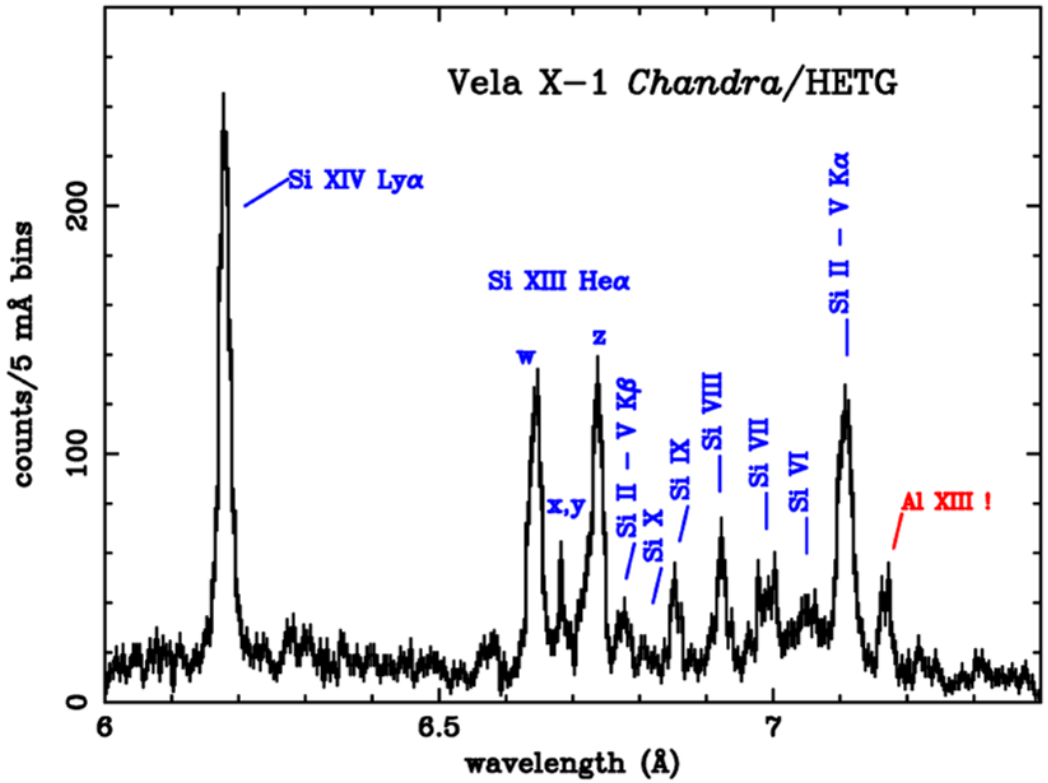
Most surprising ('bizarre') spectra: X-ray binaries



(Courtesy Masao Sako, Stanford)
(see also Watanabe et al. 2006)

Complete K-shell spectrum of Si!

(presence of both highly ionized, tenuous material, as well as large amounts of near-neutral Si (unknown!) in stellar wind from companion)

The Warm/Hot Intergalactic Medium (with IXO)

Frits Paerels

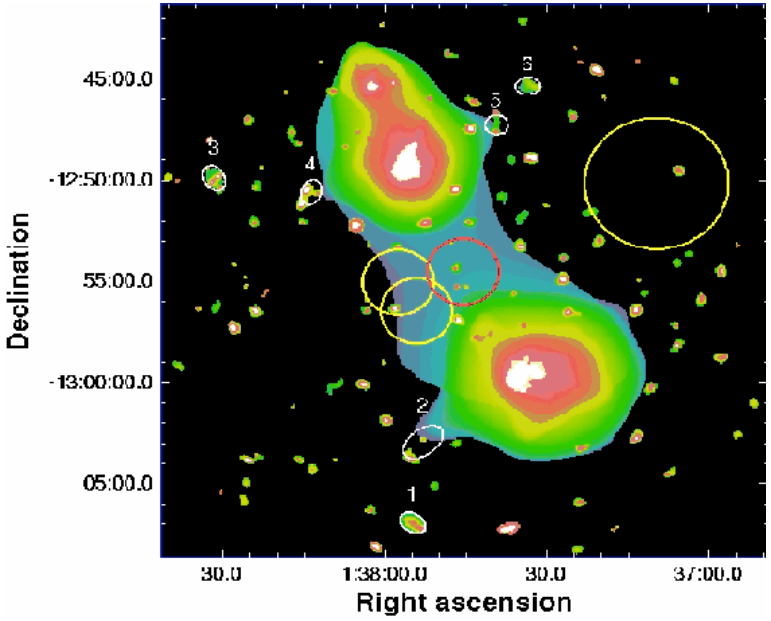
Columbia University

Unvirialized Intergalactic Gas

currently ($z < 1$) collapsing in LSS potential,
$\delta \sim 10\text{-}100$, $T \sim 10^{5\text{-}7}$ K

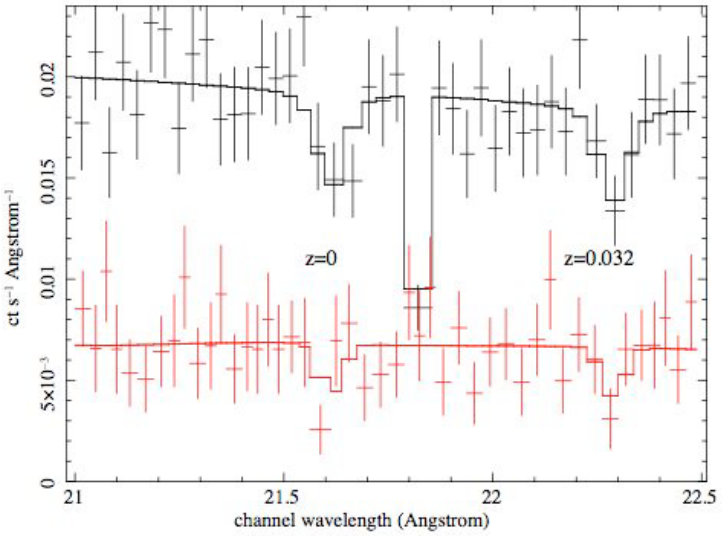
Major baryon reservoir (up to half of Ω_b)

Highy ionized; metallicity ?

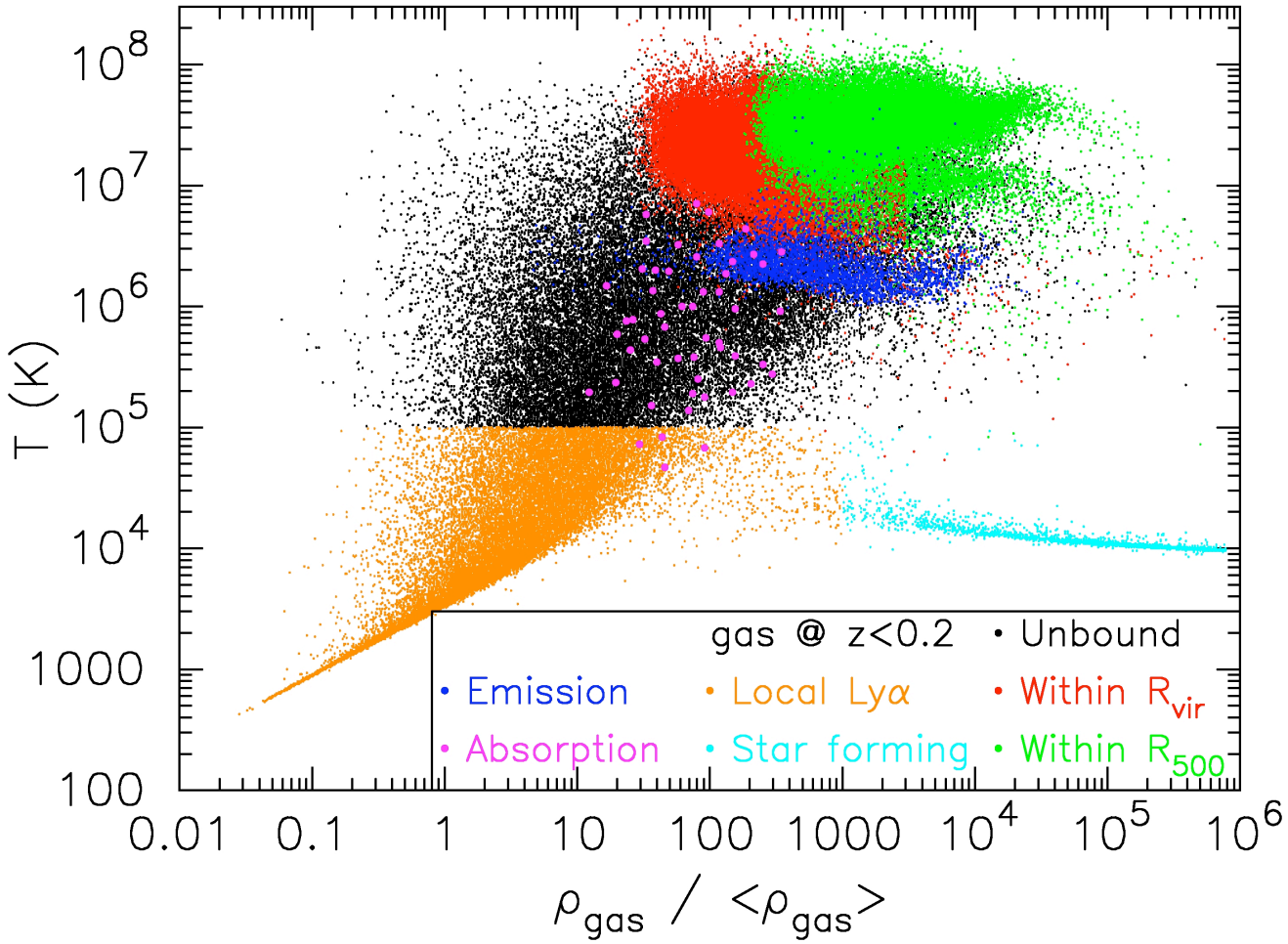


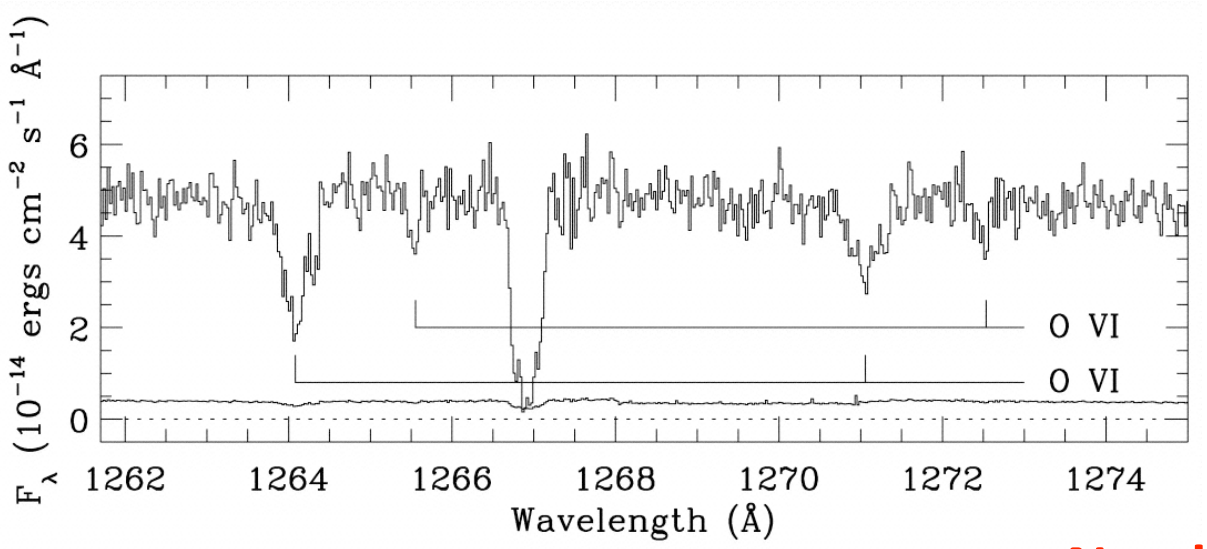
Norbert Werner et al., AA, 2008

H2356-309/Sculptor XMM/RGS



David Buote et al., yesterday


T (K)
10^8
10^7
10^6
10^5
10^4
1000
100
0.01
0.1
1
10
100
1000
10^4
10^5
10^6
ρ_{gas} / $<\rho_{gas}>$
gas @ z<0.2
• Unbound
• Emission
• Local Lyα
• Within R_{vir}
• Absorption
• Star forming
• Within R_{500}

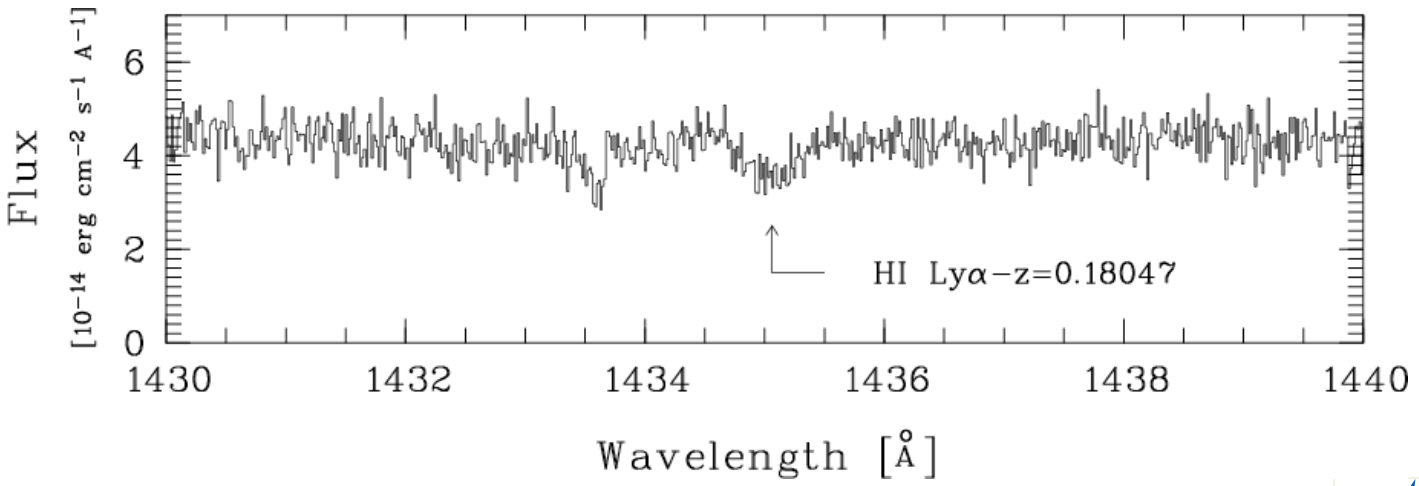


O VI: transient, thermally unstable

O VI FUV absorption (z=0.22497,0.22637);
H1821+643; Tripp , Savage, Jenkins, 2000, *ApJ*, **534**, L1

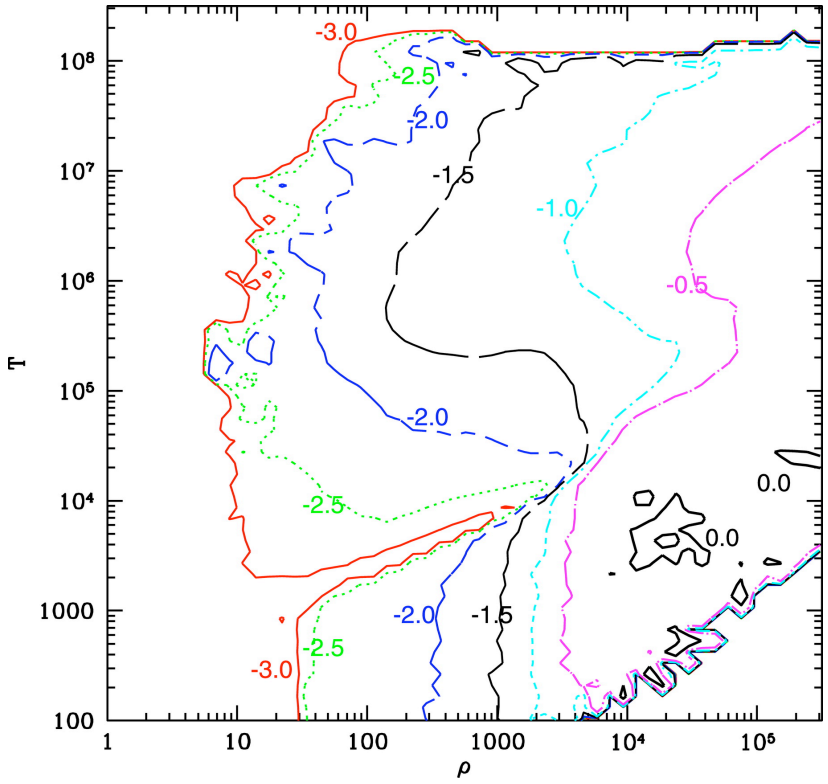
Need X-ray spectroscopy !

neutral H:
f <<< 1

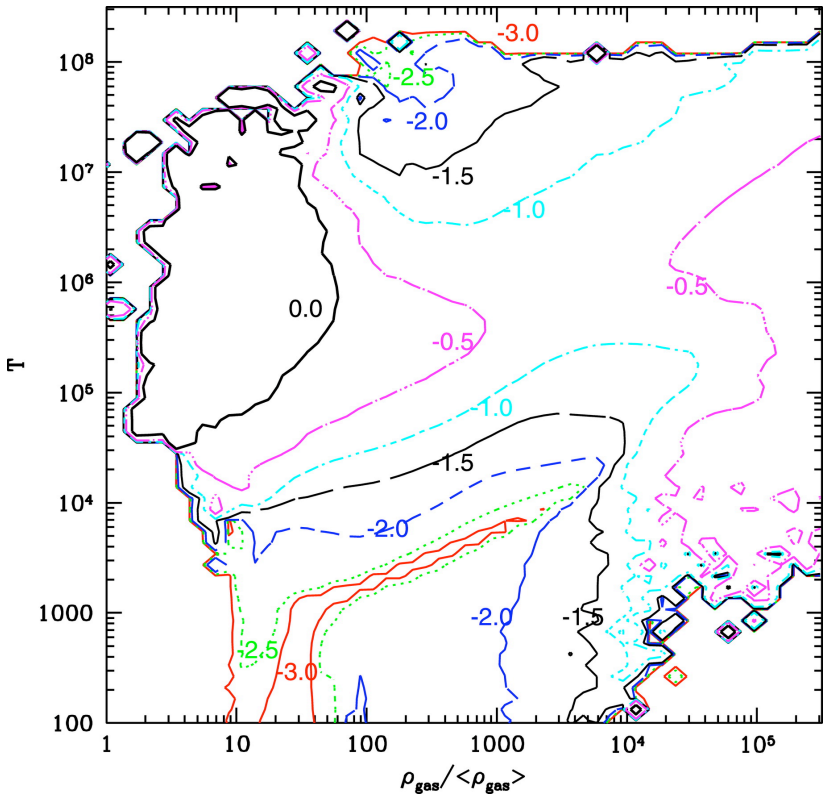


Broad Lyα (z=0.18047): b=52 km/s, T ~ 3.10^6 K;
Richter et al., 2006, *Astron.Astrophys.*, **445**, 827

Which WHIM?



No galactic Superwinds



With galactic Superwinds

Cen & Ostriker, 2006

Spectroscopic Requirements

OVII, OVIII n=1-2:

Expected Equivalent Width:

thermal width $\Delta v = (kT/m)^{1/2} = 23 T_6^{1/2}$ km/sec

Saturation at column density

$N = 2 \times 10^{15} (\Delta v/23 \text{ km/s})$ cm^{-2}

Compare: $N = 3 \times 10^{14} \delta (l/10 \text{ Mpc}) \{(Z/Z_0)/0.1\}$ cm^{-2}:

saturation at $\delta \sim 10$!

With only thermal broadening, we are looking at

EW ~ 30 km/sec

$\Delta E \sim 0.05$ eV

$\Delta\lambda \sim 2$ m Å

IXO Absorption Spectroscopy

X-ray Grating Spectrometer, R ~ 3000, A ~ 3000 cm^2:
Of order 150 continuum sources accessible (F > 2E-11 cgs);
Sample of 30 AGN/ 6 Msec: 100 O VII columns, > $10^{14.5}$ cm^{-2}

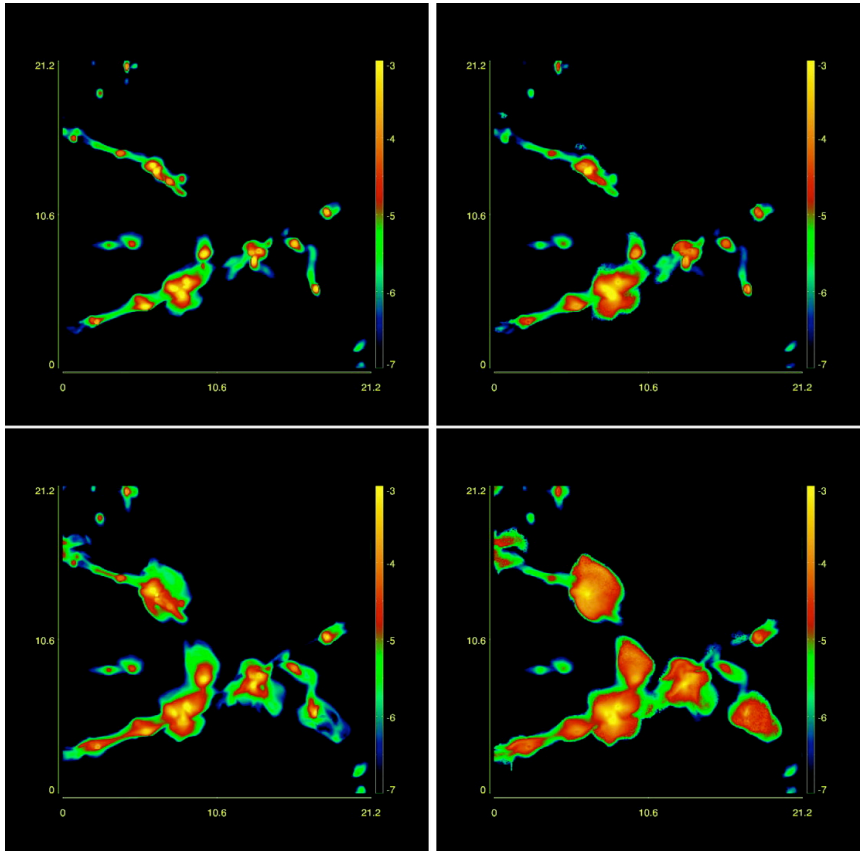
Will be difficult with 2 eV microcalorimeter,
down to similarly small column densities

For larger EW systems, grating spectrometer can determine velocity shifts/splits/widths- crucial when making connection to material traced by O VI (COS); sorting primordial/GSW gas; properties of GSW regions

Most systems will be SWG-blown WHIM (missing baryon problem harder):

Observe metal/energy injection; metal transport

O VII



O VIII

No GSW

With GSW

Emission line imaging with IXO

Expected intensity (OVII, VIII; primordial WHIM):

$I \sim 0.1\text{-}1$ photon $cm^{-2}\ s^{-1}\ sr^{-1}$

IXO XCS grasp: $\sim 2 \times 10^{-2}\ cm^2\ .\ sr$

$r \sim 2 \times 10^{-3,-2}$ counts/FOV/sec, or
200-2000 line photons/FOV/100Ksec (!)

And (much) higher near clusters

Four Key Problems

Are the 'missing baryons' in the predicted phase?

Test structure and heating of the Web by galactic superwinds

Determine extent of superwinds, and chemical enrichment/mixing

Spatial structure of the filaments, and clusters and groups