The Baryon Content of Dark Matter Halos:

Hsiao-Wen Chen

(University of Chicago)
Mapping the Dark Universe
Mapping the Dark Universe

Absorption spectrum of a distant quasar
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Absorption spectrum of a distant quasar
Mapping the Dark Universe
probing halo gas on 10-100 kpc scales

Absorption spectrum of a distant quasar
Properties of MgII absorbers

- prominent doublet features at $\lambda=2796$, 2803 Å; observable in the optical window at $z = 0.3-2.5$
Properties of MgII absorbers

- prominent doublet features at $\lambda = 2796, 2803$ Å; observable in the optical window at $z = 0.3-2.5$

- photo-ionized gas of $T \sim 10,000$ K; probing warm gas in the ISM and galactic halos (Bergeron & Stasinska '86)
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- association with luminous galaxies at $\rho \leq 100 \ h^{-1} \ kpc$ (Lanzetta & Bowen ’90; Steidel +94; Kacprzak +08)
Probing halo gas with MgII absorbers

High Velocity Clouds in the Milky Way Halo

Tobias Westmeier, CSIRO Australia Telescope National Facility
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Rao et al. (2006)

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\[ \Delta v = +184 \text{ km s}^{-1} \]

Sembach+04

High velocity MgII cloud along PG1116+215

Sensitive to low column density clouds
Empirical Constraints from a Random Sample of Foreground Galaxies

Chen & Tinker (2008)
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$z = 0.892$

$\rho = 16 \, h^{-1} \text{kpc}$

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3C336

\[ z = 0.892 \]
\[ \rho = 16 \ h^{-1} \text{ kpc} \]

PKS1354+19

\[ z = 0.4592 \]
\[ \rho = 31 \ h^{-1} \text{ kpc} \]

PKS0454-22

\[ z = 0.4847 \]
\[ \rho = 76 \ h^{-1} \text{ kpc} \]
Extent of Gaseous Halos and Covering Fraction

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23 galaxies at $z=0.3-0.9$
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$\log w(2796) \, (\text{Å})$

$log \rho \, (h^{-1} \text{kpc}) + 0.14 \times (M_B-M_B^*)$

Chen & Tinker (2008)
The extent of Mg$^+$ ions scales with galaxy luminosity, $R_{\text{gas}} = 91x(L_B/L_{B^*})^{0.35}$.

The gas covering fraction is $\kappa_g \sim 100\%$ around galaxies of $> 0.2$ $L^*$, and $< 50\%$ around fainter galaxies.

Chen & Tinker (2008)
The Origin of Halo Clouds: fuel for star formation or wind remnant?

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The Origin of Halo Clouds: \textit{fuel for star formation or wind remnant?}

\begin{figure}
\centering
\includegraphics[width=\textwidth]{figure.png}
\caption{Chen & Tinker (2008)}
\end{figure}

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\textit{photoionization}
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Chen & Tinker (2008)

Chen+ '01

comparable extent between C$^3+$ and Mg$^+$
The Origin of Halo Clouds: fuel for star formation or wind remnant?

Two-phase medium: pressure confined cold clouds in hot halos

Mo & Miralda-Escudé '96; Maller & Bullock '04

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CIV

MgII profiles

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Constraining halo gas content over a broad mass range

luminous red galaxies vs. MgII Absorbers at $z = 0.4-0.7$

Visualization of SDSS DR5

Courtesy of Mark SubbaRao
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Halo Occupation of Dark Baryons

An empirical mapping between DM halos and baryons through a statistical approach.

Tinker & Chen (2008)
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DATA

frequency distribution function + 2-pt clustering amplitude

Prochter et al. (2006)
Steidel & Sargent (1992)

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Bouché et al. (2006)

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MODEL
known dark matter halos
+ *gaseous halo profile*

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- density profile: \((r^2+a^2)^{-1}\)
- gaseous extent: \(R_g = \frac{1}{3} R_{200}\)
- mass dependence: \(M_h^{1/3}\)

\[
W(s|M) = \frac{W_0 \sigma_{cl} f_g}{M_{cl}} \times \int_0^\infty \rho(\sqrt{s^2 + l^2})dl
\]

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RESULTS

$P(W|M_h)$: incidence and extent of cold gas vs. DM halo mass

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*the data demand a transition in the halo gas content*

Tinker & Chen (2008)
Comparisons with Theoretical Expectations

The growth of hot halos vs. halo mass

Keres et al. 2005

Tinker & Chen 08

Keres et al. 2005
Summary

- A self-consistent model is established to characterize the origin of absorption systems uncovered in QSO spectra.

- A larger galaxy-absorber pair sample allows a detailed investigation of $\kappa_g$ vs. $L_B$ (a proxy of $M_h$) and $\kappa_g$ vs. $\rho$. 
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*individual probes*

**A MagE survey of MgII in SDSS galaxies**

J.-R. Gauthier, J. Helsby, J. Tinker, S. Shectman, I. Thompson
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2D map of individual halos

Thilker+ '04

~ 10 kpc