Reconstructing cosmic reionization

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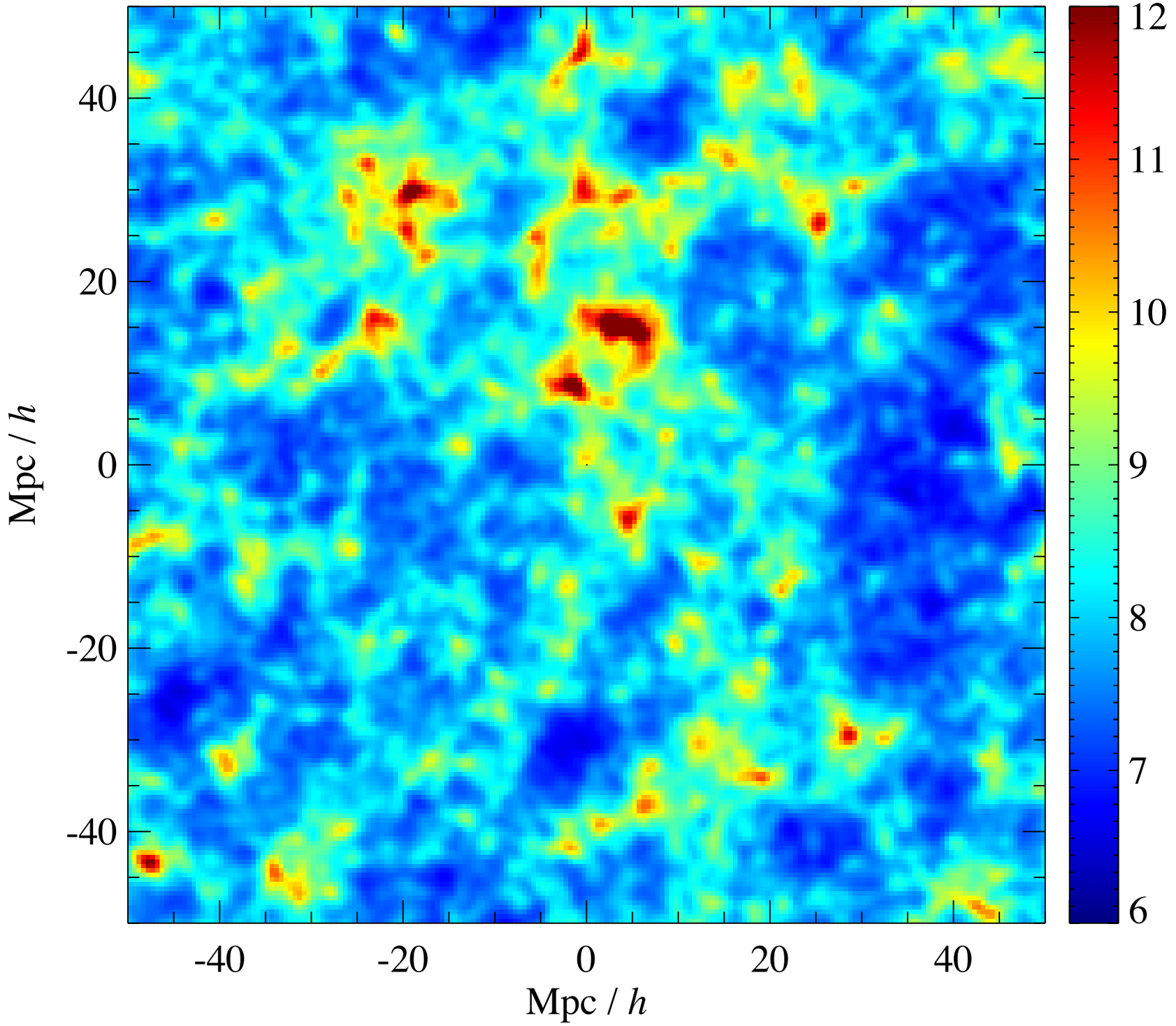
Based on LCP, Trac, & Cen, *1605.03970*

Hydrogen reionization



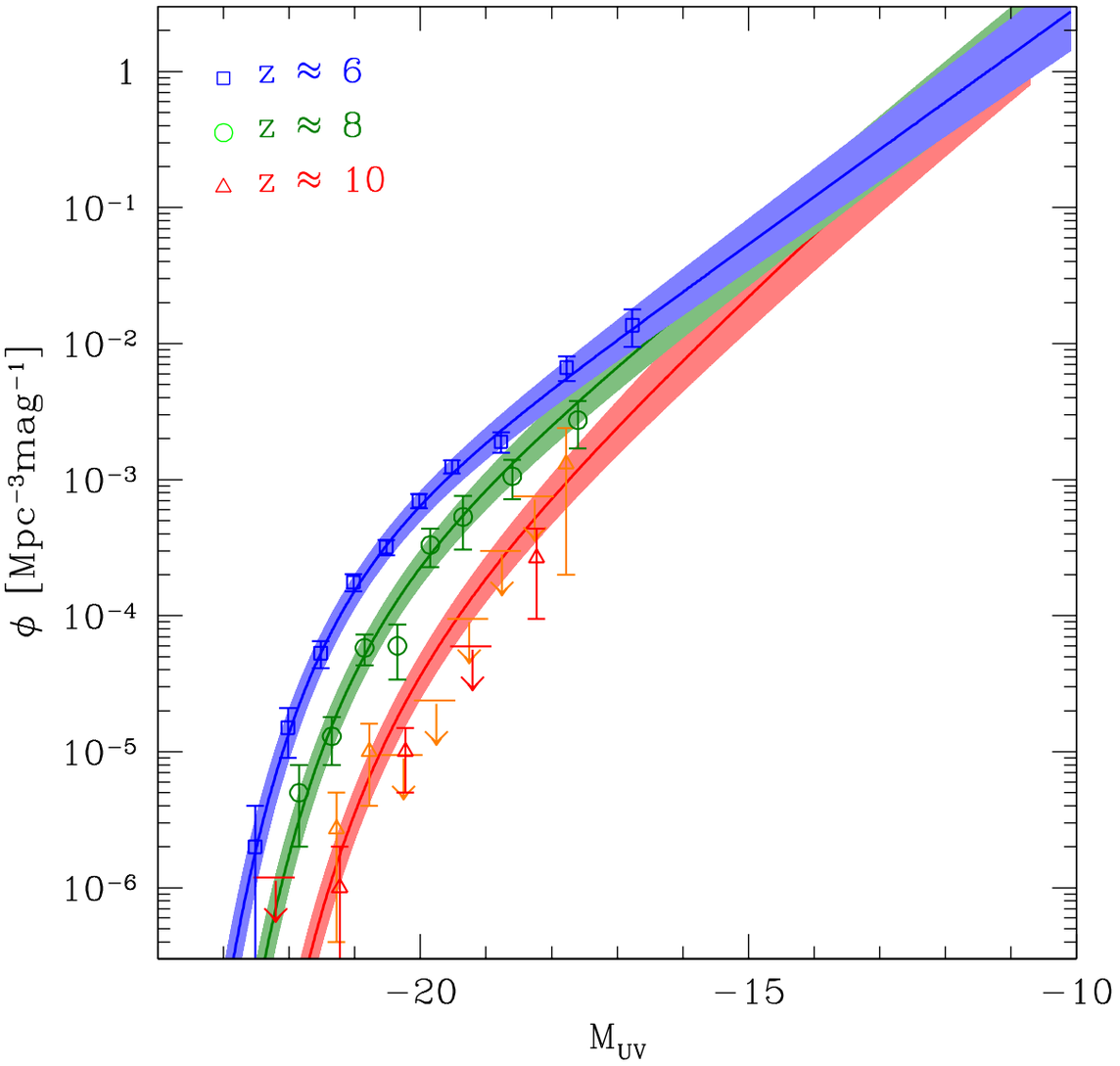
"Inside-out" ionization

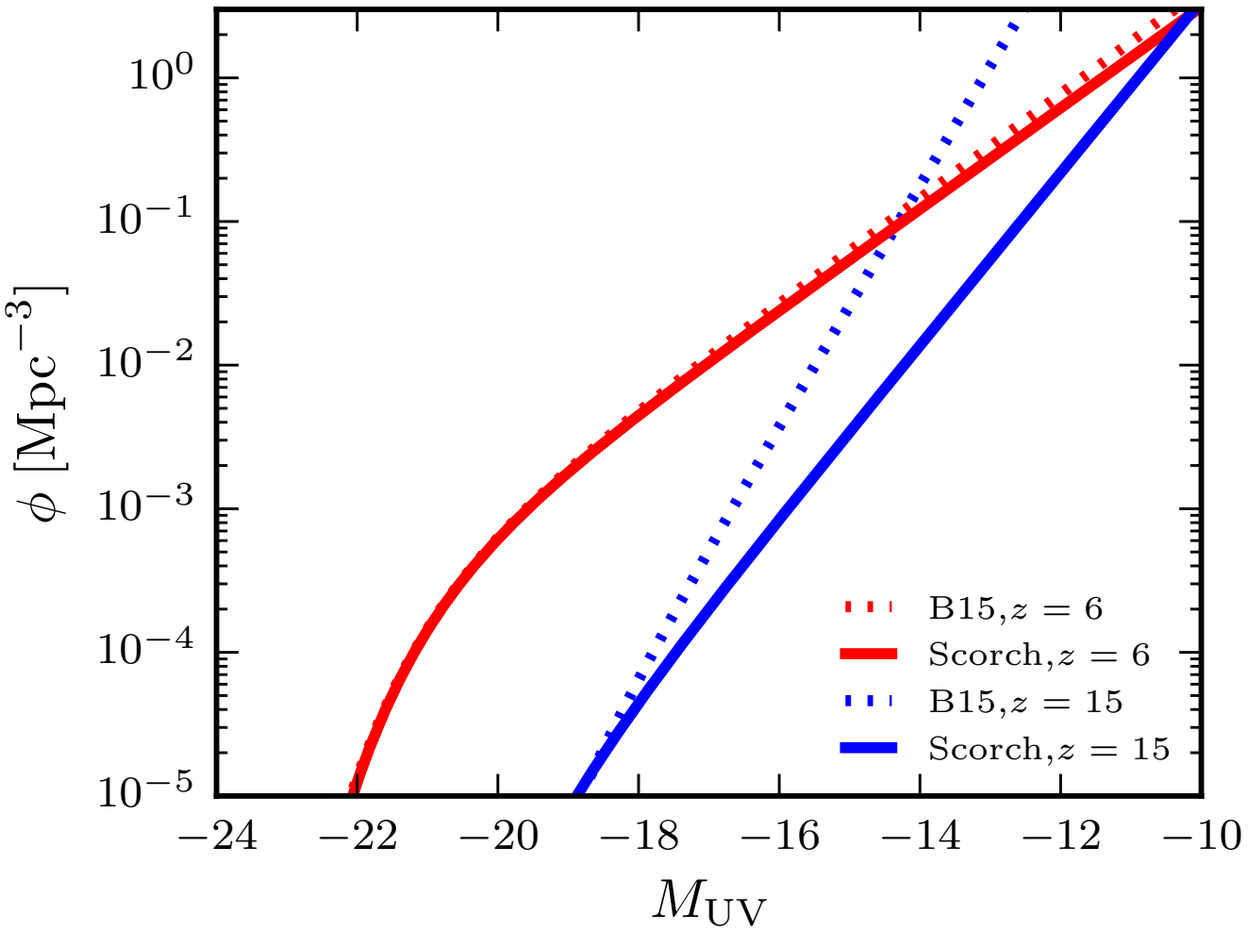
Patchy

Largely complete by z~6-8

Fig. from Battaglia, *et al.*, ApJ, *1211.2821*

The role of low-luminosity galaxies





Extrapolating Schecter fit to HST data to lower luminosity and higher redshift

Trac & Cen, ApJ, *1507.02685*
LCP, Trac, & Cen, *1605.03970*

Escape of ionizing photons into the IGM

Number of galaxies at given UV luminosity:

$$\phi_* \left(\frac{L}{L_*}\right)^{\alpha} \exp\left(\frac{L}{L_*}\right)$$

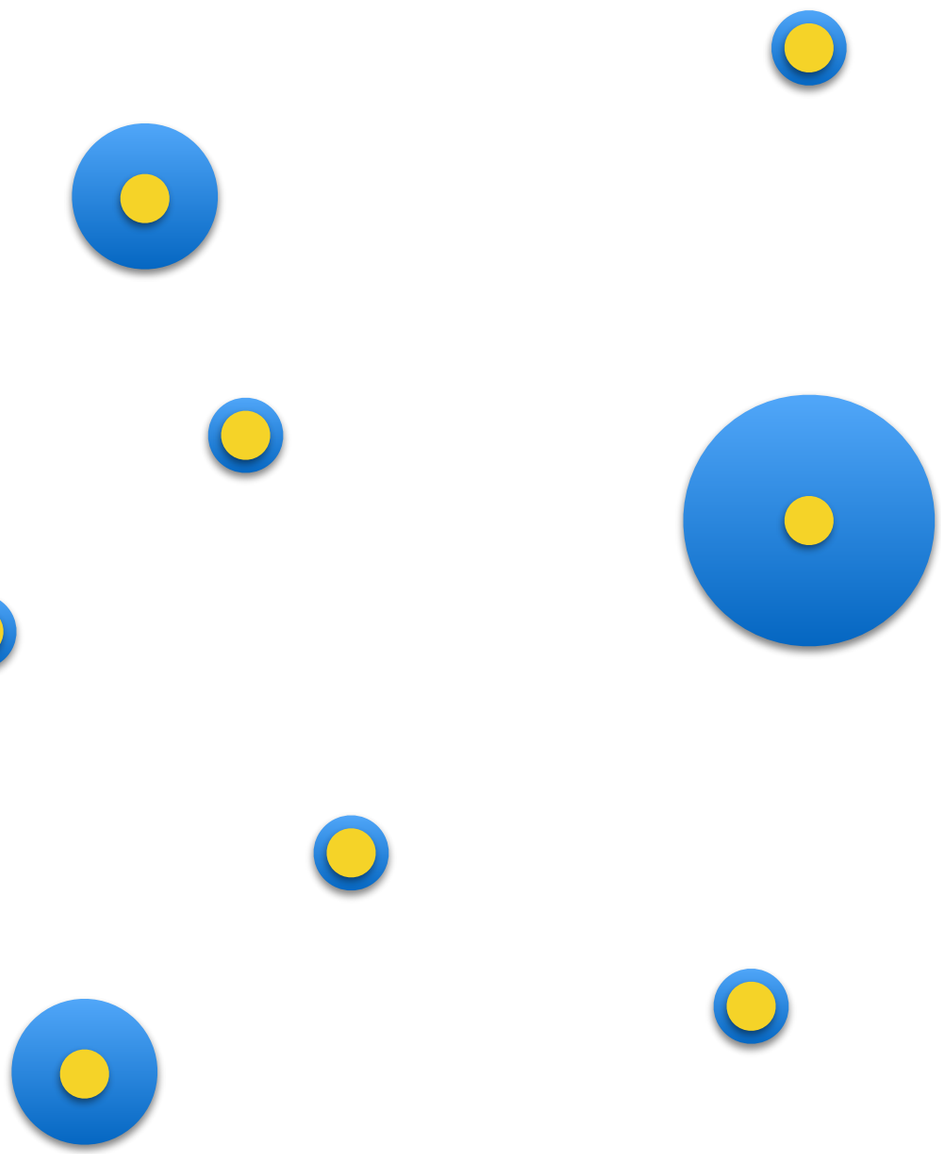
Converting UV luminosity to H ionizing luminosity:

$$L_{\rm ion} = \xi_{\rm ion} L_{\rm UV}$$

Fraction of intrinsic flux that escapes into IGM:

$$f_{\rm esc}(z)$$

Modeling reionization bubbles

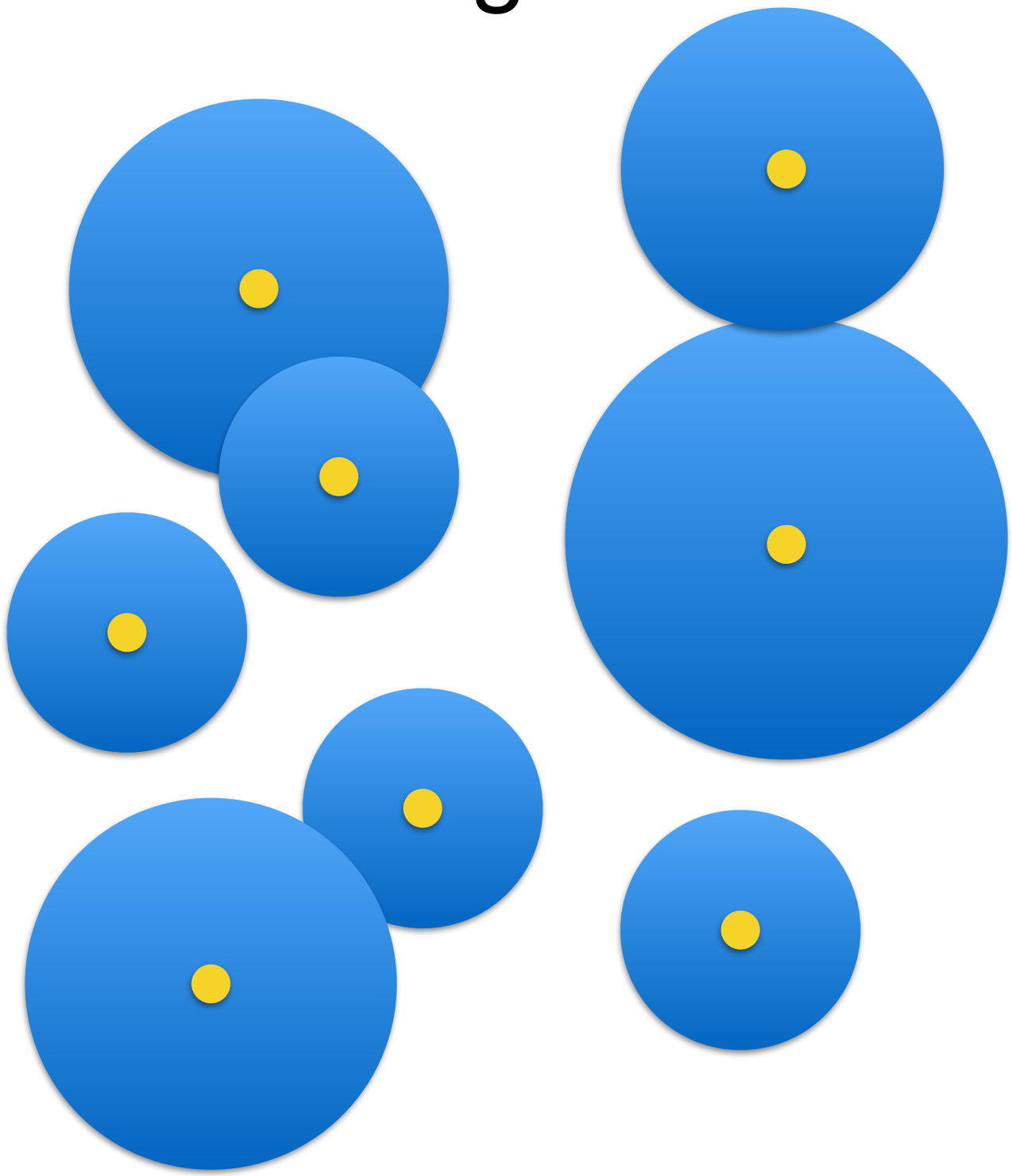


$$z \sim 12$$

$$\frac{dQ_{\rm ion}}{dt} = \frac{\dot{n}_\gamma}{n_{\rm H}} - \frac{Q_{\rm ion}}{\bar{t}_{\rm rec}}$$

$$Q_{\rm ion} = \frac{V_{\rm ion}}{V_{\rm H}}$$

Modeling reionization bubbles

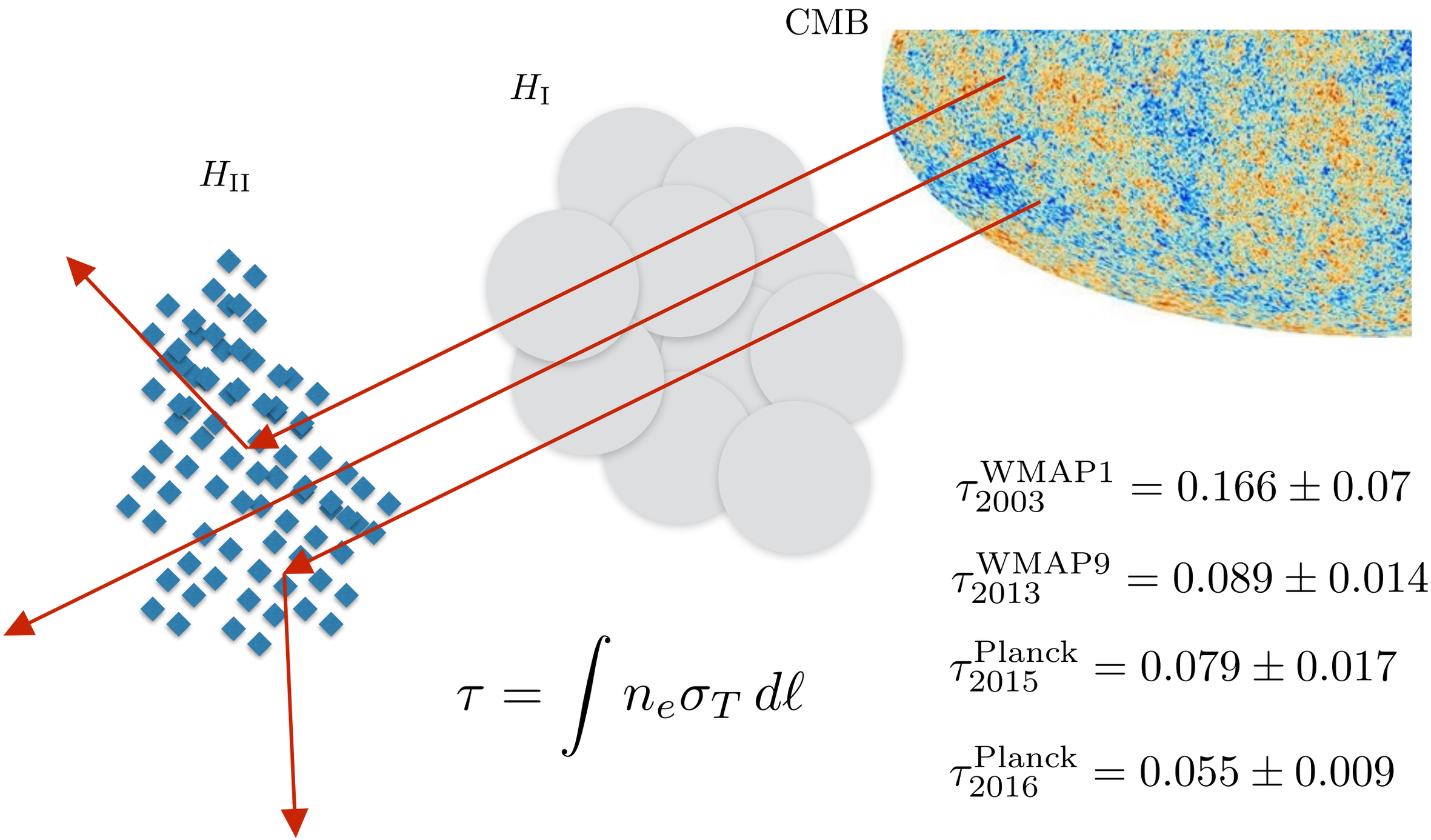


$$z \sim 6 - 7$$

$$\frac{dQ_{\rm ion}}{dt} = \frac{\dot{n}_\gamma}{n_{\rm H}} - \frac{Q_{\rm ion}}{\bar{t}_{\rm rec}}$$

$$Q_{\rm ion} = \frac{V_{\rm ion}}{V_{\rm H}}$$

High redshift CMB constraints



$$\tau = \int n_e \sigma_T \, d\ell$$

$$\tau_{2003}^{\rm WMAP1} = 0.166 \pm 0.07$$

$$\tau_{2013}^{\rm WMAP9} = 0.089 \pm 0.014$$

$$\tau_{2015}^{\rm Planck} = 0.079 \pm 0.017$$

$$\tau_{2016}^{\rm Planck} = 0.055 \pm 0.009$$

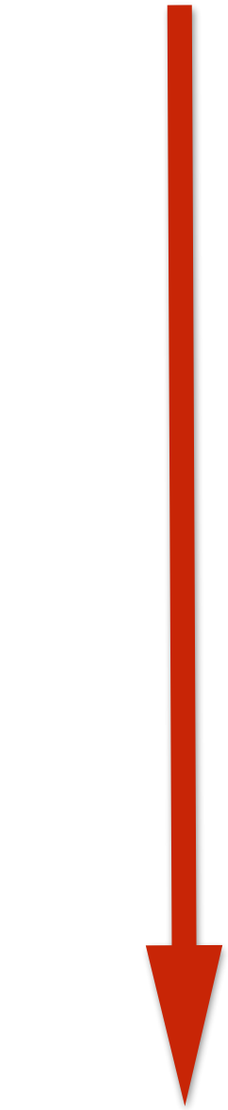
Data

$f_{\rm esc} < 0.1$ at $z < 3$ (Boutsia, et al., 2011)

$x_{\rm HI} < 0.16$ at $z < 5.8$ (McGreer, et al., 2014)

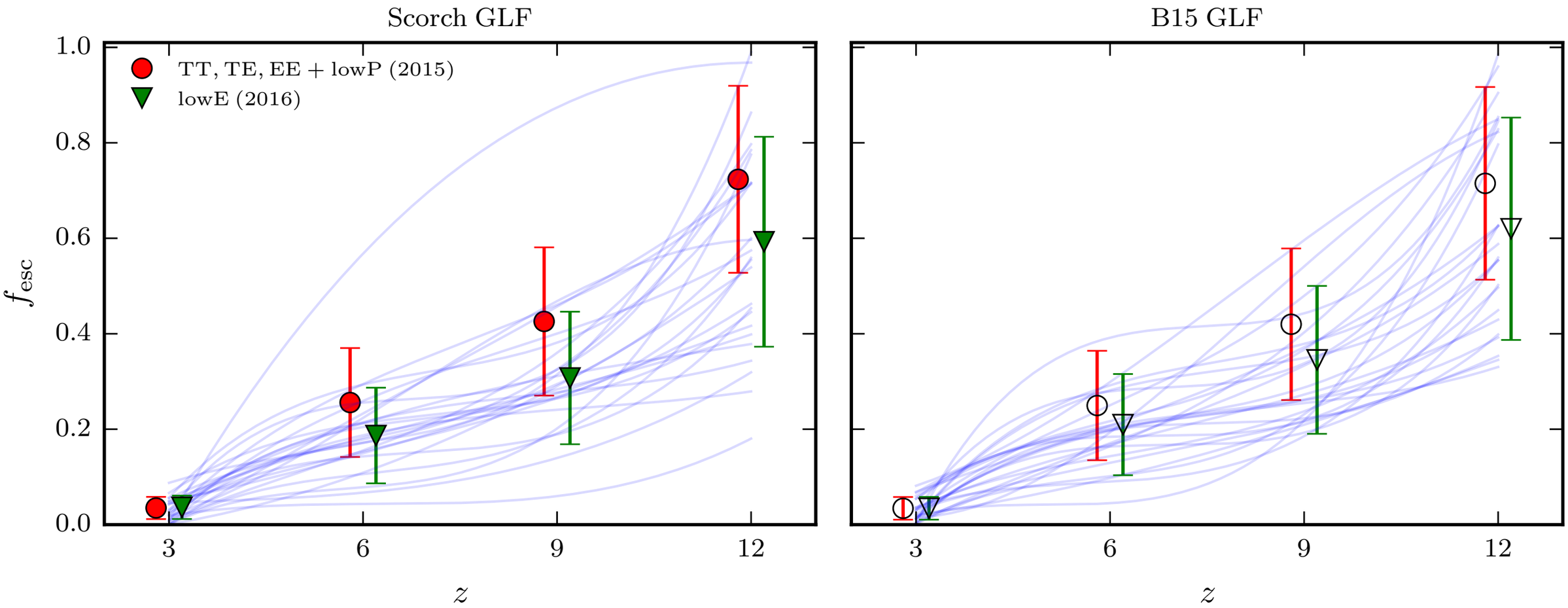
GLF calibrated to HST at $z = 6 - 10$

τ weighted by Planck at $0 \leq z \leq z_{\rm CMB}$ $(6 \lesssim z \lesssim 12)$



increasing z

Reconstructing the escape fraction



Consistency between escape fraction reconstructions with different luminosity functions.

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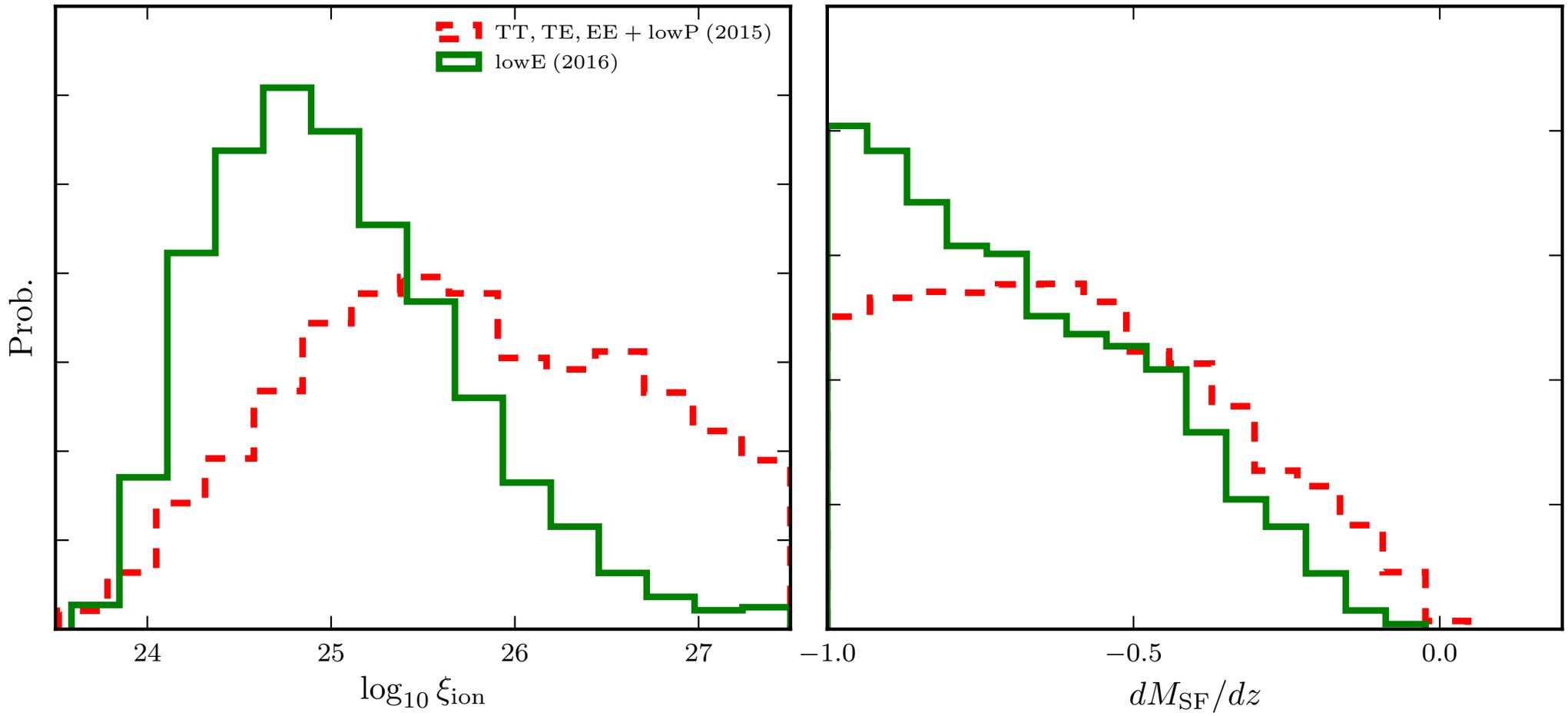
Empirical luminosity function



Reduced intrinsic photon production efficiency and strong evidence for evolving limiting magnitude with latest Planck data

$$L_{\rm ion} = \xi_{\rm ion} L_{\rm UV}$$

$$M_{\rm SF} = -10 + \frac{dM_{\rm SF}}{dz}(z-6)$$

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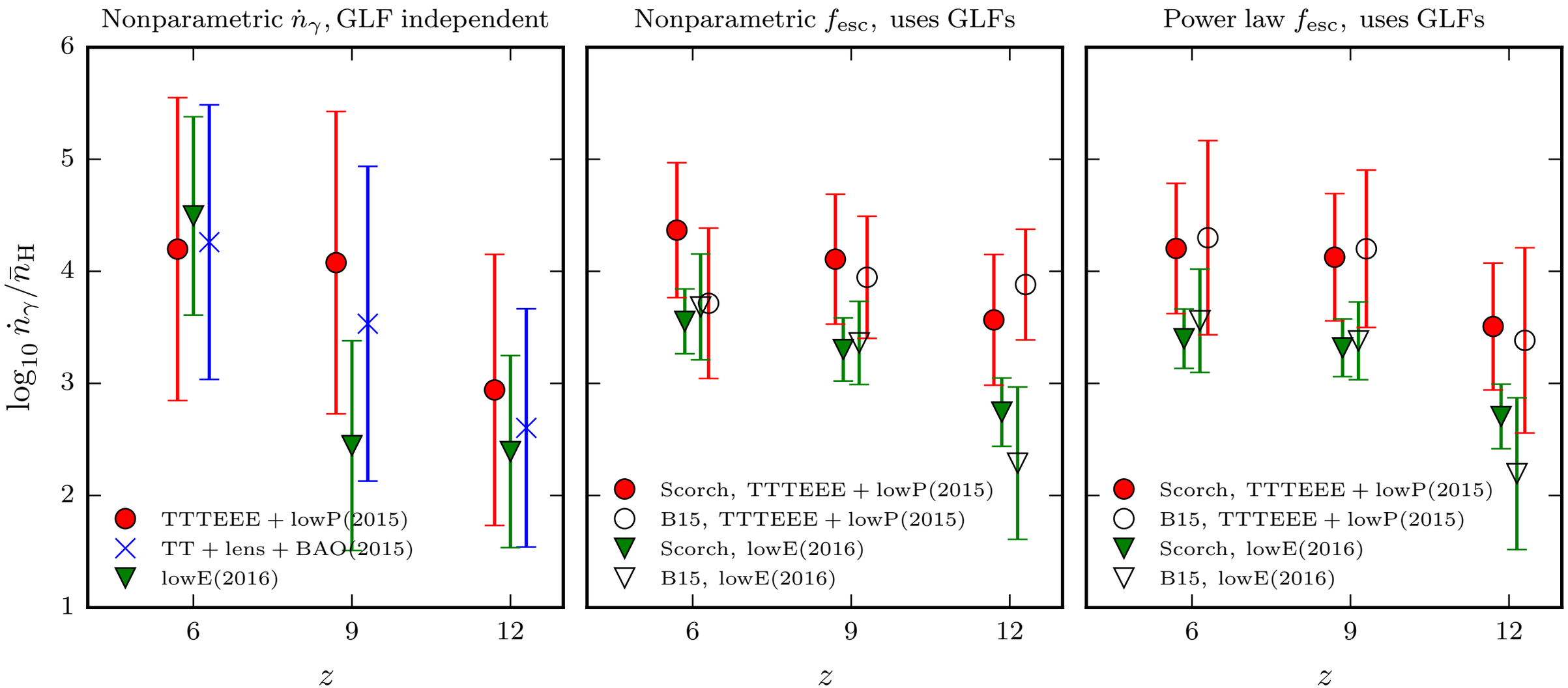
Model-independent photon production rate



Most general non-parametric results show slight preference for suppressed photon production rate at z~9.

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Conclusion

Performed free-form fit to escape fraction and escaped photon production rate.

Results not strongly dependent on galaxy luminosity function assumptions at high redshift or low luminosity.

Lower Thomson optical depth from Planck 2016 better fit by lowering intrinsic ionizing photon production efficiency (does depend on prior).

Strong evidence for redshift evolution in limiting magnitude of empirical galaxy luminosity functions and escape fraction.

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