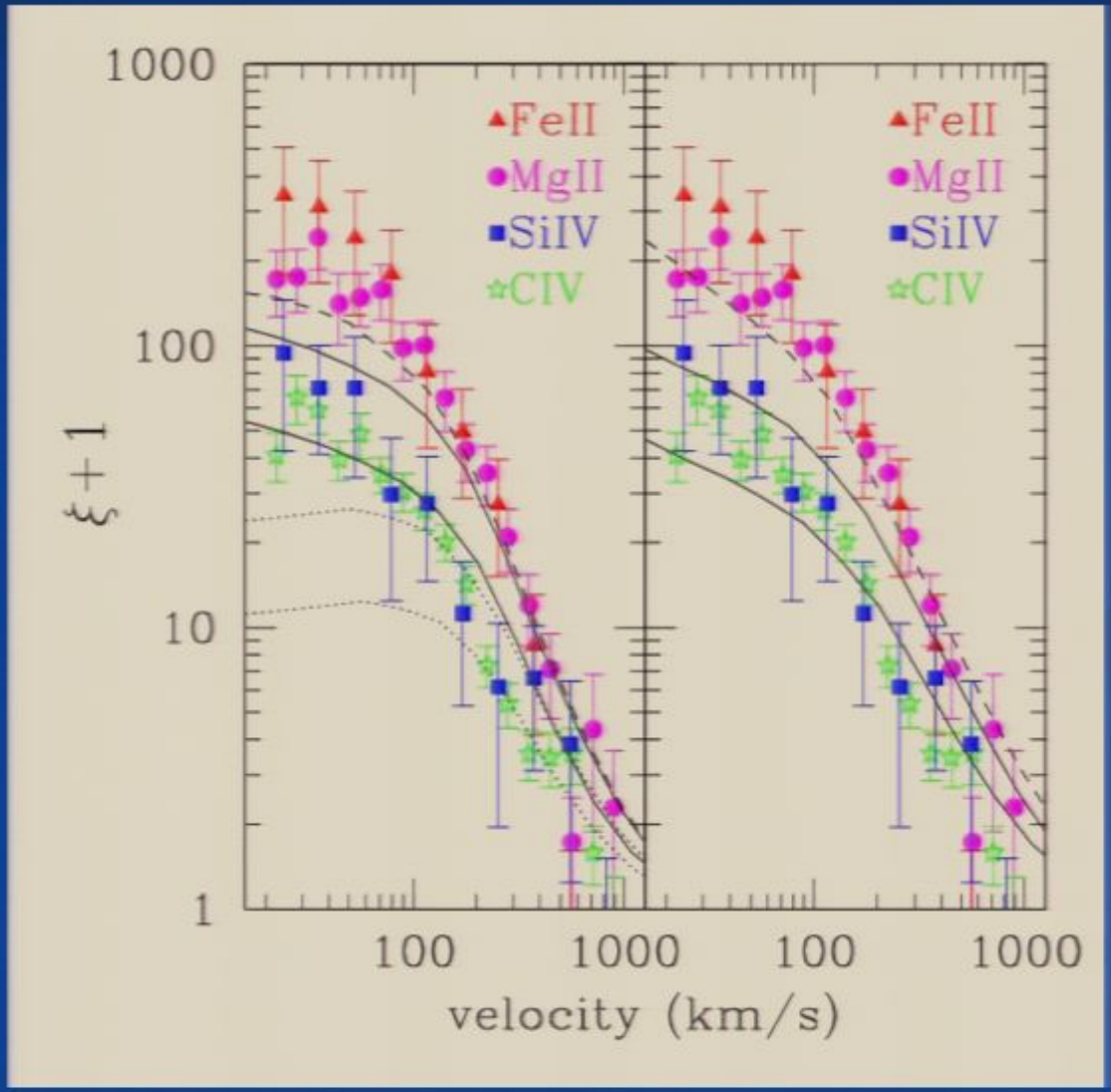
--- a fixed mass M_s

Bubble Model: Z=1/5 solar





Analytical model



Metals have been ejected into ISM by rare pollution centers identified with M=few 10^9 solar collapsed peaks at z=7.5, expanded to the radius R=1-2 comoving Mpc and then passively evolved with future clustering (at later stage nonlinear corrections should be accounted for). The picture works for both CIV/SiIV and MgII/FeII correlations, but is degenerate with respect to size of the metal sources versus redshift of pollution

Calculation: 4 point joint probability of high excursions in the Gaussian density field. Main signal – from clustering of metal sources (at large separations – as in Kaiser 1984)