Are we really tracing the WHIM or is it just outflows?

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We investigate the impact of feedback (SN, AGN) and metal-line cooling on the predicted distribution of gas mass and heavy elements over various phases at low redshift, focusing our attention on the warm-hot ($5 \lesssim \log(T/\mathrm{K}) \lesssim 7$), diffuse ($\Delta \lesssim 10$) phase. Using a model which includes feedback and metal-line cooling, we further study the physical state (temperature, density) and chemical enrichment of gas detected in absorption by broad H I Lyα absorbers (BLA; $b_{\mathrm{H\,I}} > 40\,\mathrm{km\,s^{-1}}$), O VI, and Ne VIII.

Approach

We use high-resolution, cosmological, hydrodynamic simulations from the OverWhelmingly Large Simulations project (*OWLS*, Schaye et al. 2010), using a 50 Mpc/h Box at z = 0.25. We focus on four particular models:

MODEL	FEEDBACK	METAL-LINE COOLING
NOSN_NOZCOOL	χ	χ
NOZCOOL	✓ (SNIIe)	χ
REF	✓ (SNIIe)	✓
AGN	✓ (SNIIe, AGN)	✓

Main Findings

- Accretion shocks due to gravitational infall into the potential wells of dark matter halos heat ~ 30 per cent of the total gas mass to temperatures $T \geq 5 \times 10^4$ K by $z = 0.25$ (Fig. 1, top-left panel).
- Feedback by SNe and AGN each displace ~ 15 per cent of the gas from the ISM in halos to the warm-hot diffuse; thus, roughly half of of the gas mass predicted to be in the WHIM at low redshift (~ 60 per cent) has been heated by accretion shocks while the other half is due to strong feedback (Fig. 1, top-left panel).
- Feedback is required to transport metals to IGM; the distribution of heavy elements is highly sensitive to feedback and metal line cooling (Fig 1, top-right panel).
- The warm-hot gas is predicted to have a metallicity $Z \sim 0.1\ Z_\odot$ (Fig. 1, bottom-left panel); most metals reside in high-metallicity gas with $Z \gtrsim 0.1\ Z_\odot$ (Fig. 1, bottom-right panel).
- BLAs, O VI and Ne VIII absorbers typically trace gas at $\Delta \sim 10$ and $\log(T/\mathrm{K}) \sim 5-6$, but contain only a few percent of the baryons in the warm-hot, diffuse gas phase (Fig. 4).

→ strong evidence that these type of absorbers are tracing outflows rather than in-falling, shock-heated gas

- Detection of the bulk of warm-hot gas requires a sensitivity (in terms of the H I central optical depth) of $\log \tau_0 \lesssim -2$ (or $f_{\mathrm{H\,I}} \sim -6.5$).

* For more details see Tepper-García et al. (2011, 2012)

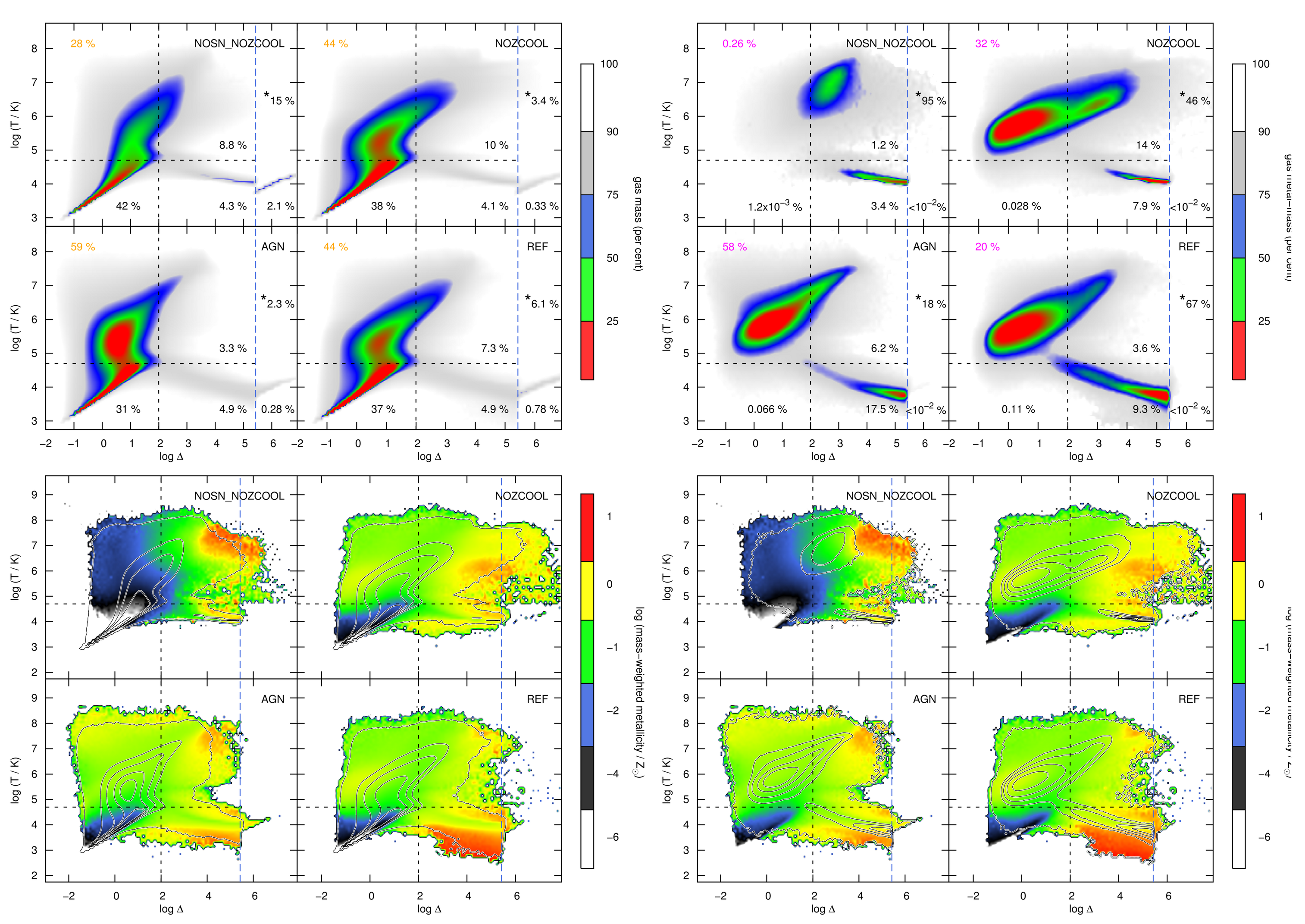
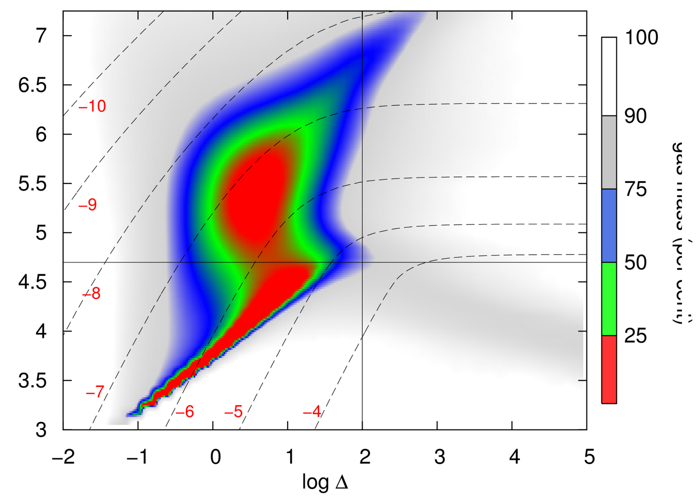


Figure 1. *Top:* Distribution of gas mass (left) and gas metal mass (right) over various phases predicted by different models (see Tab. 1). The vertical (horizontal) dotted line indicates the density (temperature) threshold at $\Delta = 10^2$ ($T = 5 \times 10^4$ K) that separates unbound (cool) from collapsed (warm-hot) gas. The region to the right of the blue dashed line shows the high-density, star-forming gas with physical densities $n_{\mathrm{H}}^* \geq 0.1\,\mathrm{cm^{-3}}$ (or $\Delta \gtrsim 3 \times 10^5$ at $z = 0.25$). The coloured areas show the cumulative gas (metal) mass (in per cent) indicated by the colour bar on the right. The percentages in each panel show the baryon mass (metal mass) fraction in the corresponding phase defined by the temperature/density thresholds; the baryon mass fraction in the diffuse, warm-hot gas is highlighted in orange (magenta). The starred percentage indicates in each case the baryonic mass fraction in stars. The left panels show the effect of our two most extreme scenarios, i.e. including both feedback by SNII and AGN with respect to neglecting feedback altogether; the right panels show the effect of neglecting radiative cooling by heavy elements. Clearly, feedback by SNII (and AGN) heats a significant amount of gas above temperatures $T = 5 \times 10^4$ K, with the WHIM fraction increasing from 28.5 per cent (top-left) to 58.8 per cent (bottom-left). Interestingly, the IGM fraction only changes by ~ 10 per cent, indicating that feedback shifts a large fraction of the ISM from haloes into intergalactic space. *Bottom:* Gas metallicity of various gas phases as predicted by different models. The coloured areas show the gas metallicity (in solar units) indicated by the colour bar on the right. The contours in each panel indicate the gas (metal) mass distribution shown in the corresponding panel in the top row.



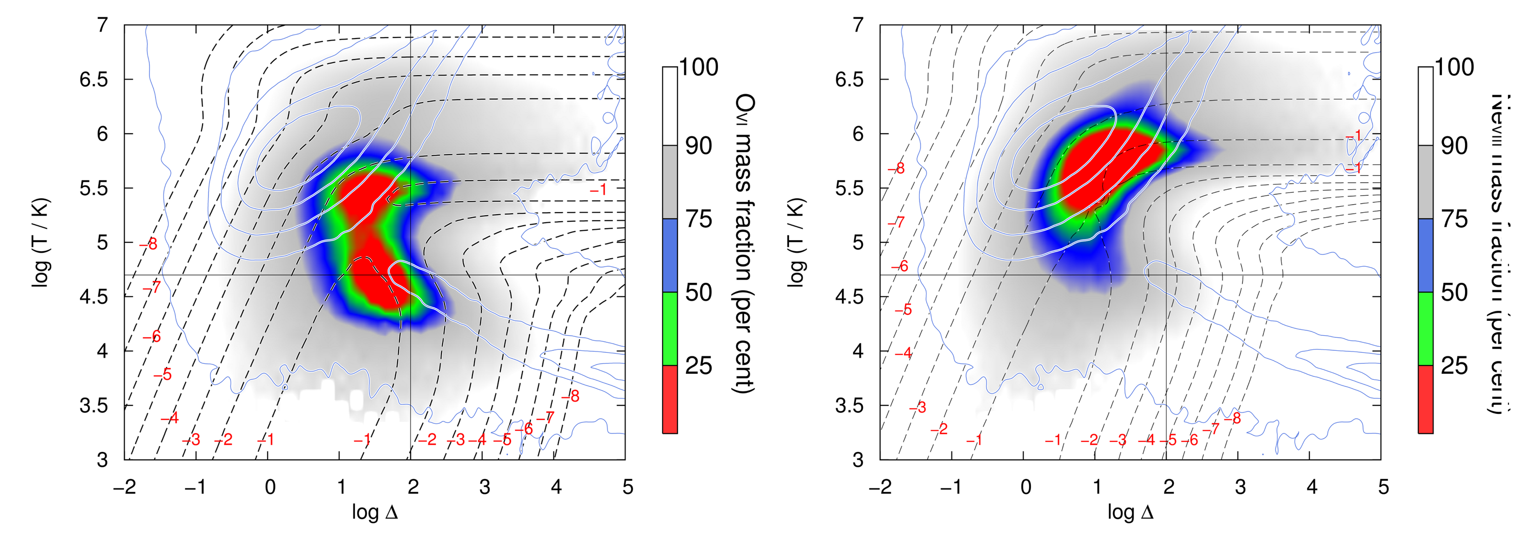


Figure 2. Ion mass-weighted distribution on the temperature-density plane (*AGN* model). *Top-right:* H I. *Bottom-left:* O VI. *Bottom-right:* Ne VIII. In each panel, the coloured areas show the cumulative gas mass (in per cent) indicated by the colour bar on the right; the contours indicate the corresponding ion fraction (i.e. H I, O VI, or Ne VIII) in ionisation equilibrium; the logarithmic value is indicated next to the corresponding contour.

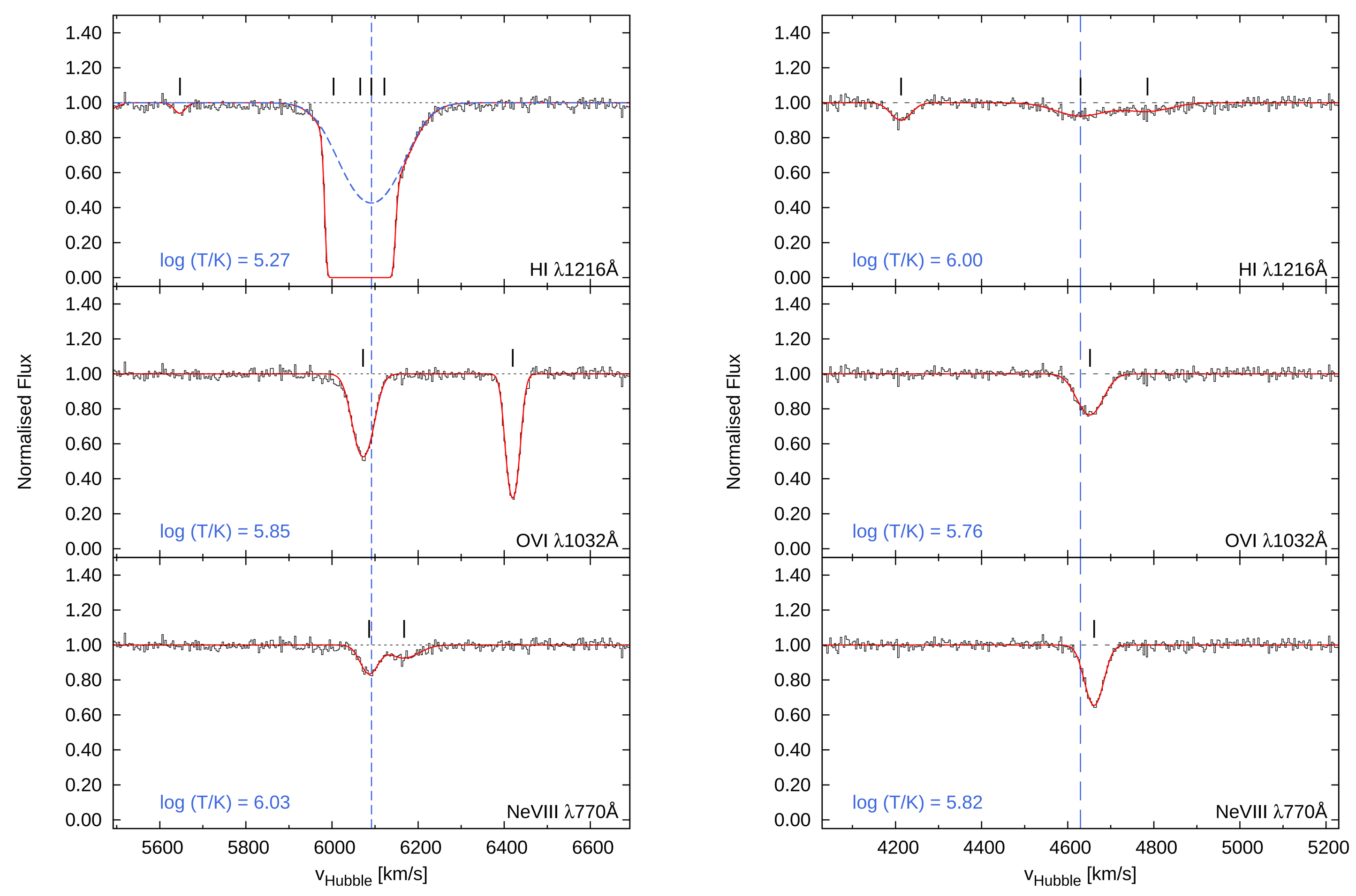


Figure 3. Examples of synthetic spectra with S/N=50 (black) and corresponding fits (red) displaying systems featuring absorption by H I (top), O VI (middle), and Ne VIII (bottom), which arise in gas at temperatures $\log(T/\mathrm{K}) \sim 5-6$. The top-left panel shows a broad H I absorption line (BLA) which overlaps with a strong H I absorption feature, corresponding to a multi-phase systems. The right panel shows a very weak BLA arising in highly ionised, highly enriched gas.

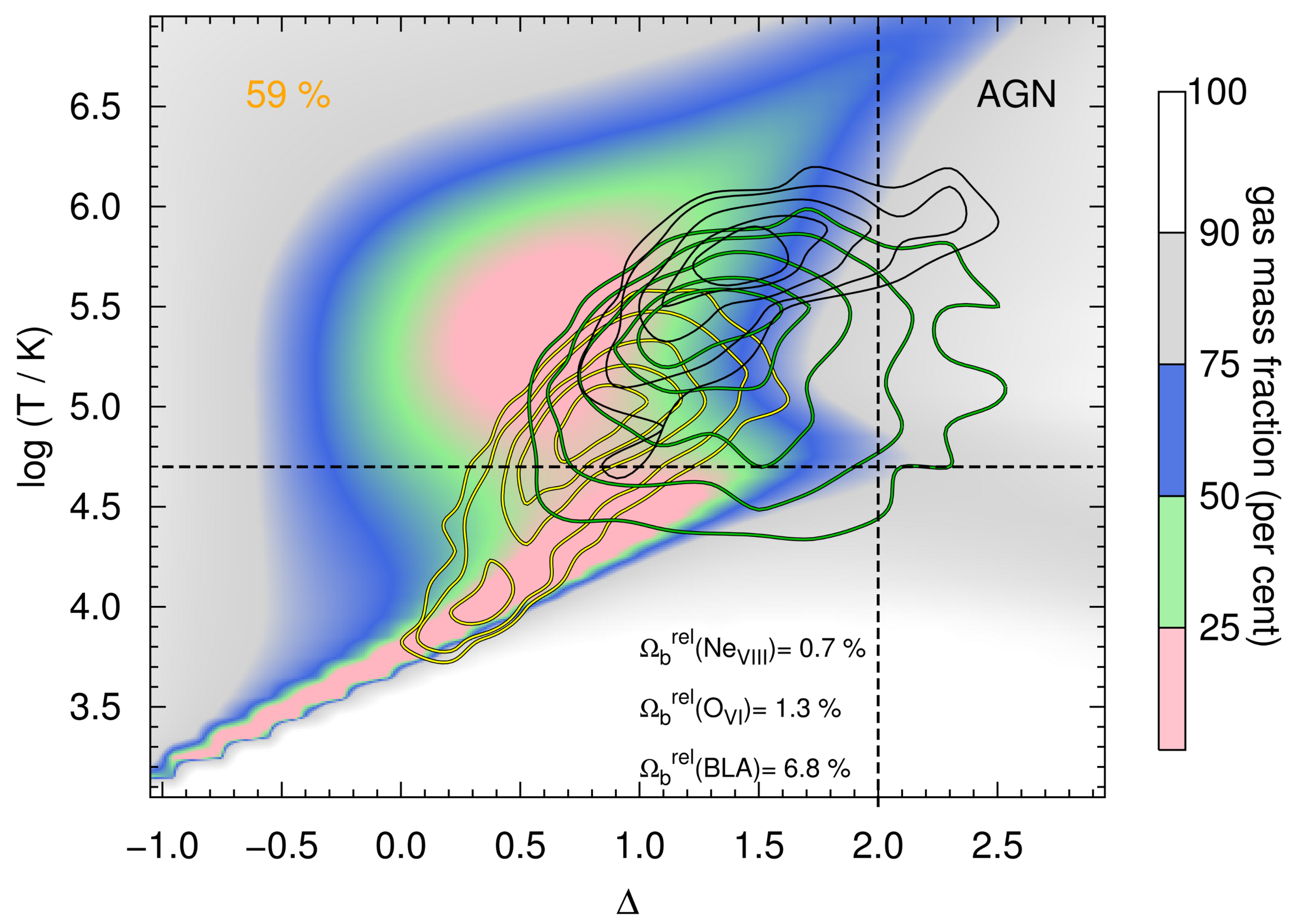


Figure 4. Distribution of temperature and overdensities of the gas traced by BLAs (yellow contours), O VI absorbers (green contours), and Ne VIII absorbers (black contours) identified in spectra with S/N=50 at $z = 0.25$ (*AGN* model). The coloured areas show the distribution of gas mass over various phases and are identical to the distribution shown in the corresponding inset in the top-left panel of Fig. 1. The numbers quoted as Ω_b^{rel} indicate the amount of baryons, relative to the cosmic mean baryon density, traced by each type of absorber.