FLASHLIGHT: Fluorescent Lyman-Alpha Survey of Cosmic Hydrogen LIGHTed by Quasars

Fabrizio Arrigoni Battaia (MPIA)

with Joseph F. Hennawi (MPIA), Sebastiano Cantalupo (UCSC-ETH), J. Xavier Prochaska (UCSC)

Outline : Constraining the CGM in emission

1. Experiment on the Slug Nebula: Constrains on HeII and metal lines in emission from the QSO CGM help in characterizing its properties.

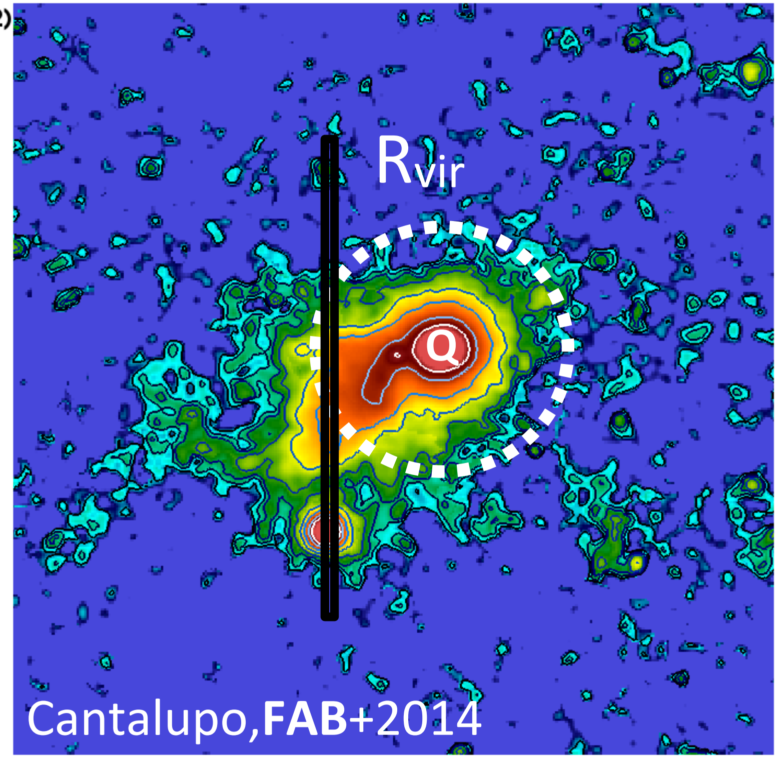
2. FLASHLIGHT: How often can we detect the CGM in emission? What is the typical Lyα signal around a bright QSO?

Photoionization Modeling of CGM Emission

R ~ 160 kpc

L_ν (or i_{QSO} =17.28)

$$U = \frac{\Phi}{c n_{\rm H}} \propto \frac{L_\nu}{n_{\rm H}}$$



Model parameters:

- $\log N_{\rm H}$ = 18 to 22
- $n_{\rm H}$ = 0.01 to 100 cm^{-3}
- f_C = 1.0
- Z = 0.001 to 1 $Z_\odot$

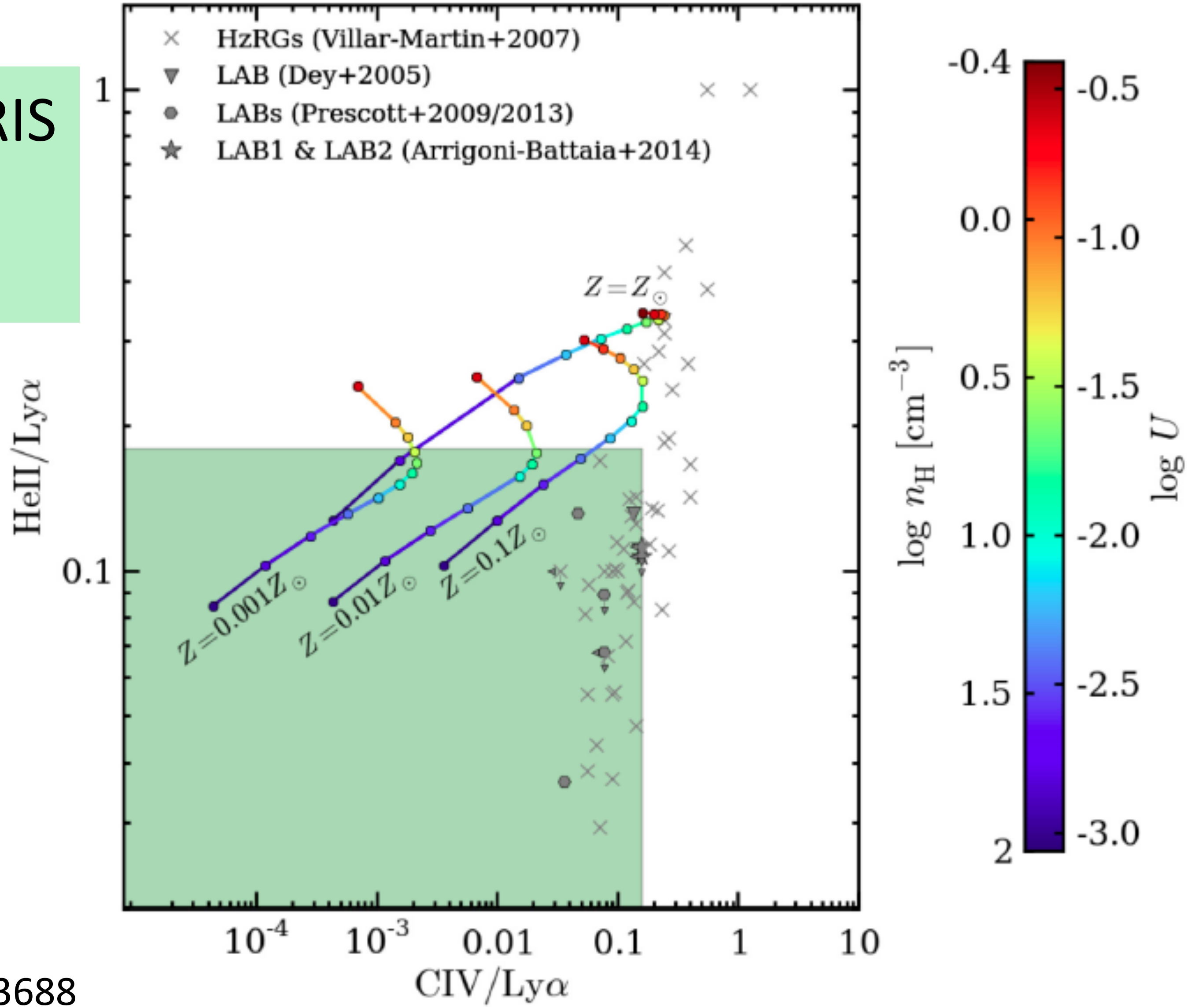
$$\mathrm{SB}_{Ly\alpha} \propto f_c n_H N_H$$

Hennawi&Prochaska 2013

$SB_{Ly\alpha} \approx 7 \times 10^{-18}$ cgs/arcsec^2

Photoionization Modeling of CGM Emission

2 hours Keck/LRIS
HeII/Lyα < 0.18
CIV/Lyα < 0.16

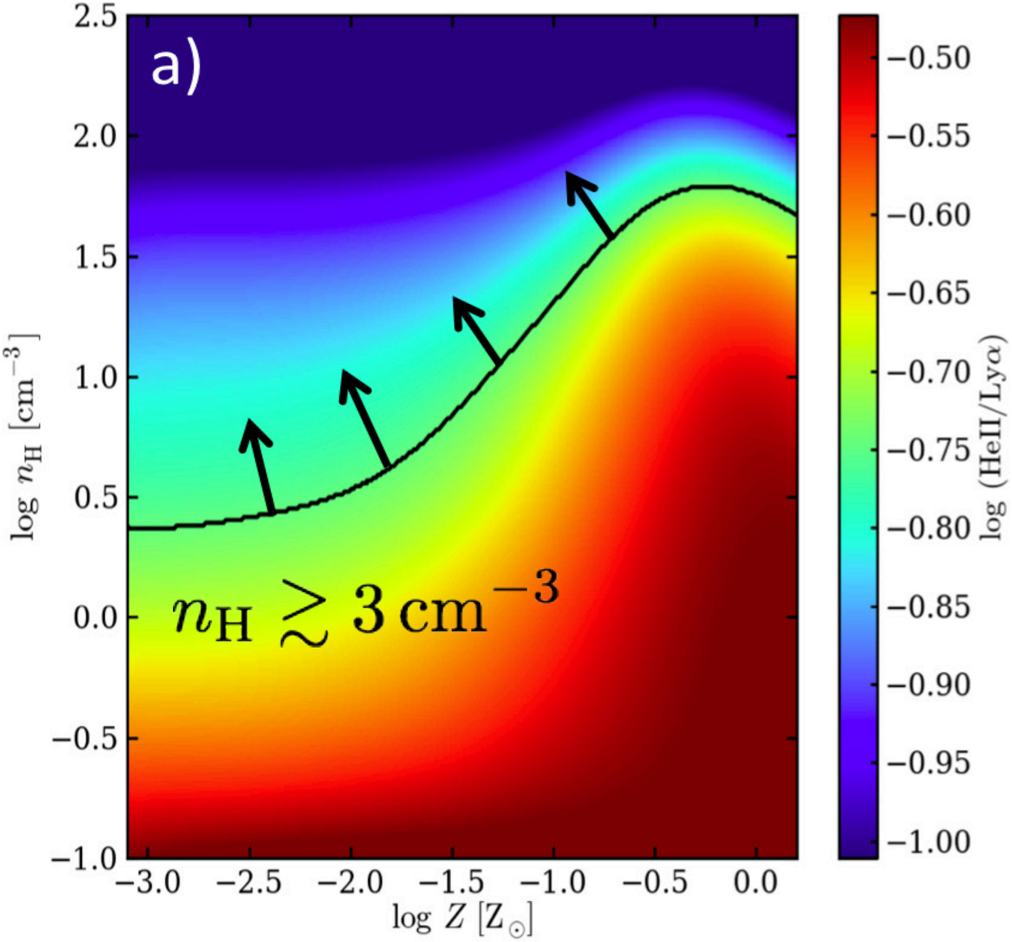


FAB+2015, Arxiv:1504.03688

Models require high n_H (and maybe low Z)

FAB+2015, Arxiv:1504.03688

HeII/Lyα < 0.18



$$j_{\rm line} \propto \frac{h\nu_{\rm line}}{4\pi} n_{\rm e} n_{\rm ion} \alpha^{\rm eff}_{\rm line}(T)$$

If both Hydrogen and Helium are completely ionized

$$\mathrm{HeII/Ly}\alpha = 0.34\,(T = 2\times10^4\,\mathrm{K})$$

If Helium is not completely doubly ionized

$$\mathrm{HeII/Ly}\alpha \propto x_{\rm He^{++}}(U)$$

where $U = \frac{\Phi}{c n_{\rm H}} \propto \frac{L_\nu}{n_{\rm H}}$

Models require clouds with parsec size

FAB+2015, Arxiv:1504.03688

$SB_{Ly\alpha} \approx$ 7 x 10^{-18} cgs/arcsec^2

$$SB_{Ly\alpha} \propto f_c n_H N_H$$

$$n_{\rm H} \gtrsim 3\,{\rm cm}^{-3}$$

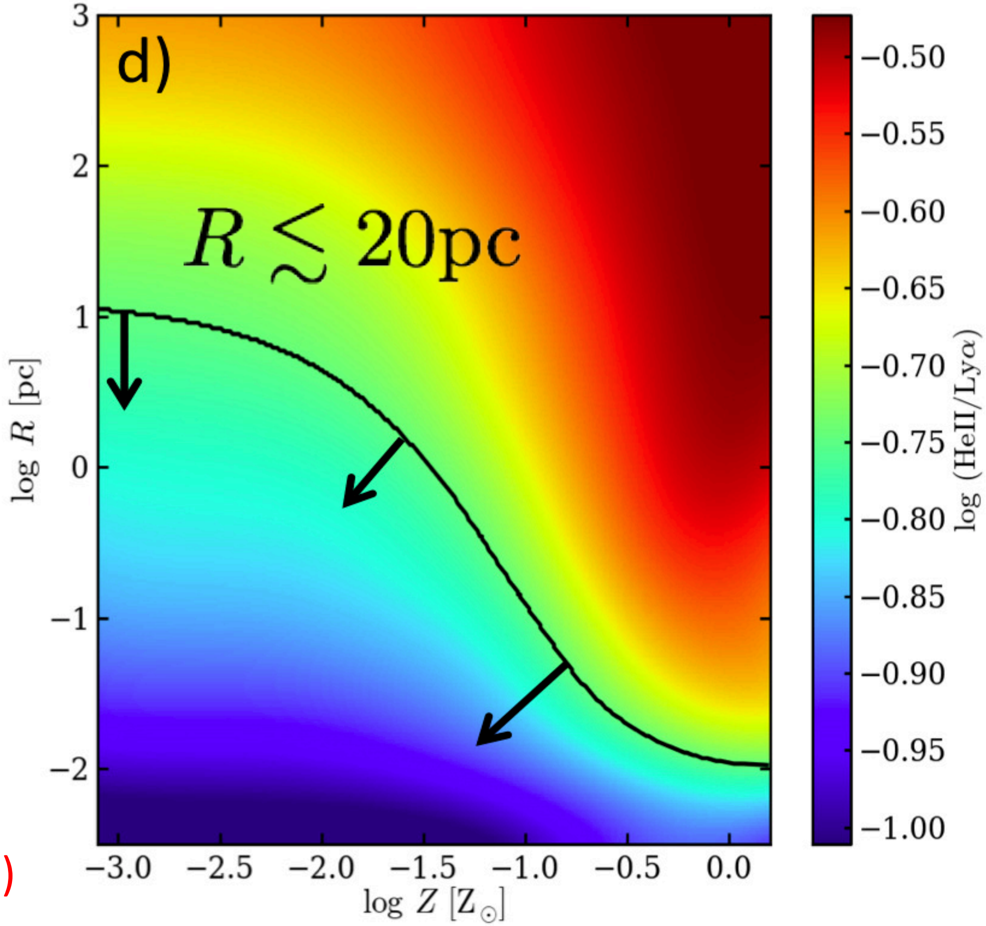
$$N_{\rm H} \lesssim 10^{20}\,{\rm cm}^{-2}$$

$$R \approx \frac{N_{\rm H}}{n_{\rm H}}$$

Agreement with Cantalupo,**FAB**+2014

Do simulations miss important physics on subkiloparsec scales?
(see also Chrighton+2015 and Hennawi+2015)

HeII/Lyα < 0.18



FLASHLIGHT: a Narrow-band Survey

FAB+2014

Targets: brightest SDSS QSOs at z~2 → Radio-quiet
Accurate z
(Mg, NIR)

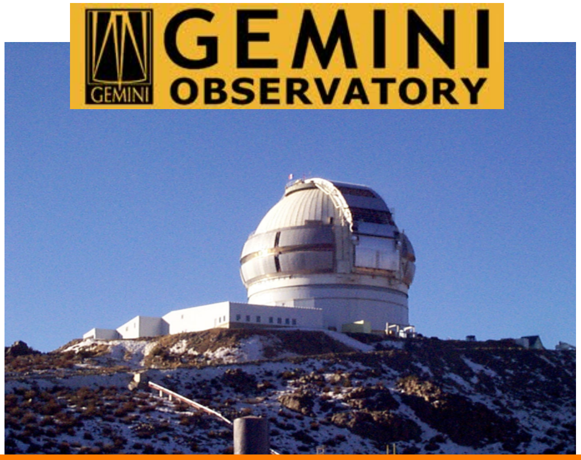
Sample: 8 QSOs on Keck/LRIS
18 QSOs on GMOS-S → in ~ 200 hours

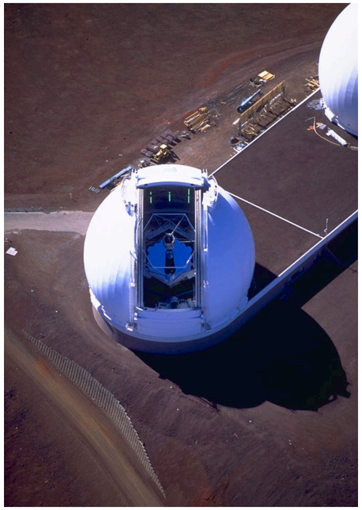
How: 4 custom-built narrow-band filters (FWHM=3-4nm)

$1\sigma \sim 5\text{-}45 \times 10^{-19}$ erg/s/cm^2/arcsec^2
(1 arcsec^2 aperture)

Exp. Time = 2-10 hrs

15 QSOs from GMOS-S

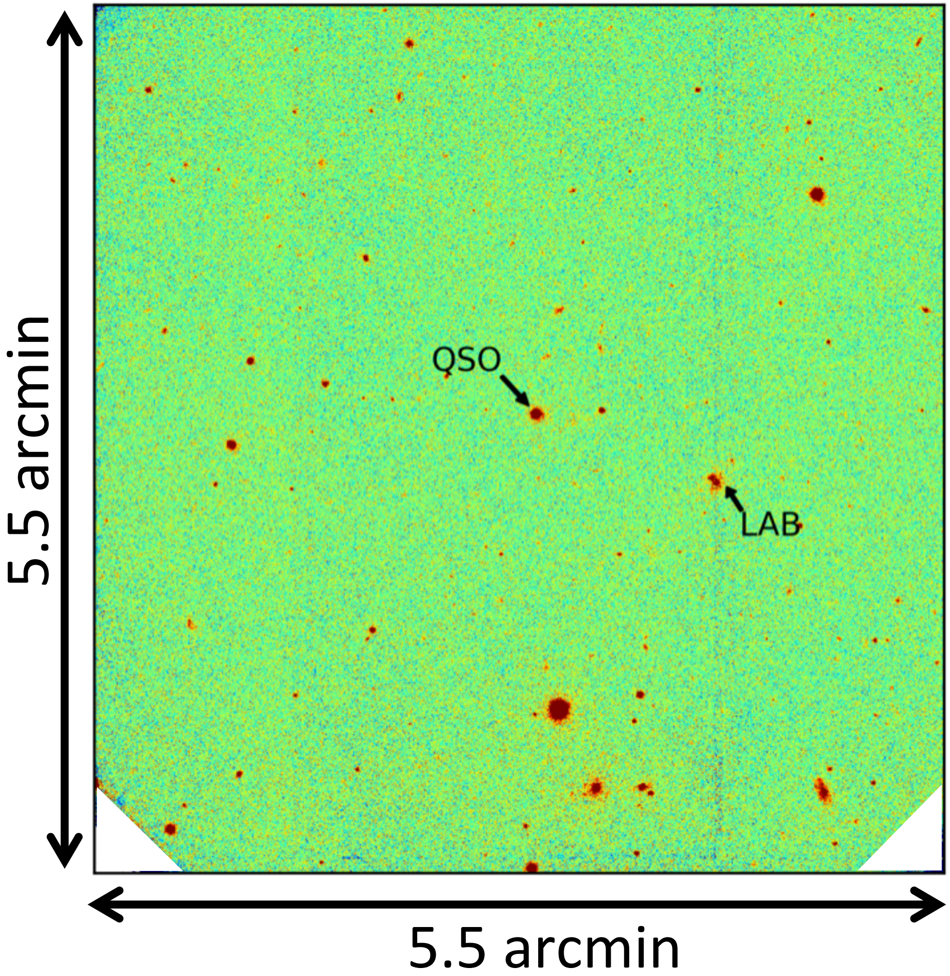




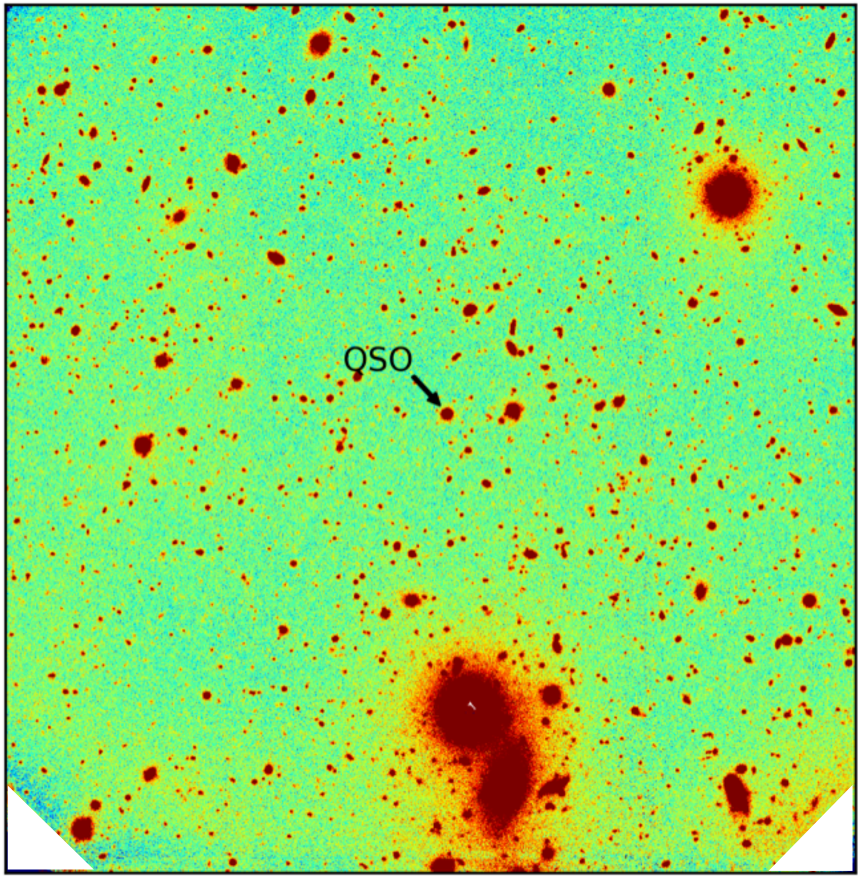
W. M. KECK OBSERVATORY
On the summit of Mauna Kea, Island of Hawai'i

Narrow-band

(Central wavelength=3955Å; FWHM=32.7Å)

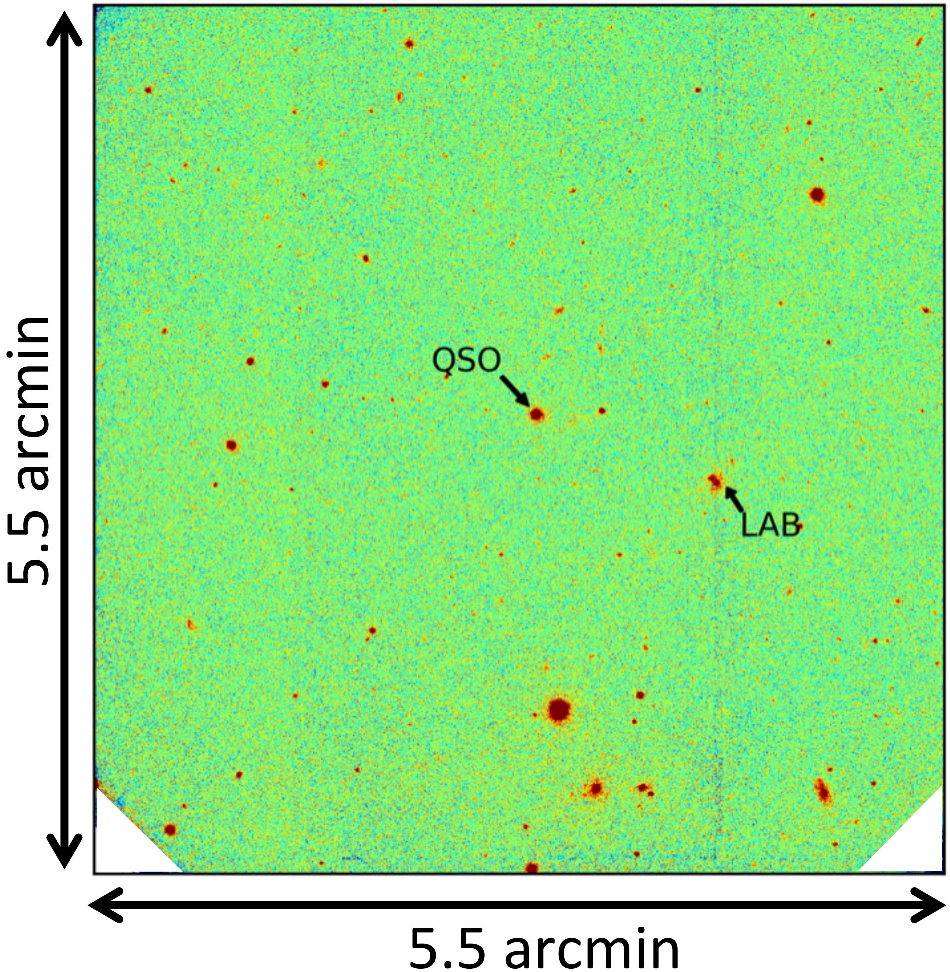


g-band

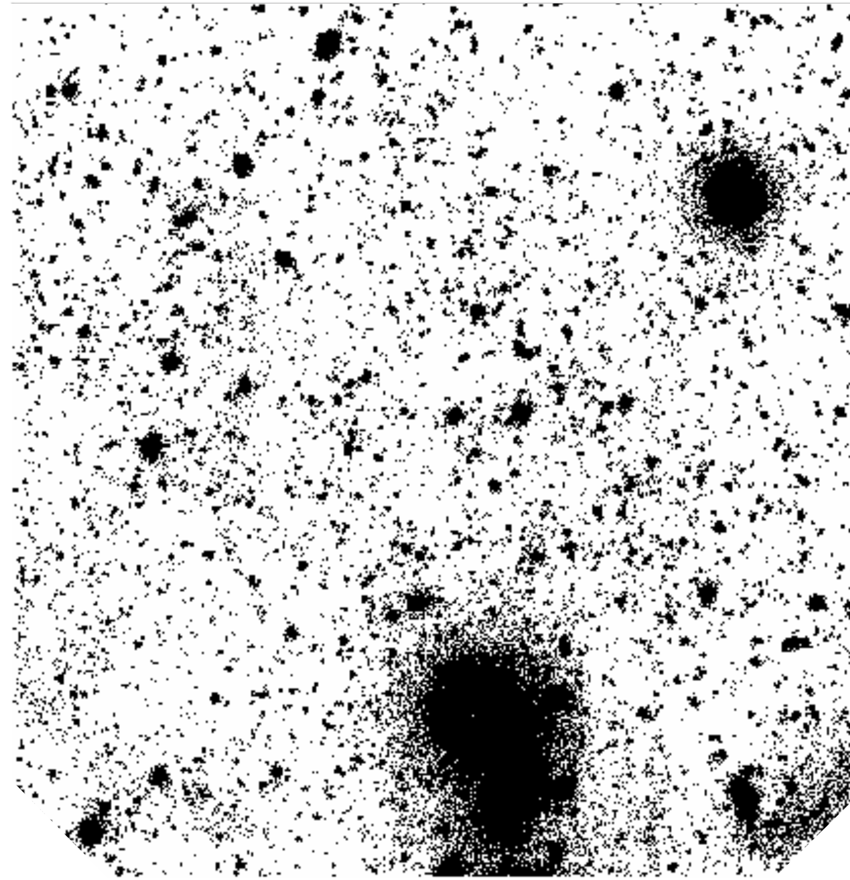


Narrow-band

(Central wavelength=3955Å; FWHM=32.7Å)

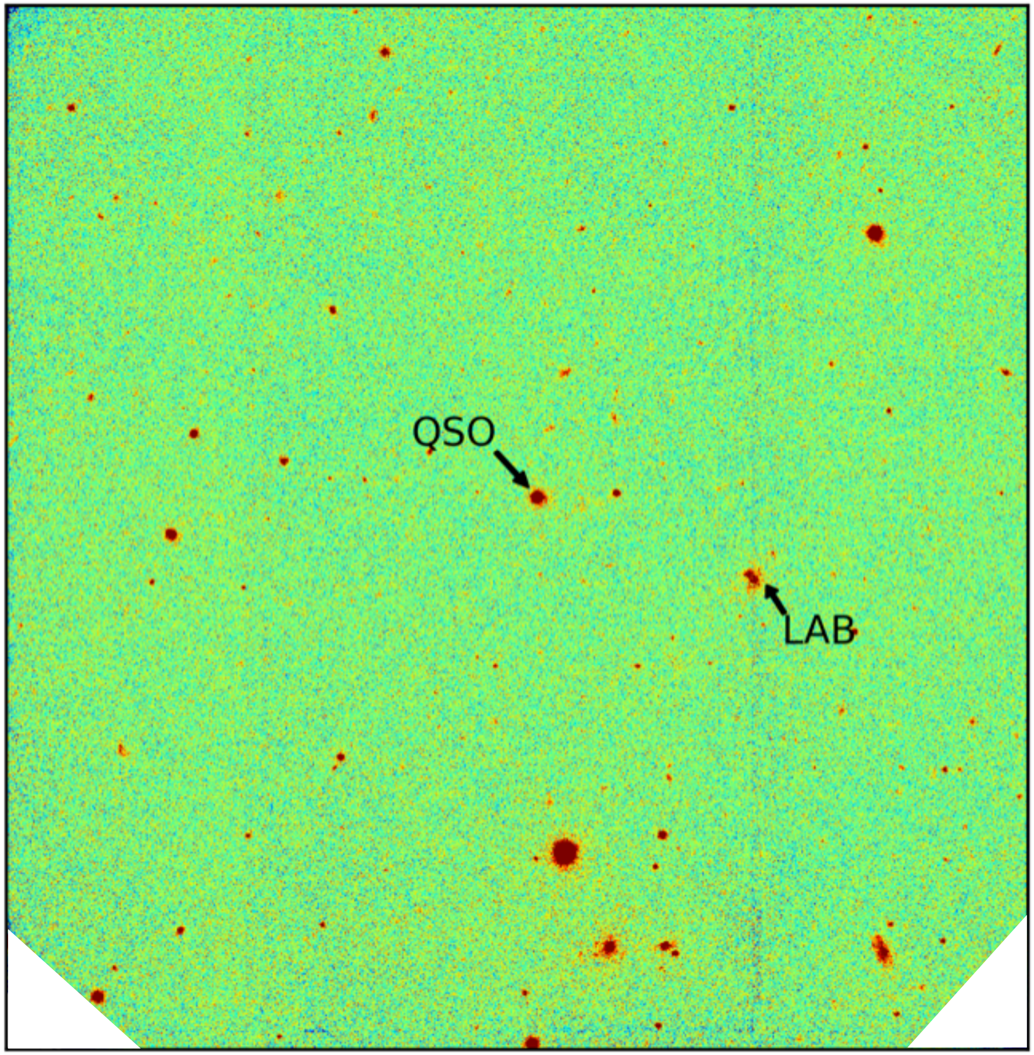


g-band

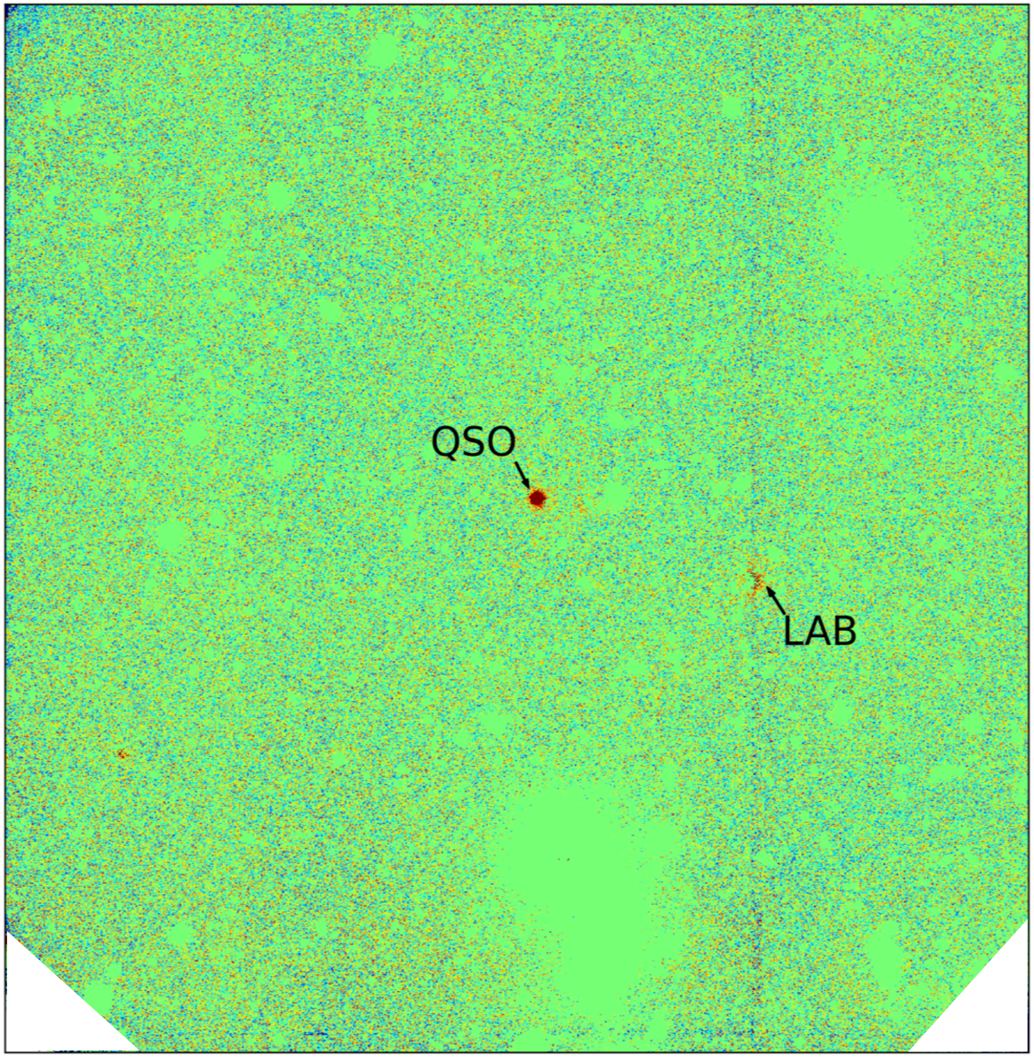


Use *g*-band image to construct mask for all continuum sources.

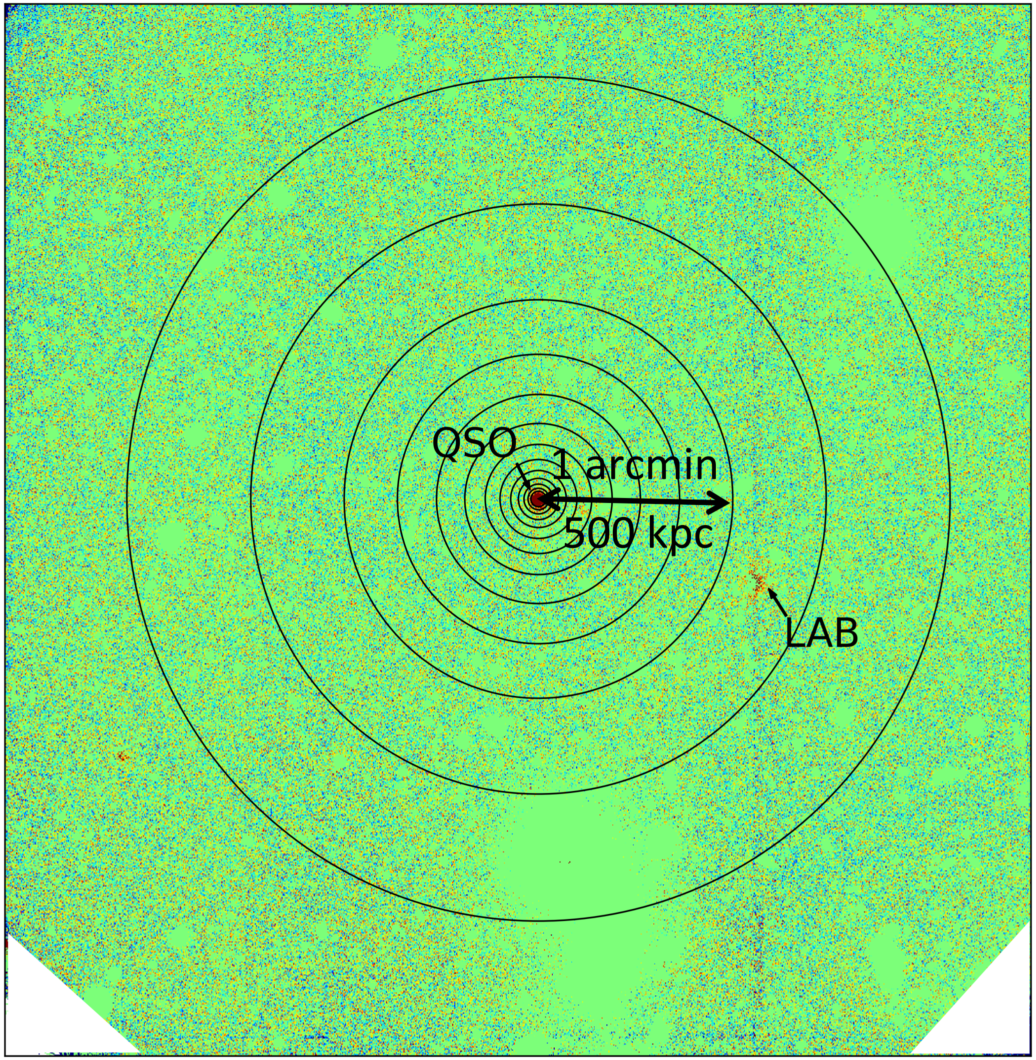
Example of a masked NB image



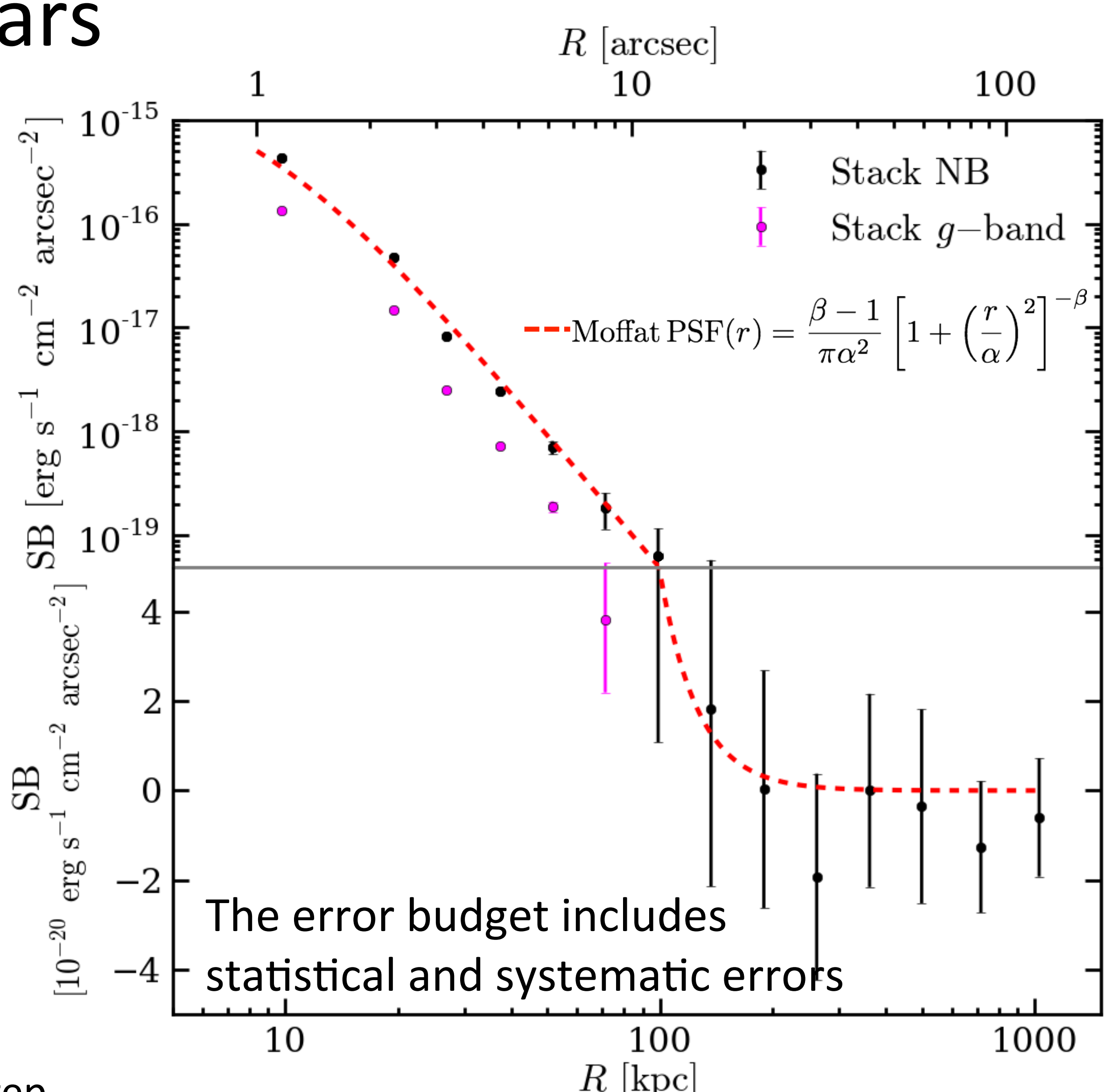
Example of a masked NB image



We extract the radial profile of 15 QSOs



Determining the Point Spread Function (PSF) from Stars

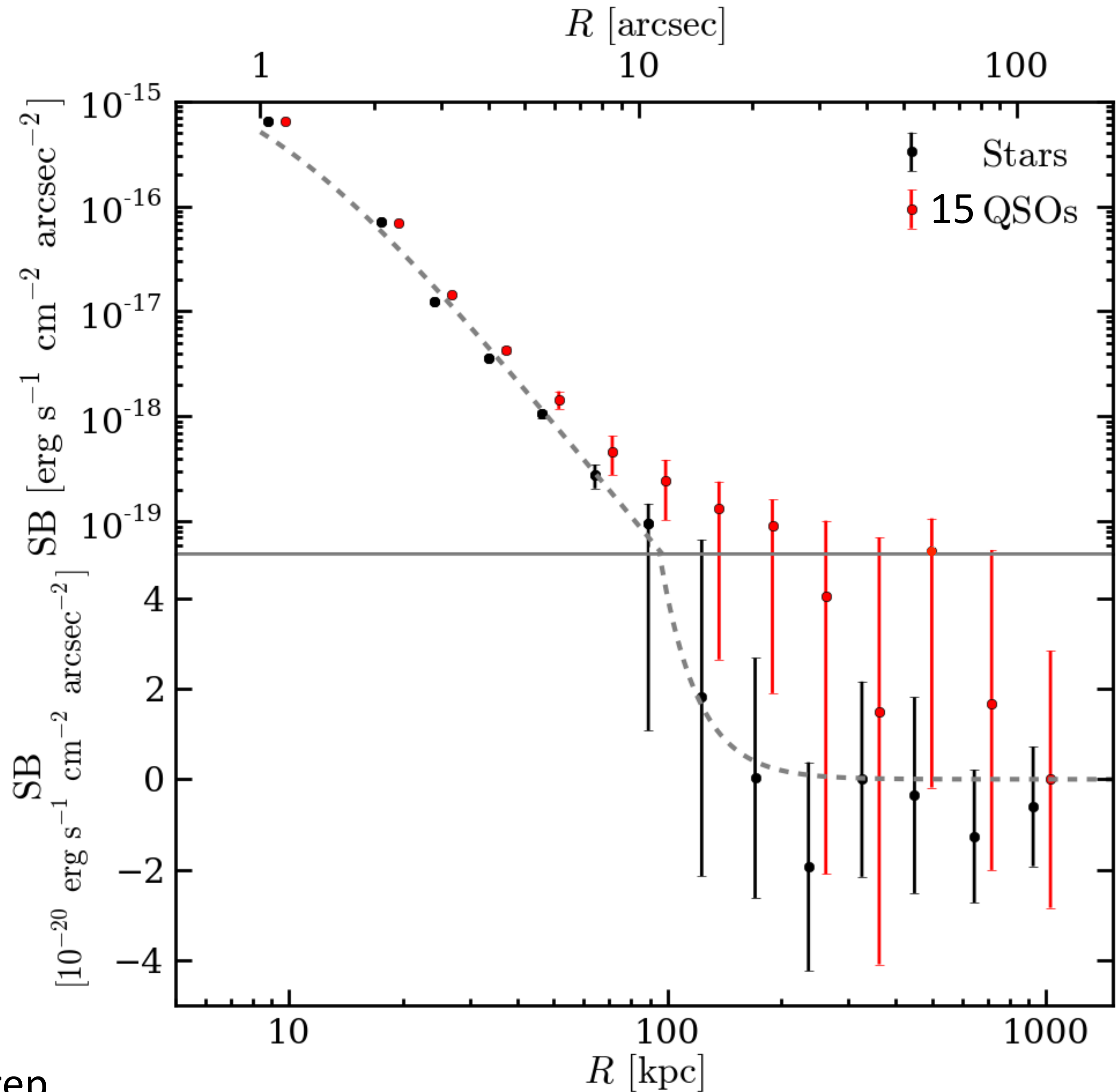


The error budget includes statistical and systematic errors

For the NB, about 100 stars are used.

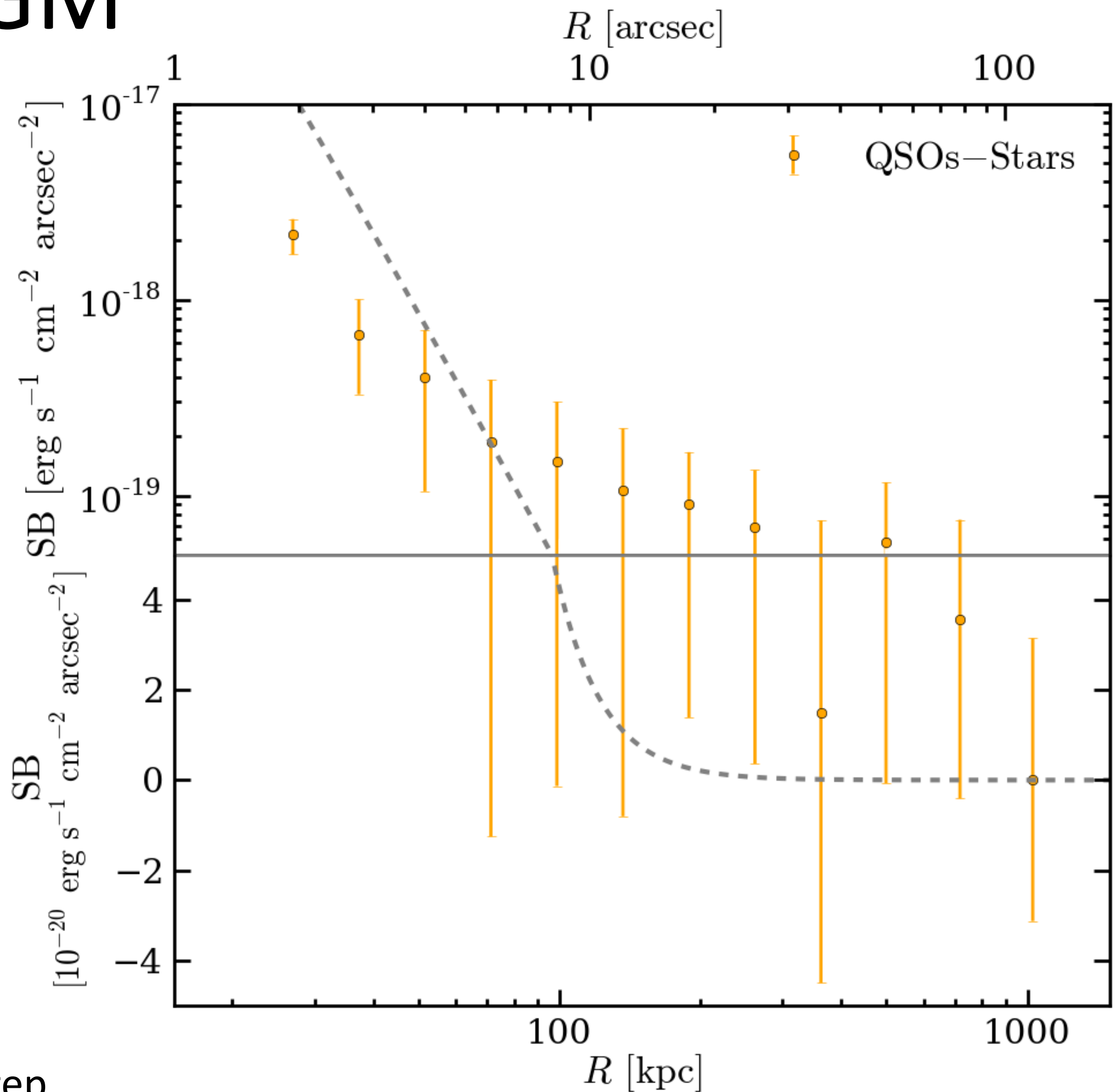
FAB+2015, in prep.

The average QSO profile differs from the PSF



FAB+2015, in prep.

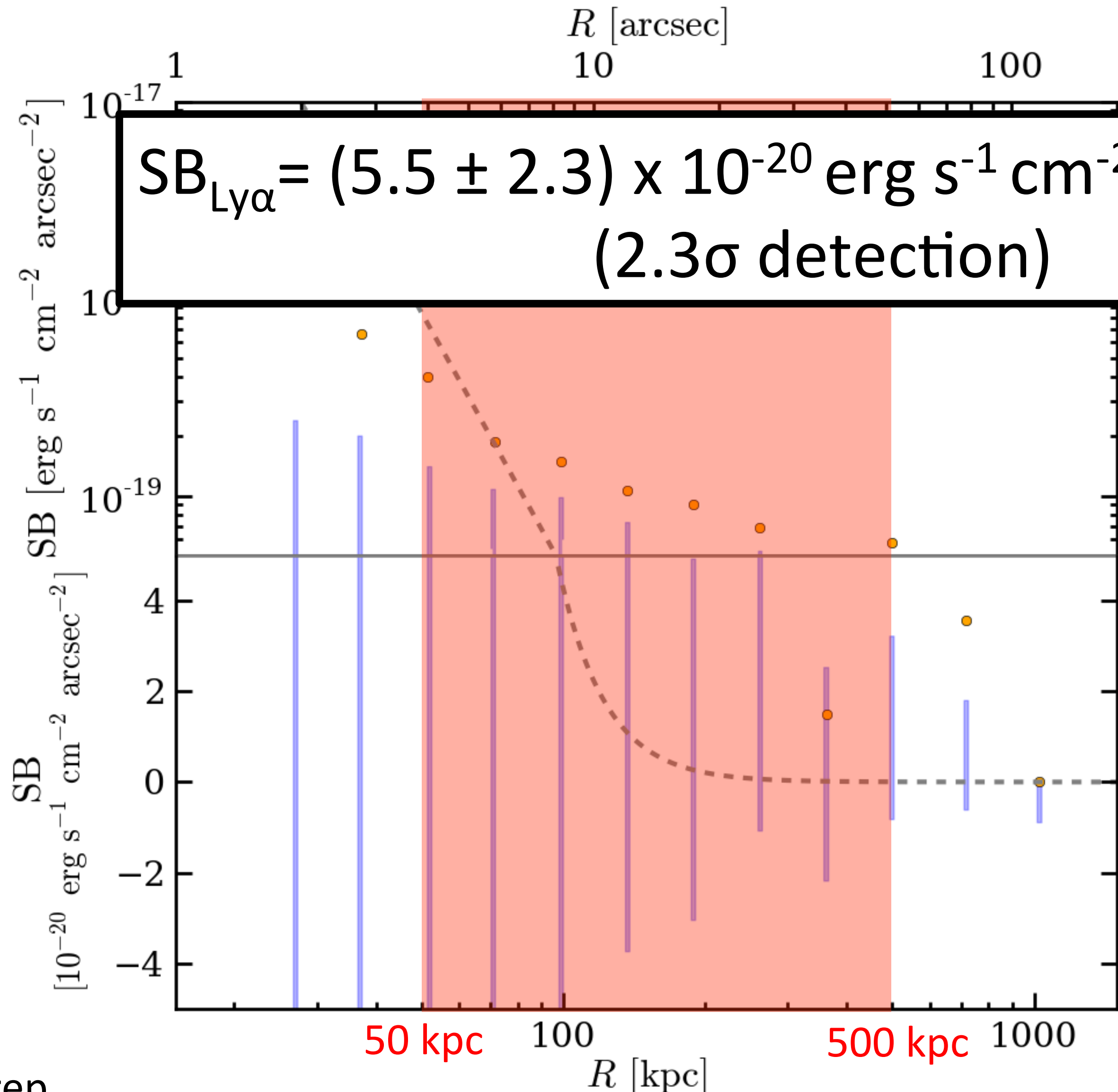
The Average Radial Emission Profile of the QSO CGM



FAB+2015, in prep.

Testing for Systematics

$SB_{Ly\alpha}$= (5.5 ± 2.3) x 10^{-20} erg s^{-1} cm^{-2} $arcsec^{-2}$
(2.3σ detection)



FAB+2015, in prep.

Constraining the average n_H of the QSO CGM

- We assume the QSOs are able to keep the gas ionized.

$$\mathrm{SB}_{Ly\alpha} \propto f_c n_H N_H$$

- From absorption line studies of optically thick absorbers (Lau+2015 submitted)

$$N_{\mathrm{H}} \approx 10^{20.5}\,\mathrm{cm}^{-2}$$

- Quasar absorption line studies of the QSO CGM suggest (QPQ series, Prochaska+2013)

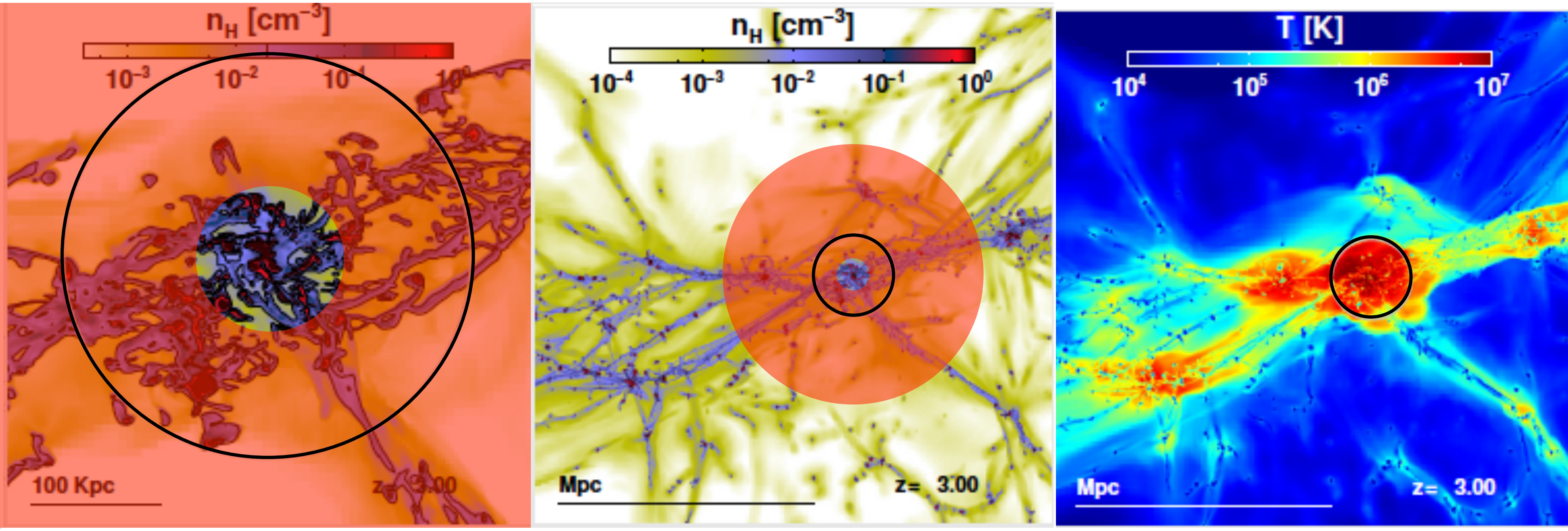
$$f_{\mathrm{C}} \sim 0.5$$

$$n_{\mathrm{H}} = 0.6 \times 10^{-2} \left(\frac{\mathrm{SB}^{\mathrm{thin}}_{\mathrm{Ly}\alpha}}{5.5 \times 10^{-20}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}} \right) \left(\frac{1+z}{3.253} \right)^{4} \left(\frac{f_{\mathrm{C}}}{0.5} \right)^{-1} \left(\frac{N_{\mathrm{H}}}{10^{20.5}\,\mathrm{cm}^{-2}} \right)^{-1} \mathrm{cm}^{-3}.$$

It is needed a careful comparison with simulations

Our stacked analysis directly constrains $\mathrm{SB}_{Ly\alpha} \propto f_c n_H N_H$

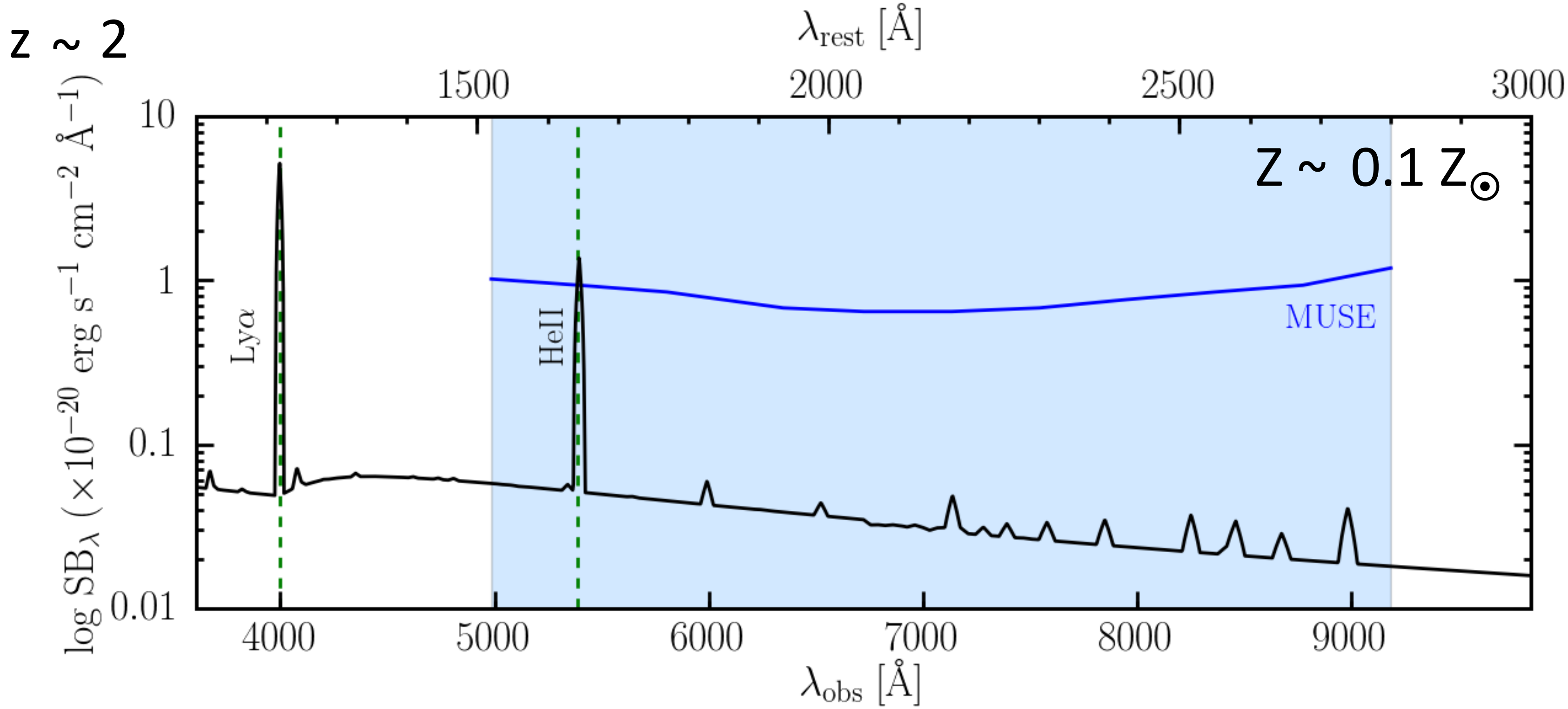
$M_{halo} \approx 10^{13}\ M_{\odot}$



Rosdahl & Blaizot 2012

We are detecting statistical signal from diffuse gas in the Cosmic Web.

Obtaining constraints from the HeII line emission



MUSE (or KCWI) might be able to detect an average HeII emission from the typical bright QSO CGM

- 50 objects; exp. time = 3 hrs; averaging over an aperture of 1600 arcsec^2 (50 kpc < R < 200 kpc)

The average HeII emission can be used to better constrain n_H, as for the Slug.

Summary

1. HeII and metal lines in emission are fundamental to unveil the physical properties of the cool gas in QSO halos (n_H, N_H, Z).

2. The observed QSO CGM requires the presence of compact (R<20 pc), dense ($n_H > 3$ cm^{-3}) cool gas clouds.

3. Only 10% of QSOs shows giant Lyα nebulae. Large surveys are needed to uncover the brightest nebulae on the sky.

4. We compute the average radial emission profile of the typical bright QSO CGM. We find $SB_{Ly\alpha} = (5.5 \pm 2.3) \times 10^{-20}$ erg s^{-1} cm^{-2} arcsec^{-2} within 50 kpc < R < 500 kpc.

5. We thus find an average $n_H = 0.6 \times 10^{-2}$ cm^{-3} (using results from Lau+2015). Comparisons with simulations are needed...