HI Gas and Metals through Comic Times

Céline Péroux

Observatoire Astronomique de Marseille Provence

PLAN

- *Cosmic evolution of the HI gas mass*
- *The missing metals problem*
- *Metallicity of HI gas*
- *Metallicity of ionised gas*

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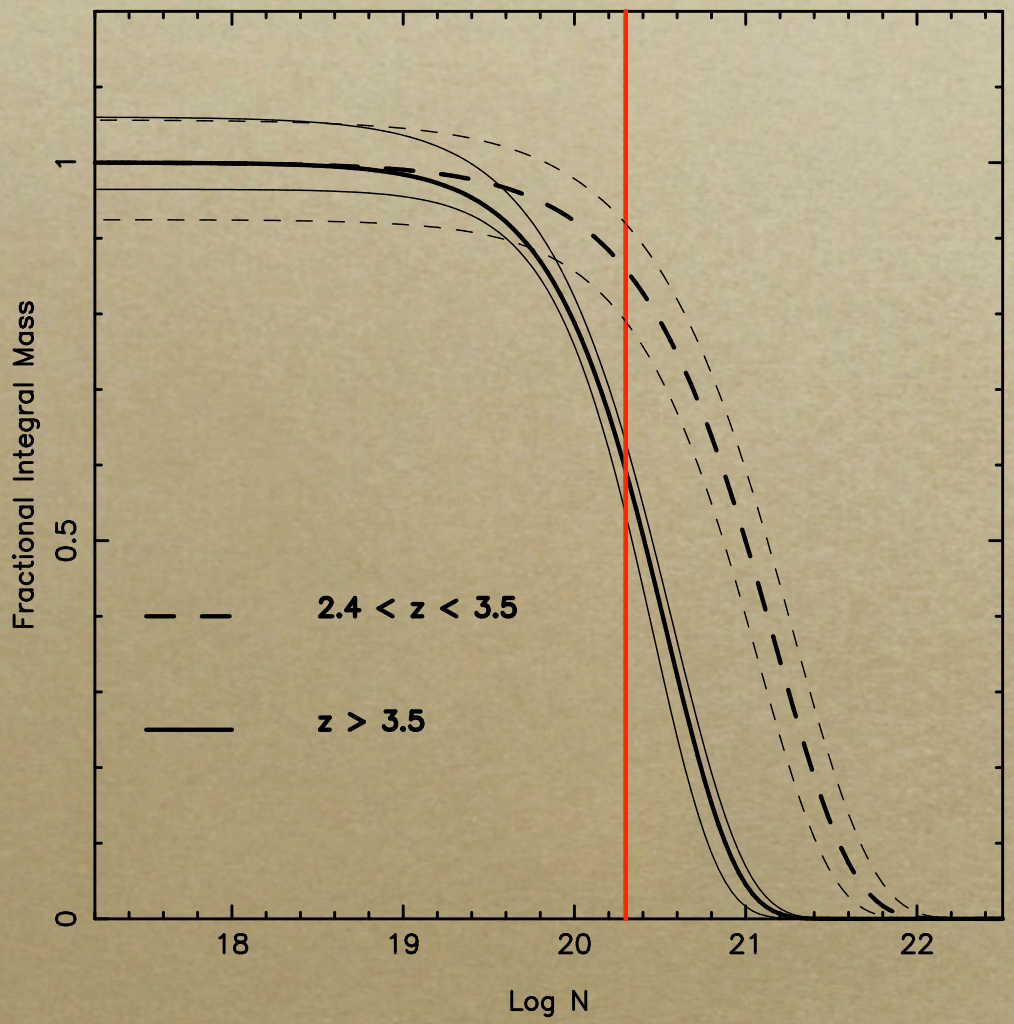
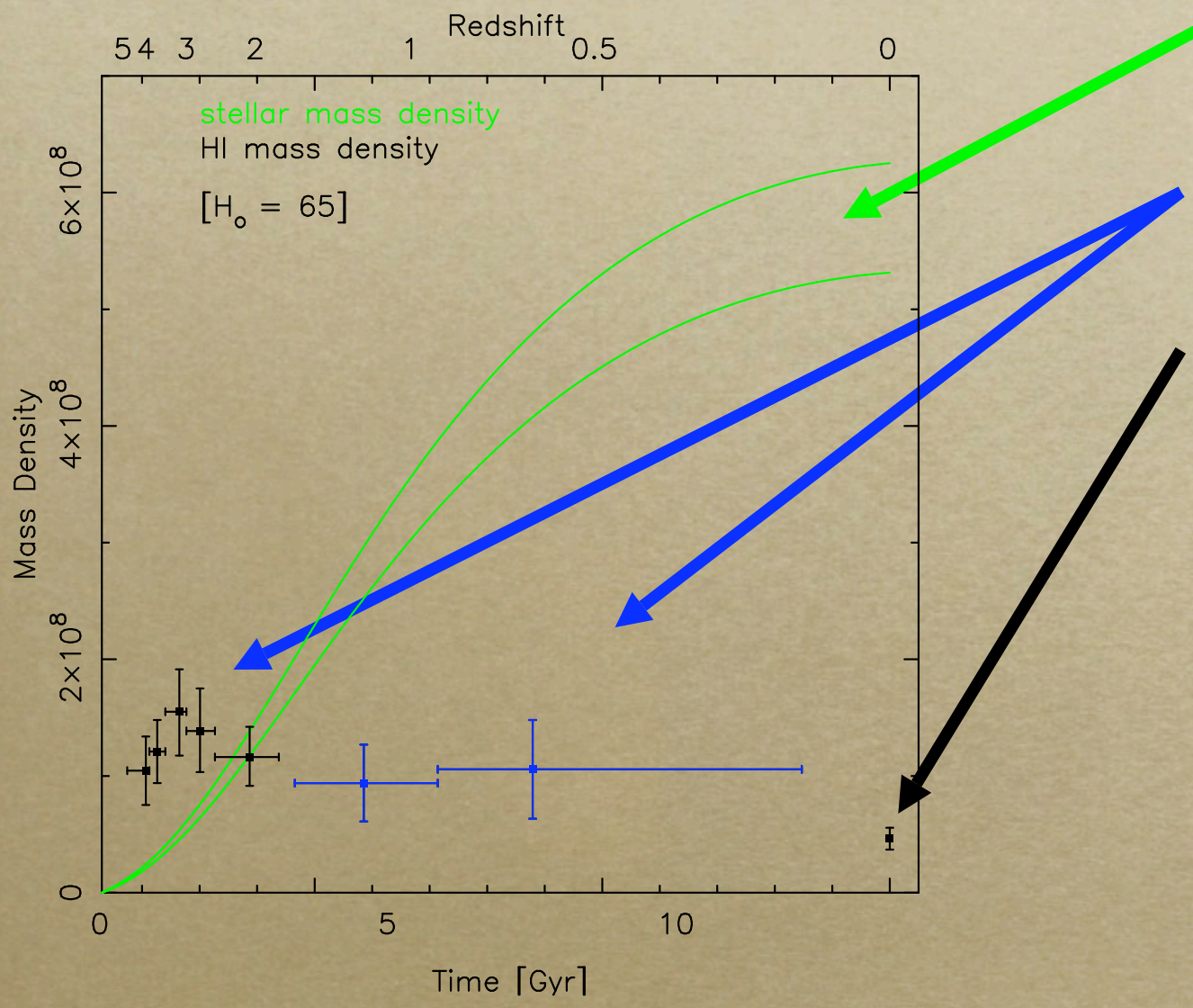
Sub-DLAs



- *Sub-DLA with log N(HI)>10^{19} cm^{-2}*

(Péroux, et al. 2003)

HI Gas through Cosmic Times



STARS

HI GAS

LOCAL GALAXIES

(Prochaska et al. 2005 & Péroux, et al. 2005)

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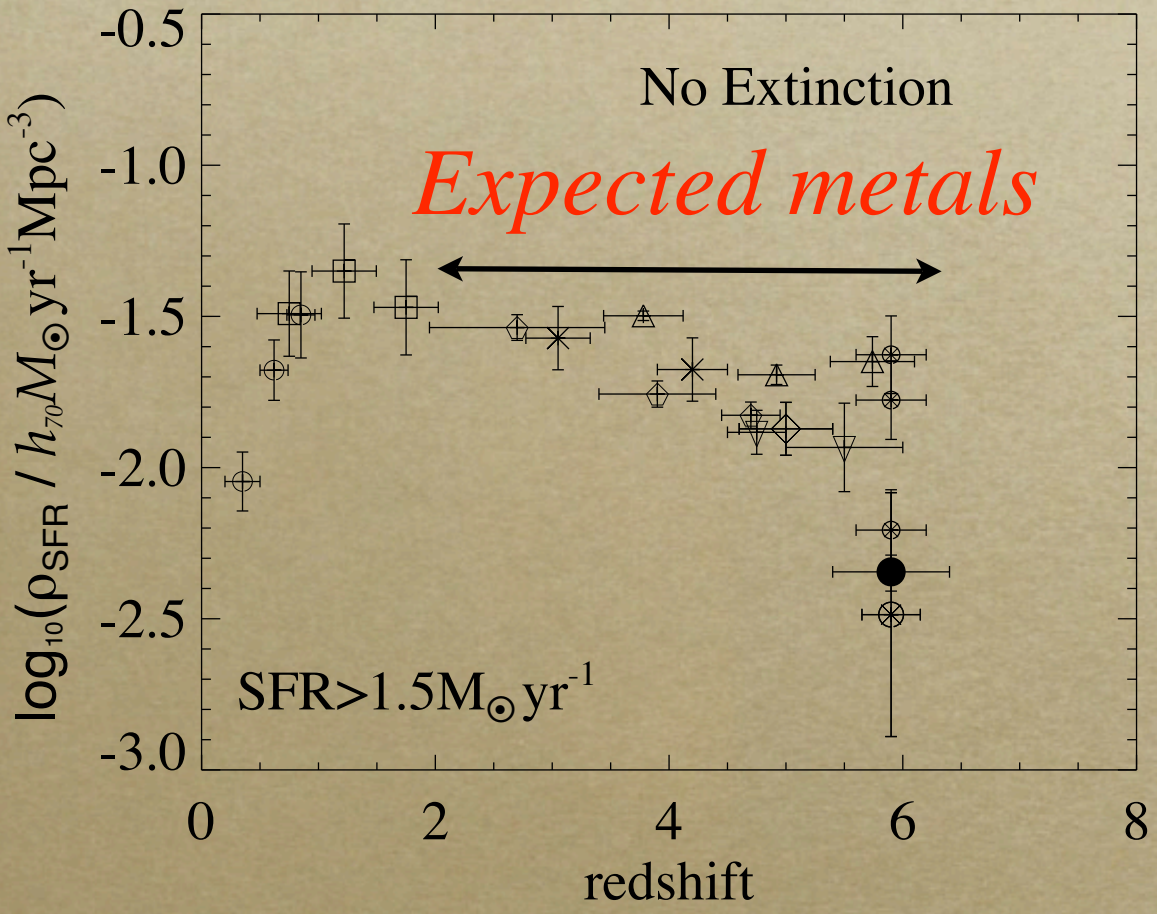
Expected Metal Production

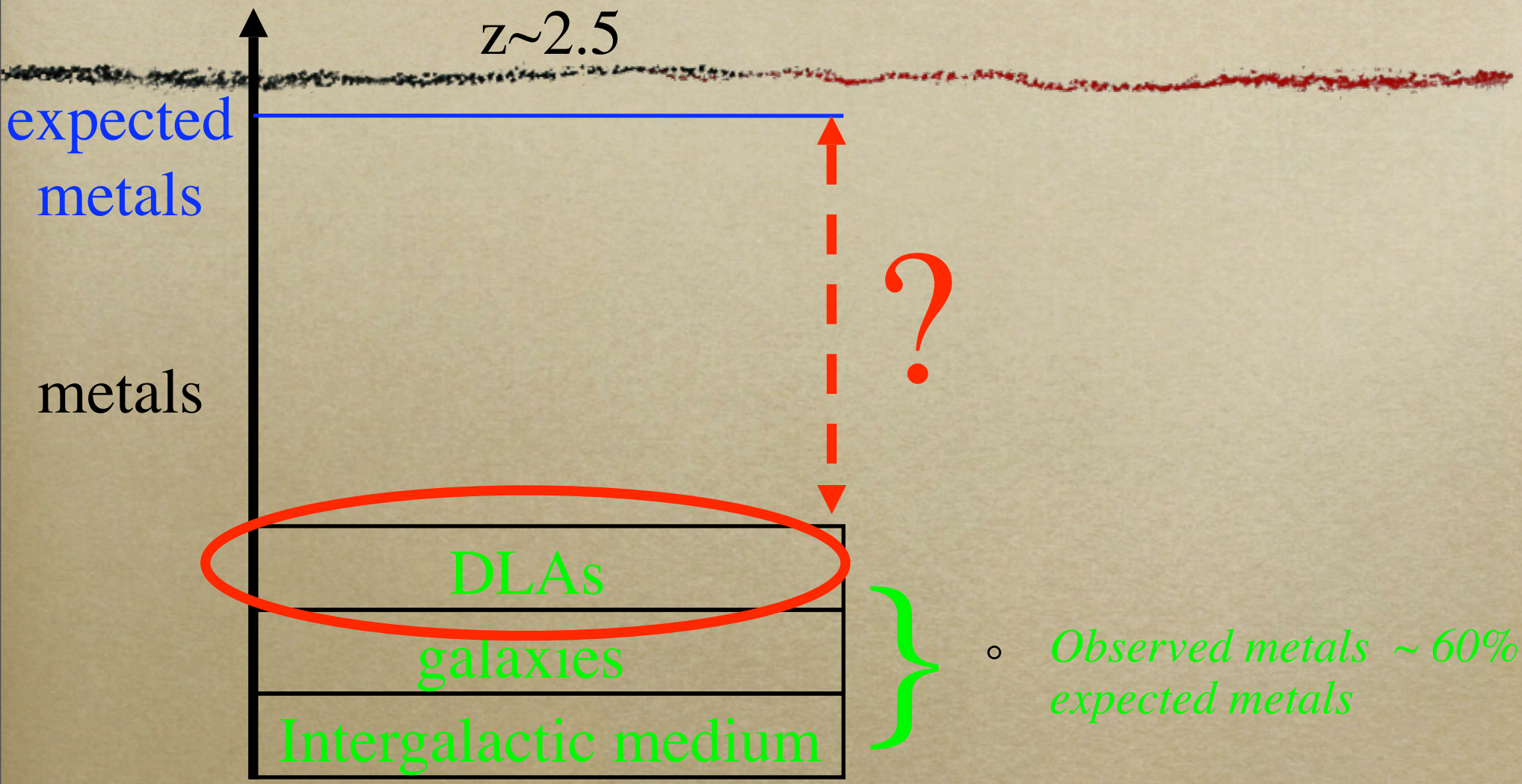


- *Star Formation History*
- *= Product of mean stellar yield & integral of star formation density*

$\varrho_{exp} = \langle p \rangle \int \varrho_*(t)$

(Madau plot)

The Missing Metals Problem



- *Observed metals ~ 60% of expected metals*

(Bouché, Lehnert & Péroux, 2005;
Bouché, Lehnert & Péroux, 2006;
Bouché, Lehnert, Aguirre, Péroux et al., 2007)

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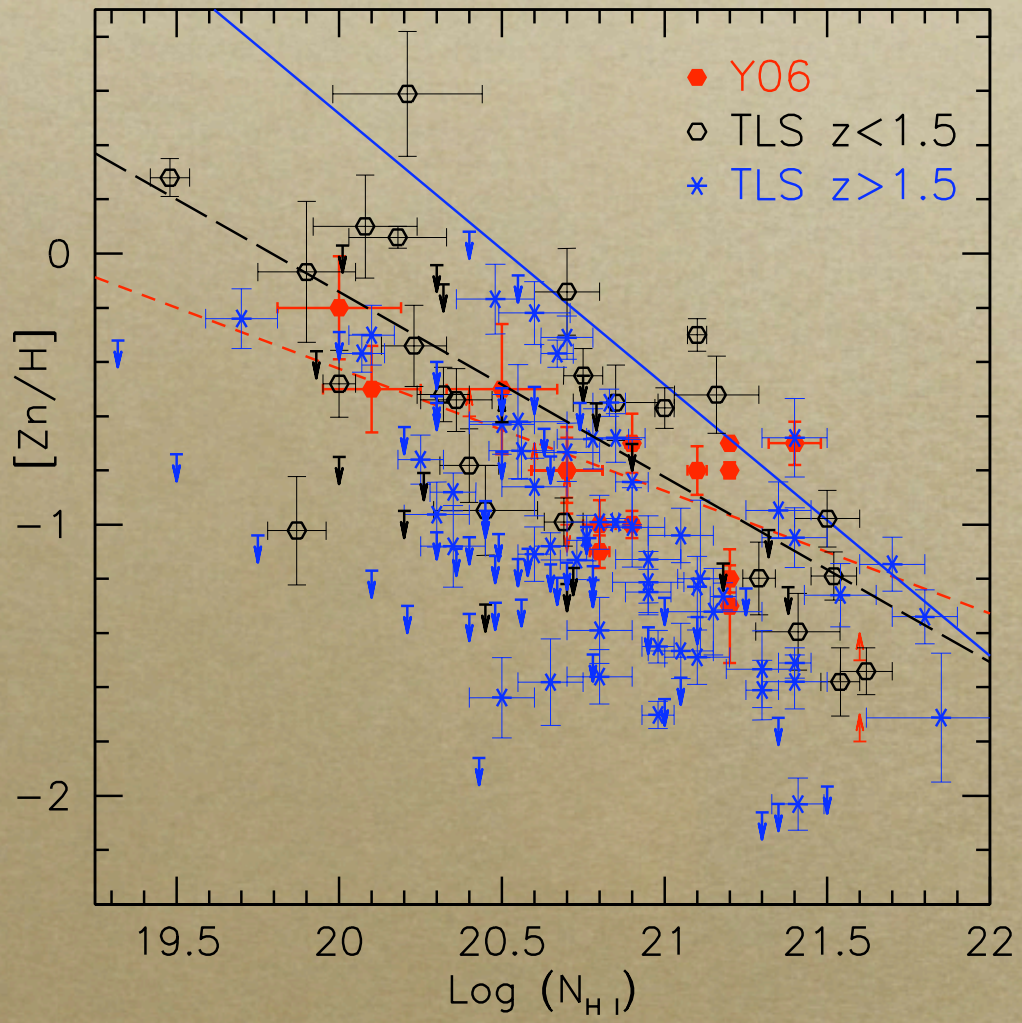
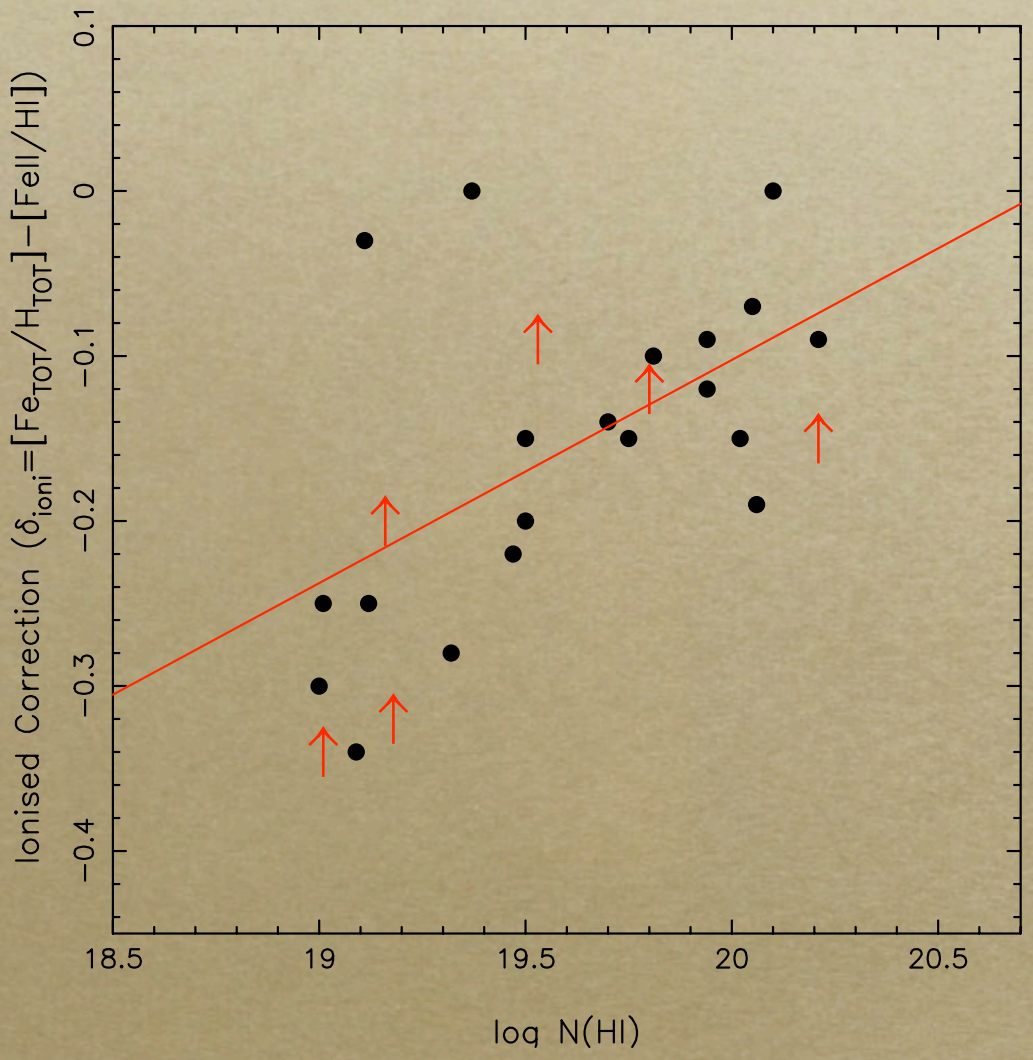
Obs Metallicity versus N(HI)



- *Zn traces total metallicity free from dust bias*
- *Sub-DLAs more metal rich*

(Khare, Kulkarni, Péroux et al. 2007)

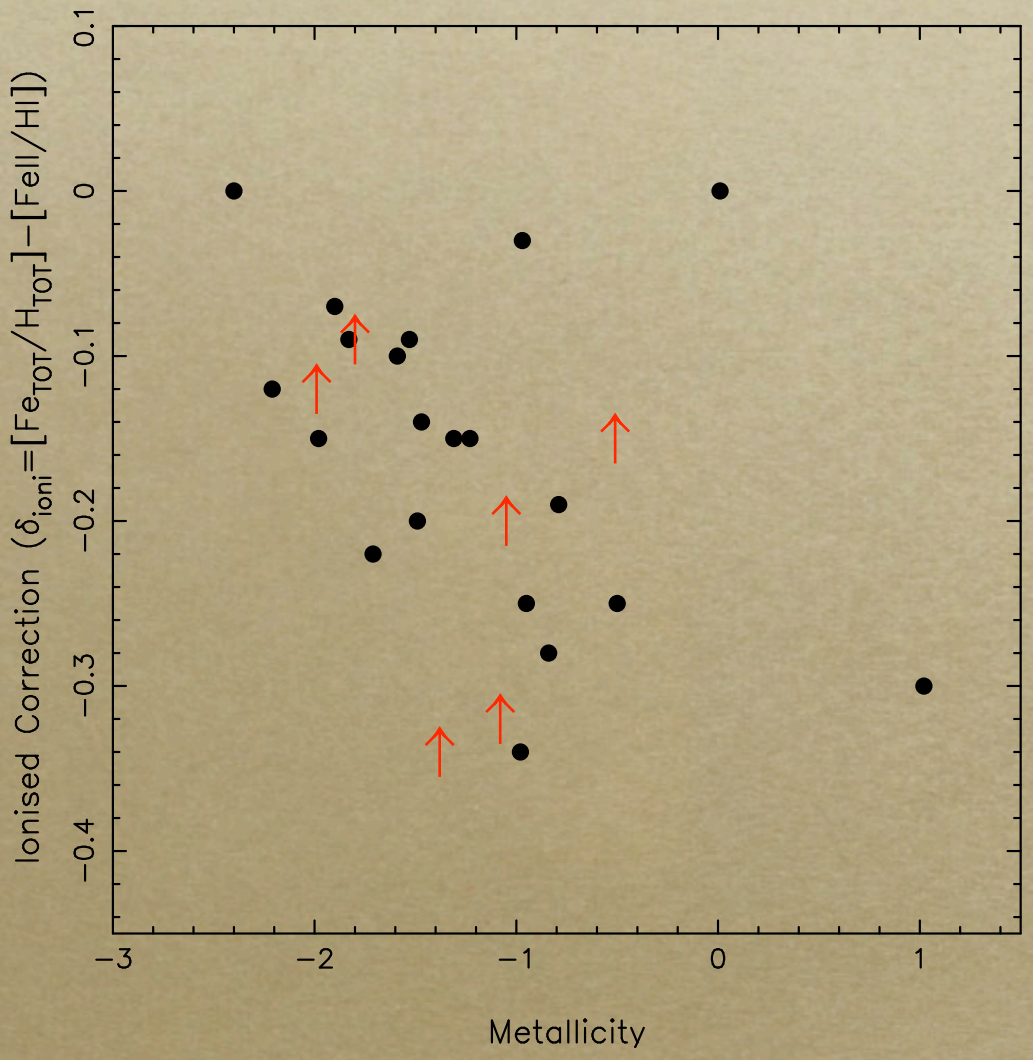
Ionisation Correction of HI Gas



- *Photo-ionisation models required*
- *Negative correction = overestimated metallicity*
- *larger correction for smaller N(HI)*

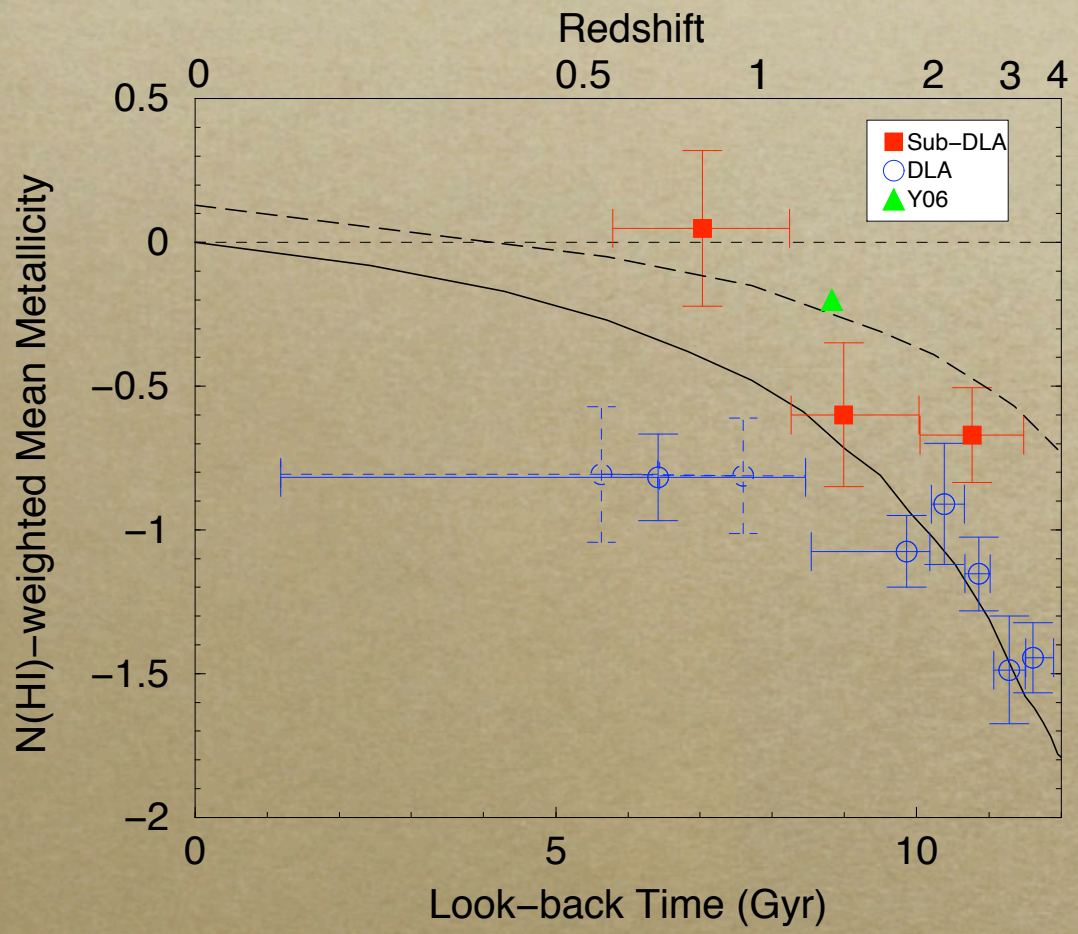
(Péroux et al. 2007)

Ionisation Correction vs Metallicity



- *Hints of smaller correction with lower metallicity*
- *Fractional correction roughly constant*

HI Metallicity through Cosmic Times



- *Sub-DLAs better tracers of global metallicity?*
- *Because of mass difference?*

  Because of obs dust bias?

(Kulkarni, Khare, Péroux et al. 2007)

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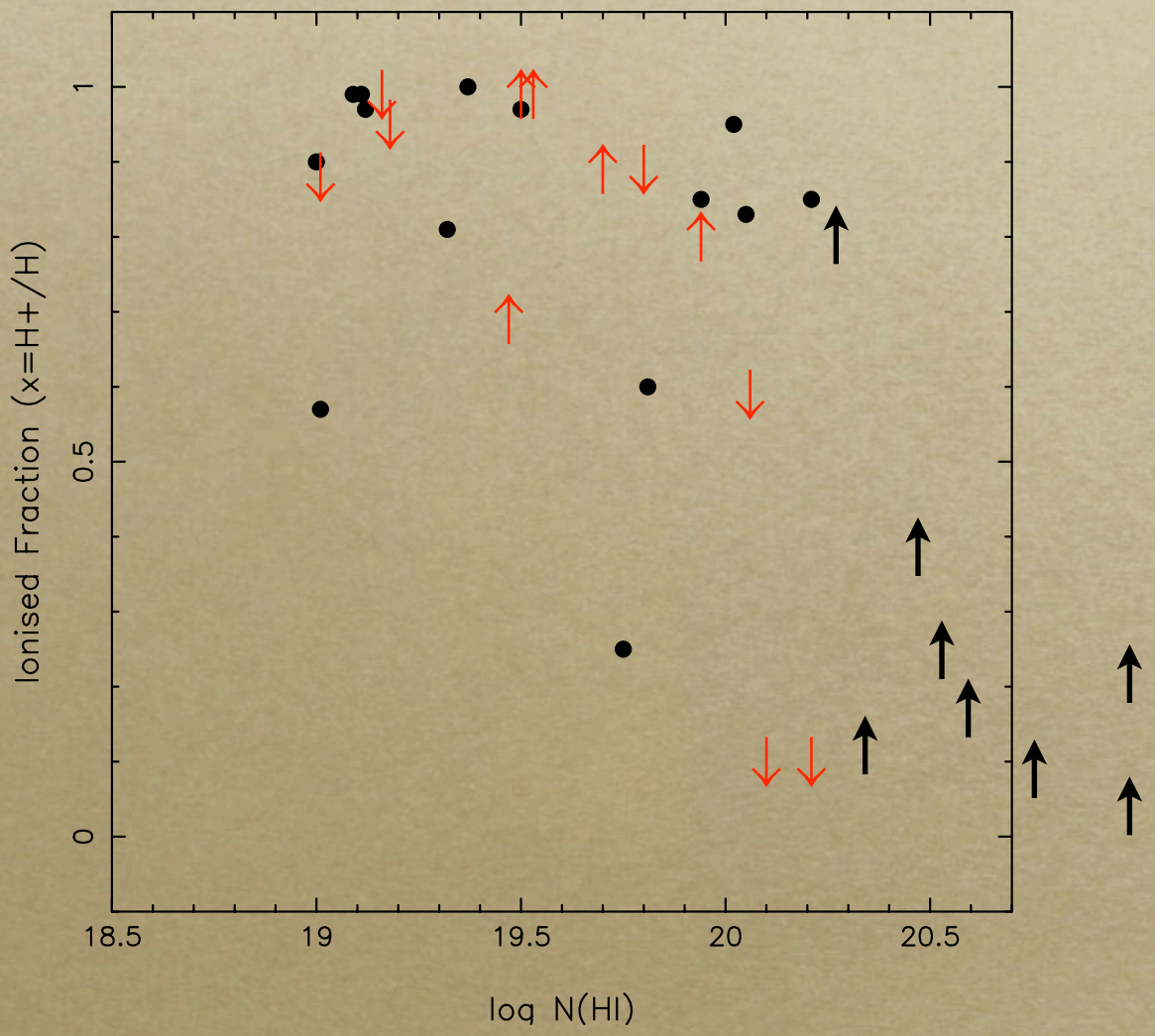
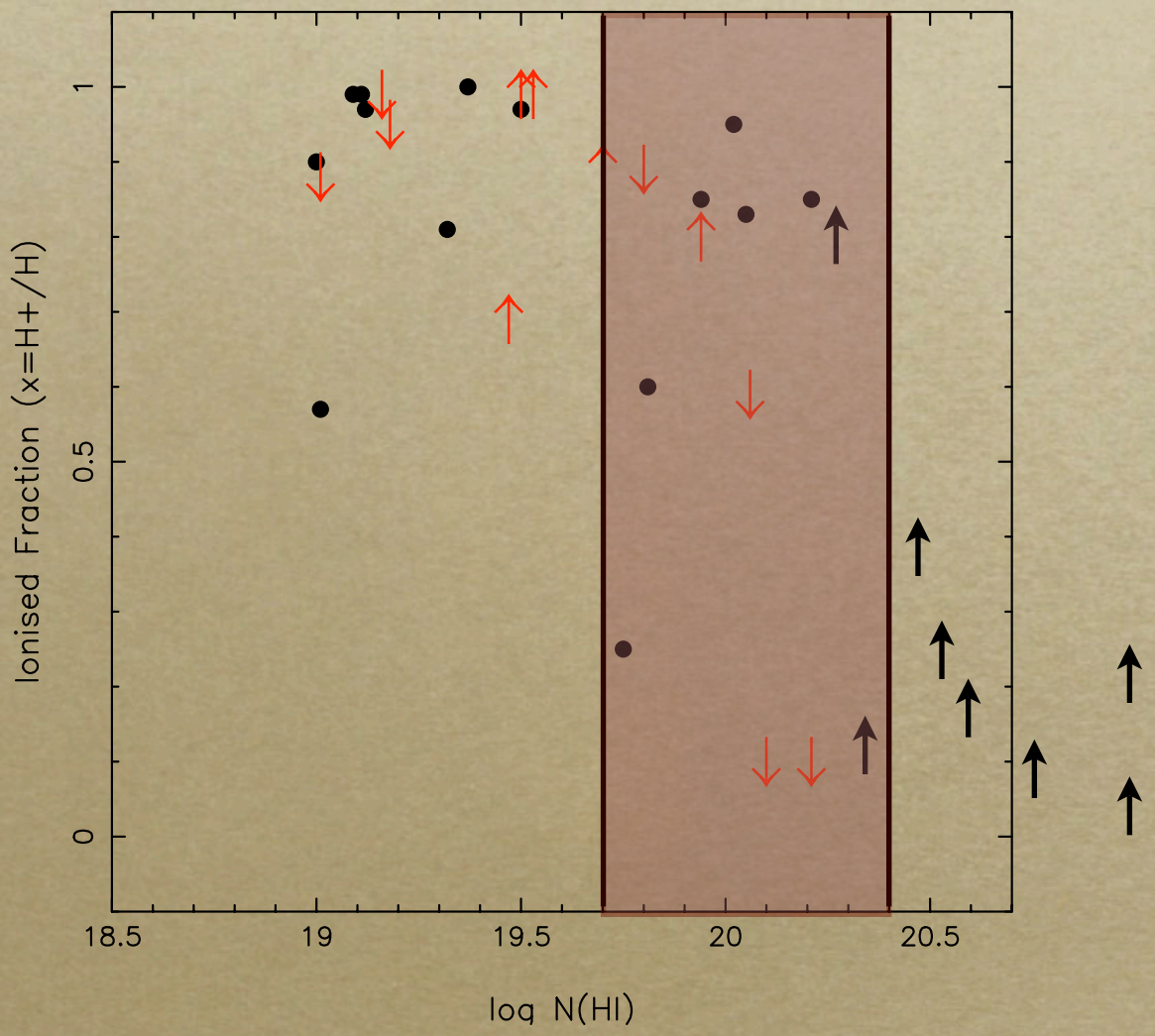
Fraction of Ionised Gas



- *x = ionised gas / total gas*

(Péroux et al. 2007
Fox et al. 2007 data = ↑)

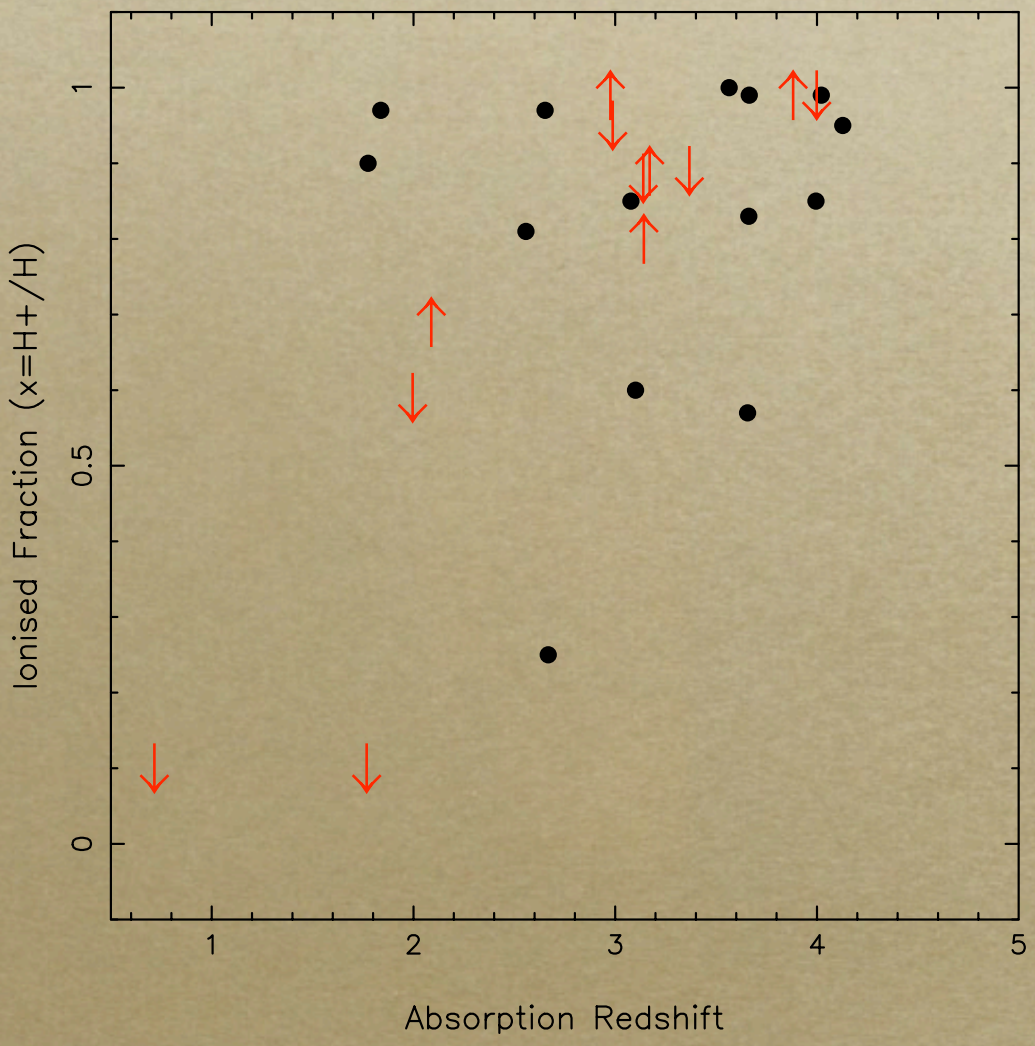
Fraction of Ionised Gas



- *x = ionised gas / total gas*
- *a number of x values are found at any N(HI)*

(Péroux et al. 2007
Fox et al. 2007 data = ↑ *)*

Cosmic Evolution of Ionised Fraction



- *Evolution expected with UV background cosmic evolution*

Contribution to Expected Metals

- *DLAs ~ 5%*
- *HI in sub-DLAs ~ 2%*
  => because contribution to Ω_{HI} small
- *Ionised gas in sub-DLAs ~ 6%*
  => assuming metallicity = HI metallicity
  => not enough to close Missing Metals Problem
  [would require $-0.46<Z/Z_{sun}(\text{sub-DLAs})<+0.14$]

(Prochaska et al. 2006; Péroux et al. 2007)

Conclusion

- *Quasar absorbers trace HI from which stars form and associated metals*
- *Most of the metals expected in the Universe at z~2.5 are missing*
- *Metals in HI and ionised gas of are not enough to close this Missing Metals Problem*