Constraining the AGN Contribution to Reionization with 4MOST

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Follow-up of Wide-Area X-Ray Surveys

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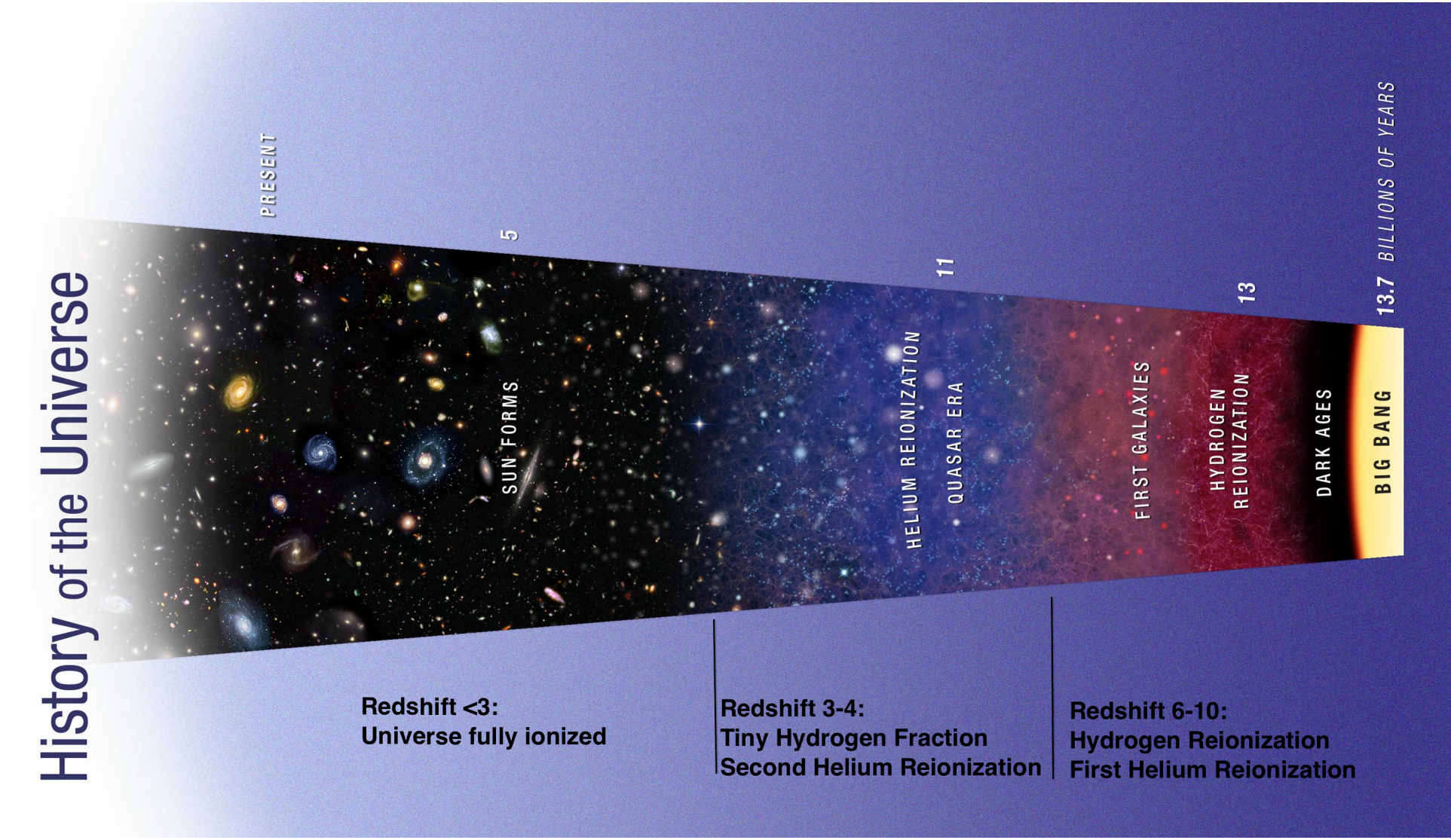
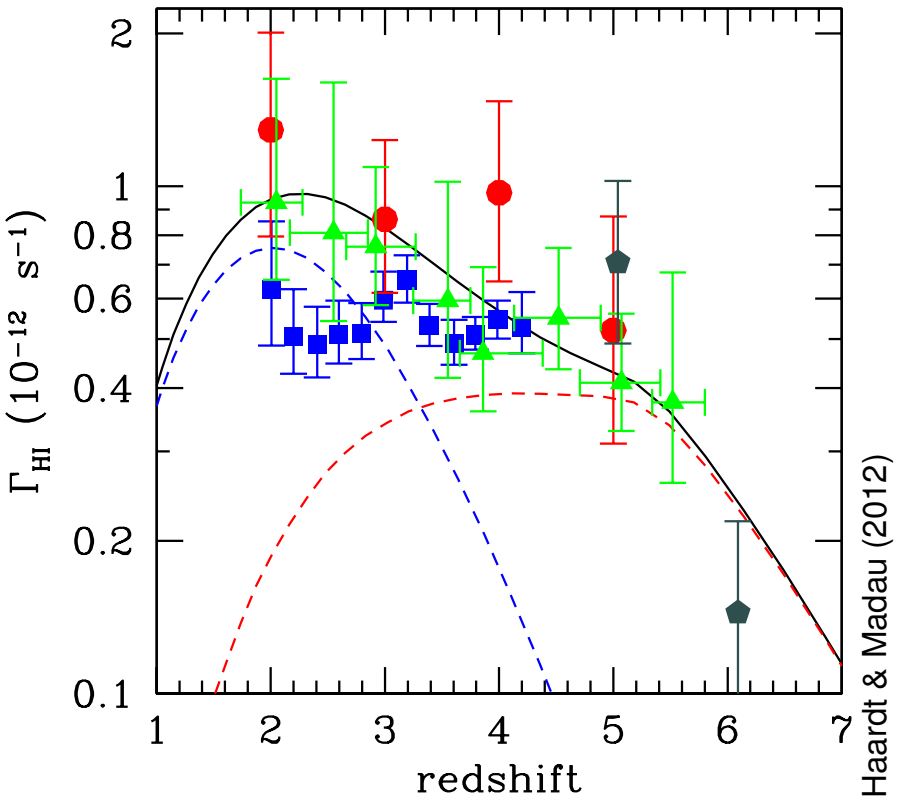
Reionization Events – Two Baryonic Phase Transitions



Credits: NASA

The AGN Contribution to the UV Background

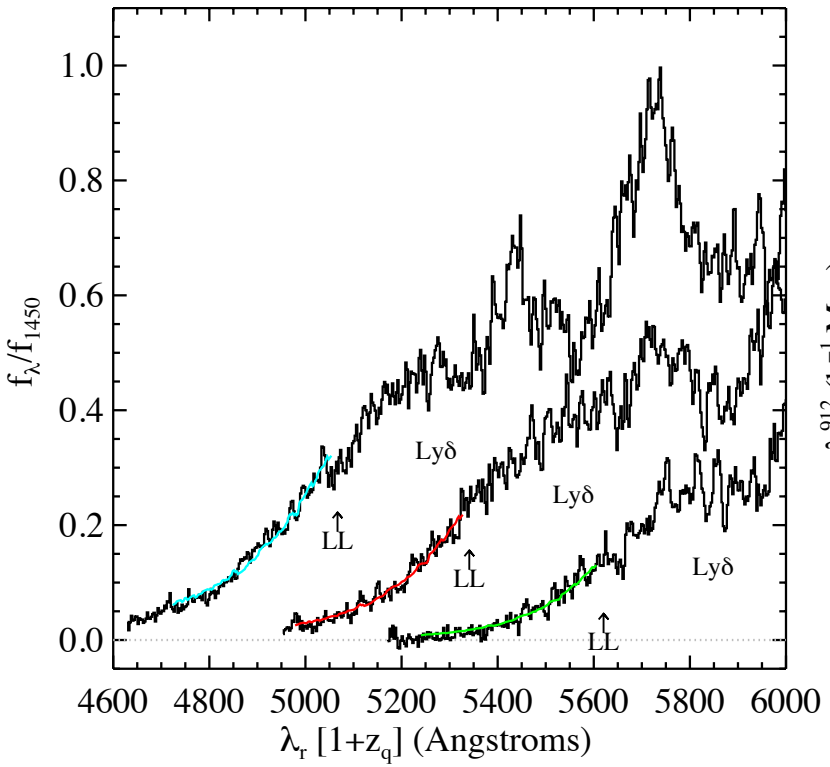
- Goal: Relative contribution from AGN and galaxies to UV background measured from the Lyα forest
- Photoionization rate: $\Gamma_{\rm HI}(z) = \int_{\nu_{912}}^{\infty} \frac{4\pi J_\nu(\nu,z)}{h\nu} \sigma_{\rm HI}(\nu) {\rm d}\nu$
- $z > 4$: MFP$\ll$Horizon$\longrightarrow$ local-source approximation
  $4\pi J_\nu(\nu, z) \simeq \lambda_{\rm mfp}(\nu, z)\,(1+z)^3\,\epsilon_\nu(\nu, z)$

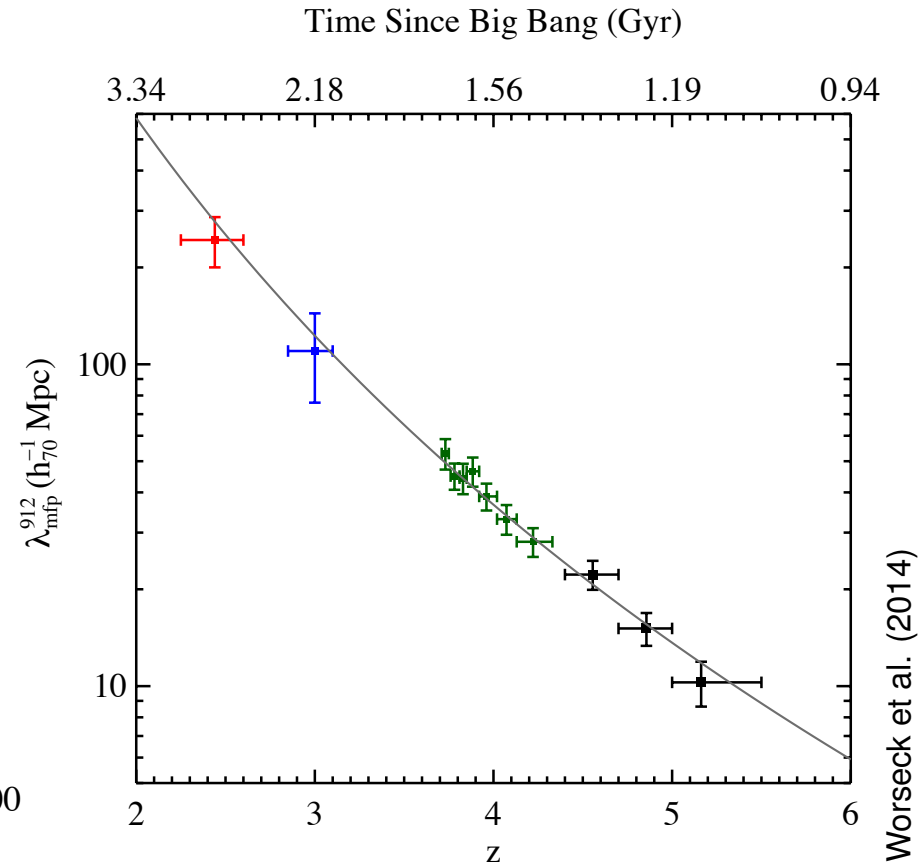


1. The Mean Free Path to Lyman Continuum Photons

- Rest-frame stacks of QSO spectra $\longrightarrow \lambda_{\mathrm{mfp},912}(z)$

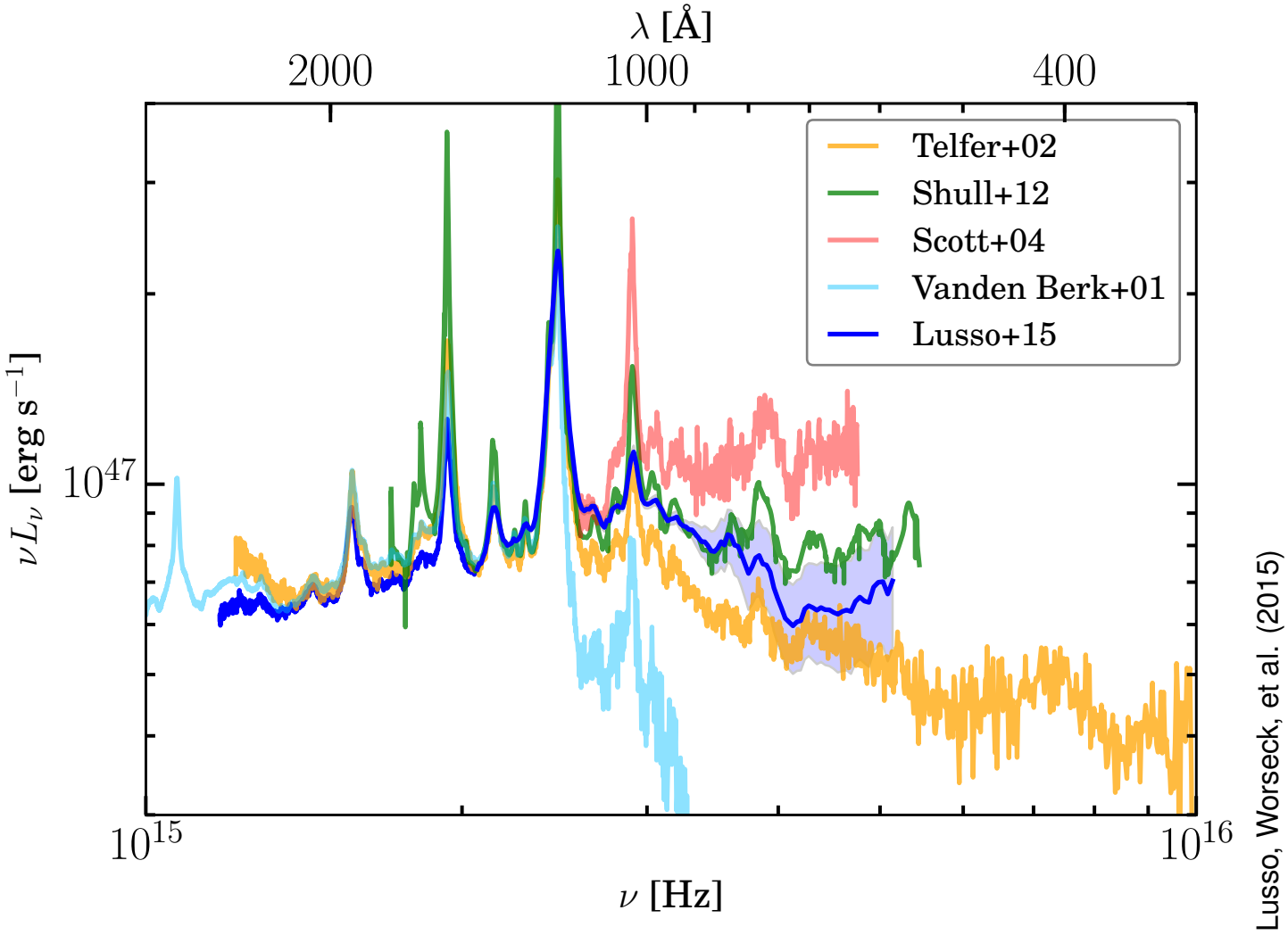
$$\lambda_{\mathrm{mfp}}(\nu, z) \approx \lambda_{\mathrm{mfp},912}(z) \left(\frac{\nu}{\nu_{912}}\right)^{1.5} = 37 \left(\frac{1+z}{5}\right)^{-5.4} \left(\frac{\nu}{\nu_{912}}\right)^{1.5} \mathrm{pMpc}$$





2. QSOs Have Hard SEDs

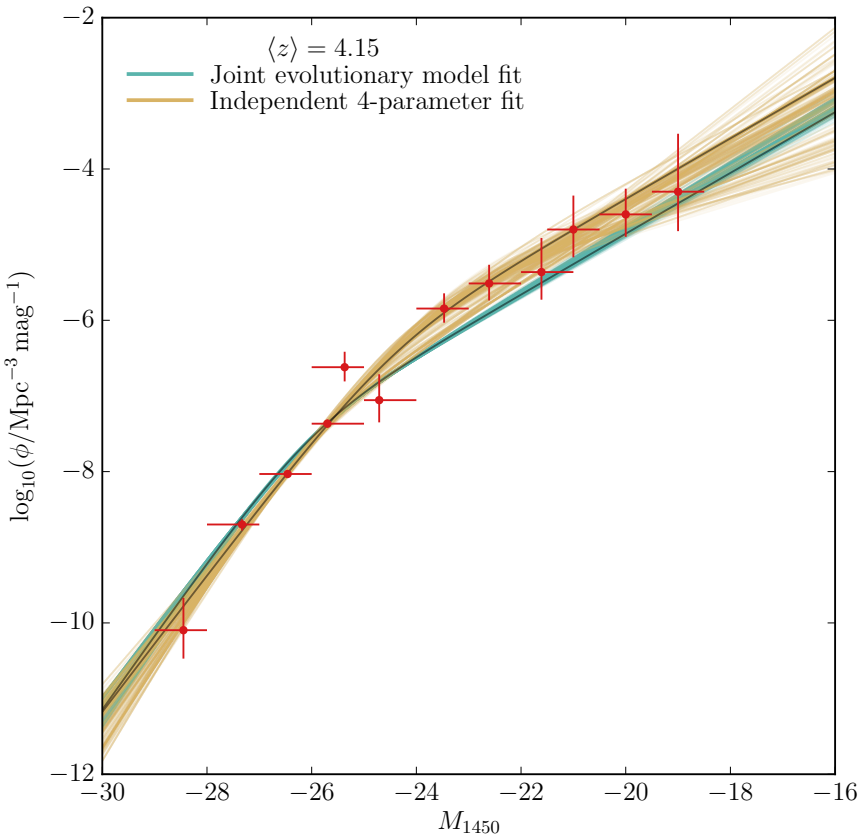
- No SED break at $\lambda \sim 1200$Å$\longrightarrow$ Emissivity increases by $\sim 30\%$

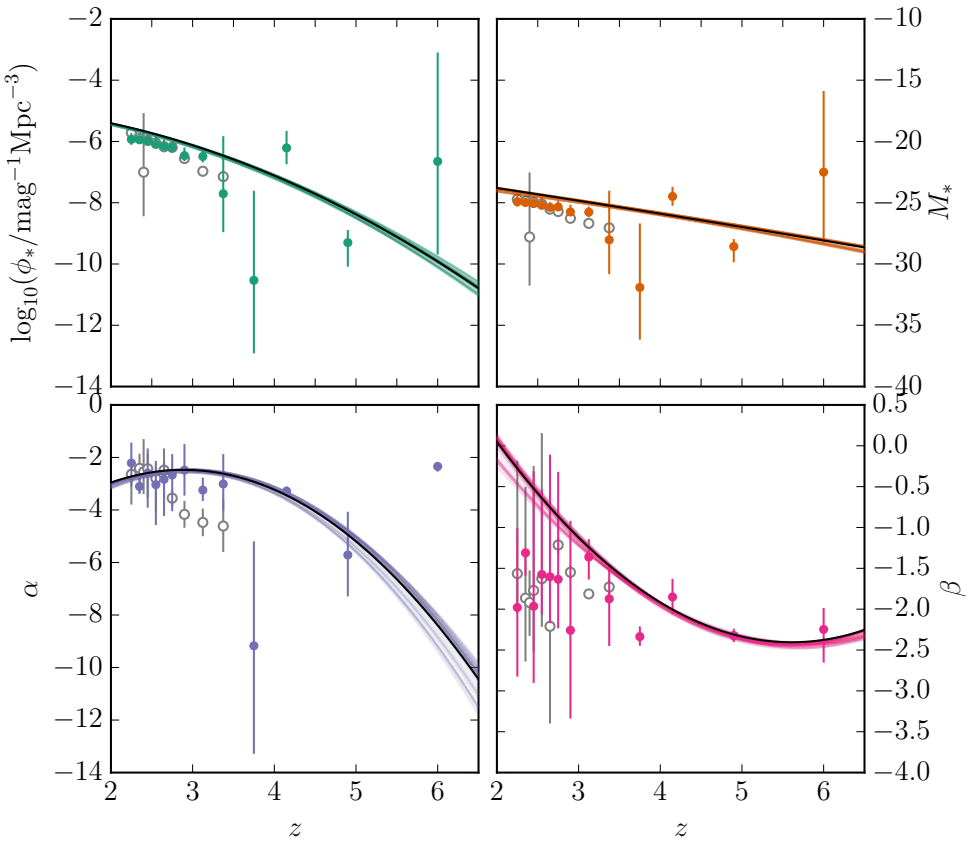


3. Reassessment of the QSO UV Luminosity Function

- MCMC analysis of $2 < z < 6$ QSO UV luminosity function data
- Emissivity: $\epsilon_\nu(\nu, z) = \epsilon_{\nu,912}(z) \left(\frac{\nu}{\nu_{912}}\right)^{\alpha_{\rm EUV}}$ for QSOs with $f_\nu \propto \nu^{\alpha_{\rm EUV}}$

  $\epsilon_{\nu,912} = f_{\nu,912}/f_{\nu,1450} \int_{L_{\rm min}}^{\infty} \phi(L, z) L_{\nu,1450}(L, \nu) {\rm d}L$

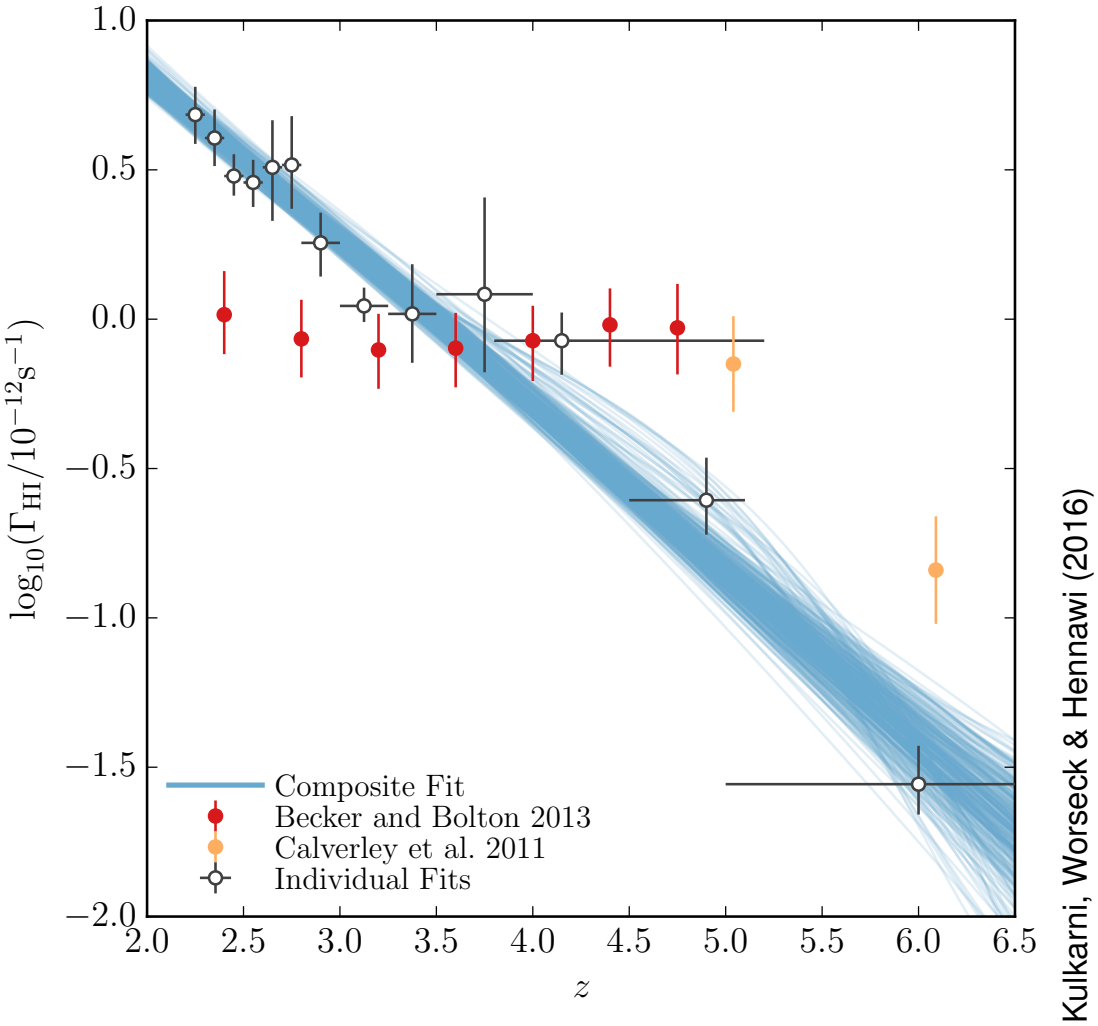




Kulkarni, Worseck & Hennawi (2016)

QSOs Dominate the UV Background at $z \lesssim 4$

- QSO emissivity depends on QSOs with $M \sim M_\star$
- Faint end of $z > 4$ quasar luminosity function poorly determined



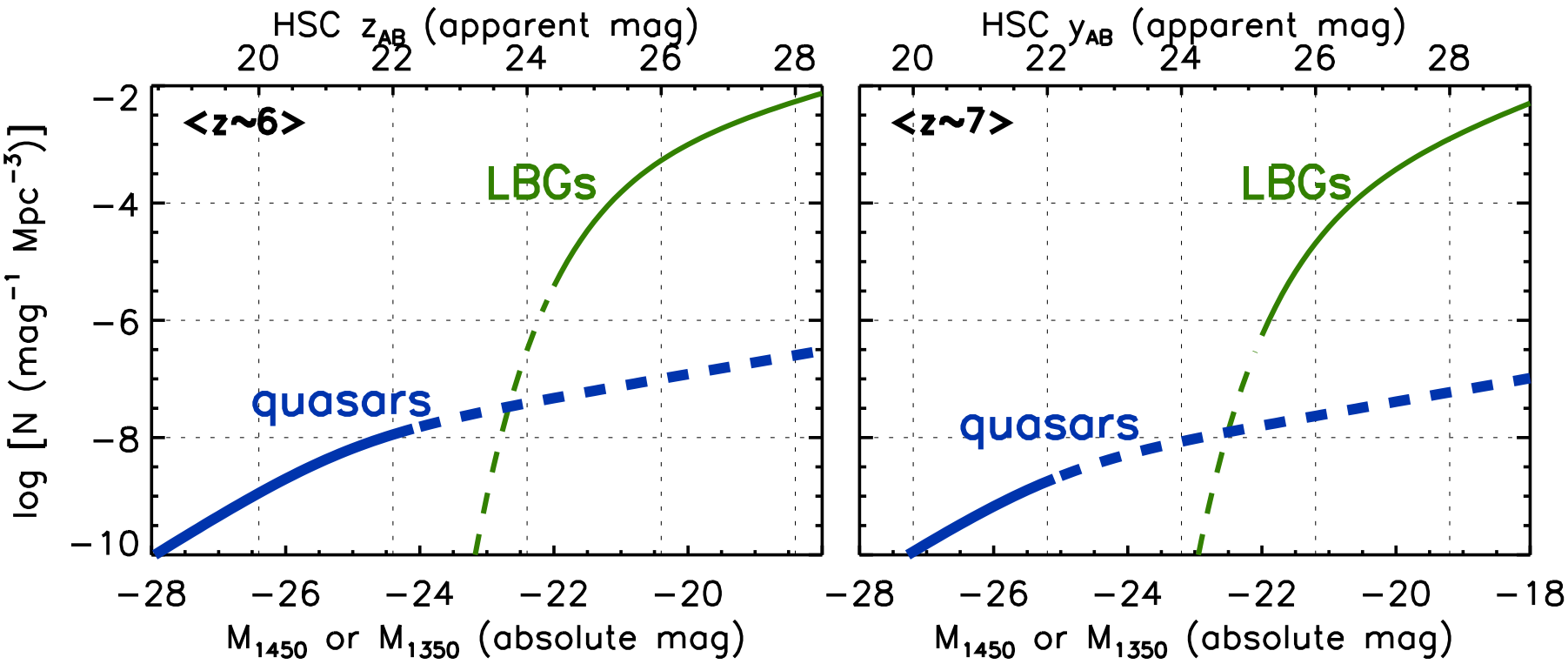
A Survey for $z > 4$ QSOs with 4MOST

- Goal: Pin down the QSO luminosity function at $z = 4$–5 and improve constraints at $z \sim 6$
- Optical + NIR color selection (VST ATLAS, DES, KiDS, VIKING)
- Two-tiered survey
  1. $i_{AB} \lesssim 24$, WAVES DEEP footprint (60–100 deg^2)
  2. $i_{AB} \lesssim 22$, eROSITA AGN footprint (13,000 deg^2)
- Low QSO surface density $\longrightarrow$ 4MOST or one-by-one follow-up

$m_{AB,lim}$	N_{QSO}/deg^2 $z \sim 4.2$	N_{QSO}/deg^2 $z \sim 5$	N_{QSO}/deg^2 $z \sim 6$
22.0	2.0	0.19	0.04
23.0	7.6	0.42	0.09
24.0	20.1	0.80	0.20

- $N_{target} = 2$–$5 \times N_{QSO}$ depending on color selection
- $\sim$ 100% completeness required
- $i_{AB} \simeq 24$, broad emission lines $\longrightarrow$ S/N$\simeq 2$ at $R \sim 300$ in 2 h

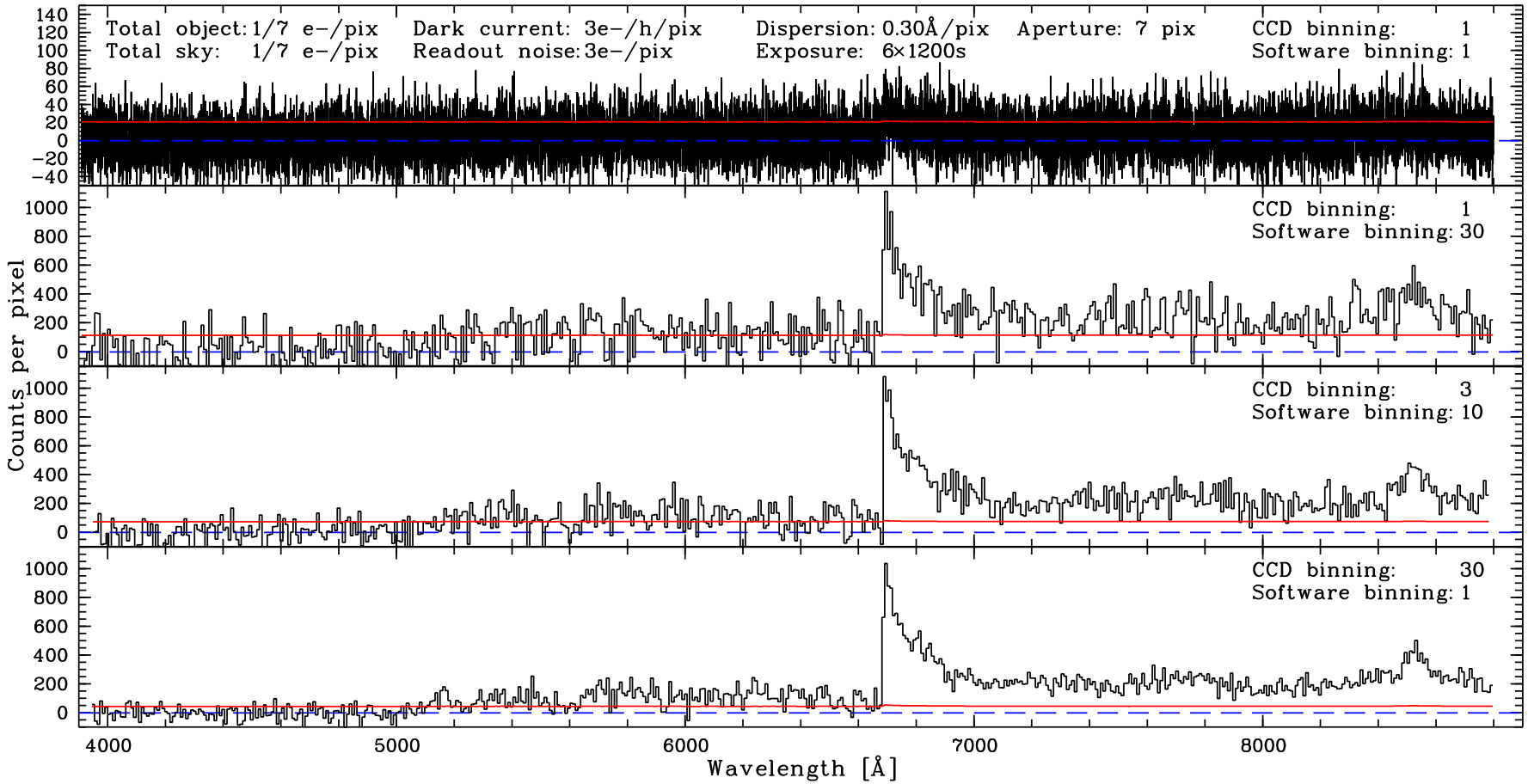
Probing the Faint End of the QSO Luminosity Function



Matsuoka et al. (2016)

4MOST CCD Binning for Extragalactic Targets

- Sky$<$ Readout noise $\longrightarrow$ Maximize S/N by binning the CCD
- Galaxy Survey: [O II] resolved at $R \gtrsim 3300$ (Comparat et al. 2013)
  $\longrightarrow$ Rebin CCD by factor 2–3 for extragalactic surveys?
  $\longrightarrow$ Split Galactic and extragalactic surveys?



Conclusions

- 4MOST is ESO's only wide-field spectroscopic survey instrument
  - Étendue 10.5× VLT/VIMOS
  - Needs to be versatile (i.e. go faint for extragalactic surveys)
- A $z > 4$ QSO survey with 4MOST
  - The faint end of the QSO luminosity function
    (currently <100 $M > M_\star$ QSOs at $z > 4$)
  - QSO emissivity constrains contribution to ionizing budget
  - Do we need galaxies for reionization?
- Other IGM science requires S/N> 10
  - The Lyα forest at $z \sim 5$ (180 $i_{AB} < 20$ $z \sim 5$ QSOs in 13,000 deg^2)
  - The mean free path to Lyman limit photons in the IGM (QSO stacks)
  - QSO proximity effect
  - IGM metals (C IV covered up to $z = 5$)