Lyα IM with broad-bang imaging: a DECaLS/BASS-DESI forecast

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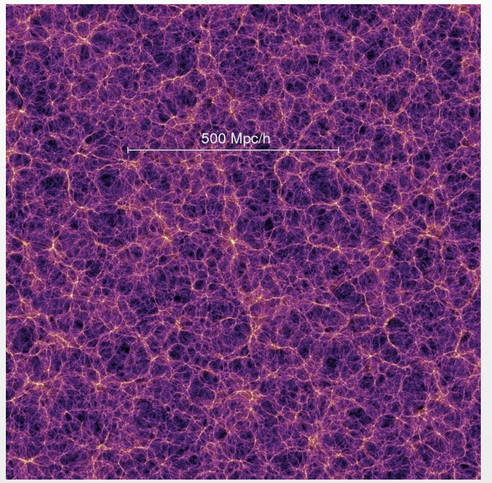
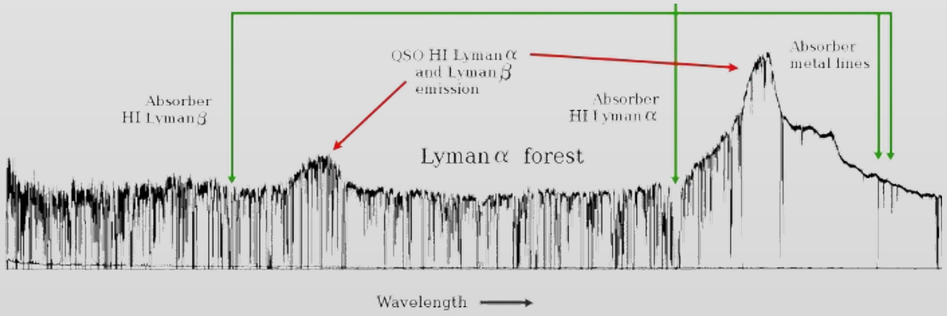
Large scale-structure in Lyα



Although we only "see" galaxies, **most baryons** lie in the intergalactic medium (**IGM**), tracing **large-scale structure**. The strongest emission line of neutral hydrogen (HI) is Lyman-alpha (**Lyα**, **λ=121.567 nm**). Lyα seems a **prime candidate** for **Intensity Mapping (IM)**.

Have we observed the Lyα large-scale structure?

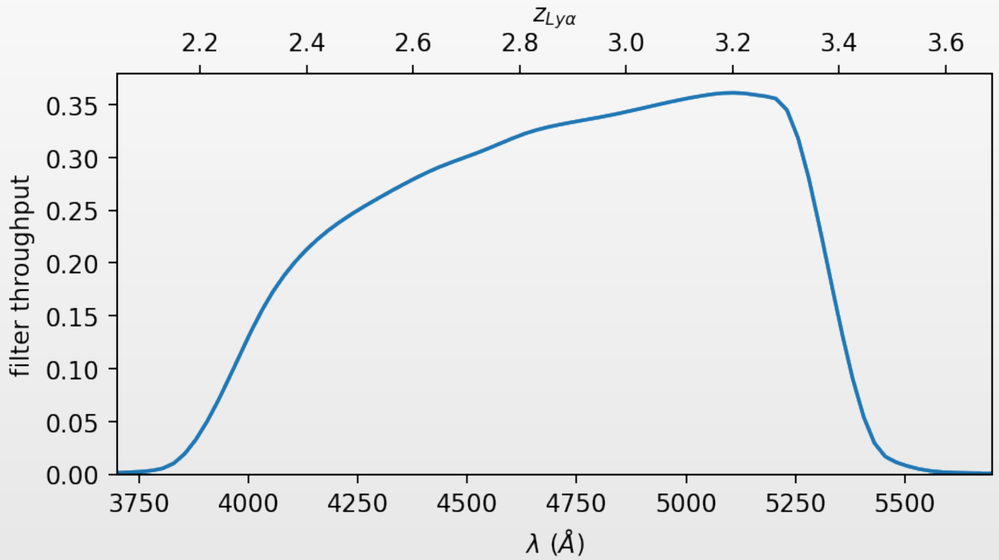
Absorption: Yes! QSO spectra (**Lyα forest**)



Emission: A little bit, but **no proper large scale detection!**

- Very faint diffuse emission
- UV line, visible at z>2.1. **All optical emission** at z<2.1 are **interlopers**!

Lyα in *g*-band images



***g*-band** images contain **Lyα emission** on **2.2 < z < 3.4**, and **tens of thousands of deg²** have **already** been **observed** (e.g, SDSS, DES, CFHTLS...).
All these images backgrounds **contain diffuse Lya emission** that could be used for IM, but **SNR is too low**! (~<1/100 !)

How can we boost SNR?

Spectroscopy: **DESI**

- Footprint: 14,000 deg2
- Lyα forest in QSO spectra (z>2.1) ~ 7e5

Cross-correlation

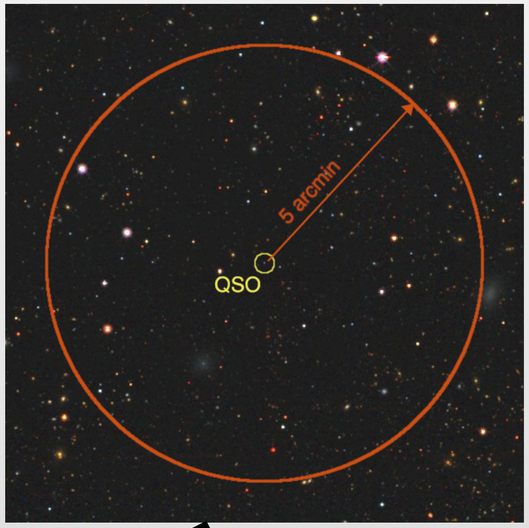
Imaging: **DECaLS/BASS**

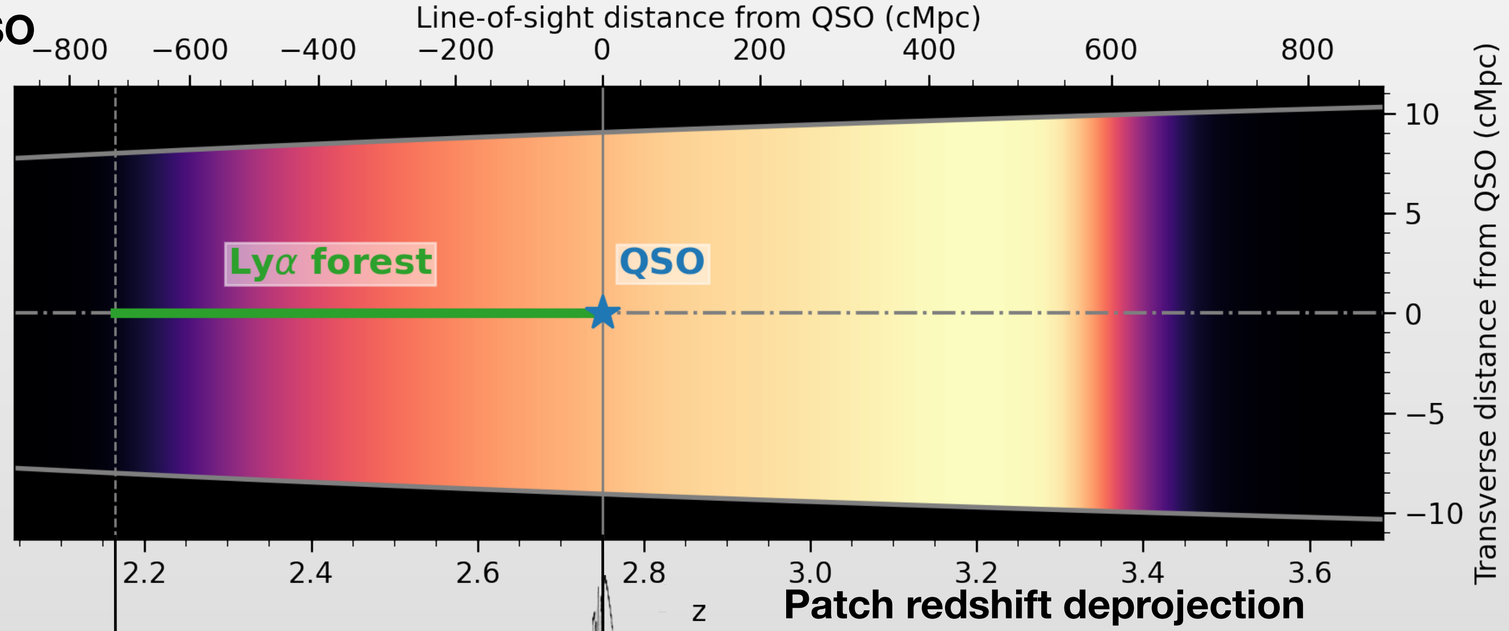
- DESI Legacy Surveys (same footprint)
- *g*-band images (Lyα emission 2.2<z<3.4)

Image-forest correlation

QSO spectra trace LSS in Lyα absorption. Integrating ***g*-band** images in **patches around QSOs** yields very **narrow Lyα emission** projected **cylinders**.

Cartoon of *g*-band patch around QSO





Cross-correlation

Rauch1998

A patch flux-Lyα forest correlation would mean a detection of LSS in Lyα emission!

Simulation

We simulate our Lyα signal with a **hydrodynamic simulation**. Snapshot at **z=3** with **pixel size** of **1.56 cMpc/h** (256 bins per side, box diameter 400 cMpc/h).

1. Compute **lightcone** from simulation box
2. **Convolve** with ***g*-band**
3. Add **real** intensity map of **BASS images**

} **DECaLS/BASS *g*-band images**

2. Draw **QSO sightlines**
3. Add **noise** + continuum subtraction **bias**

} **DESI reduced QSO spectra**

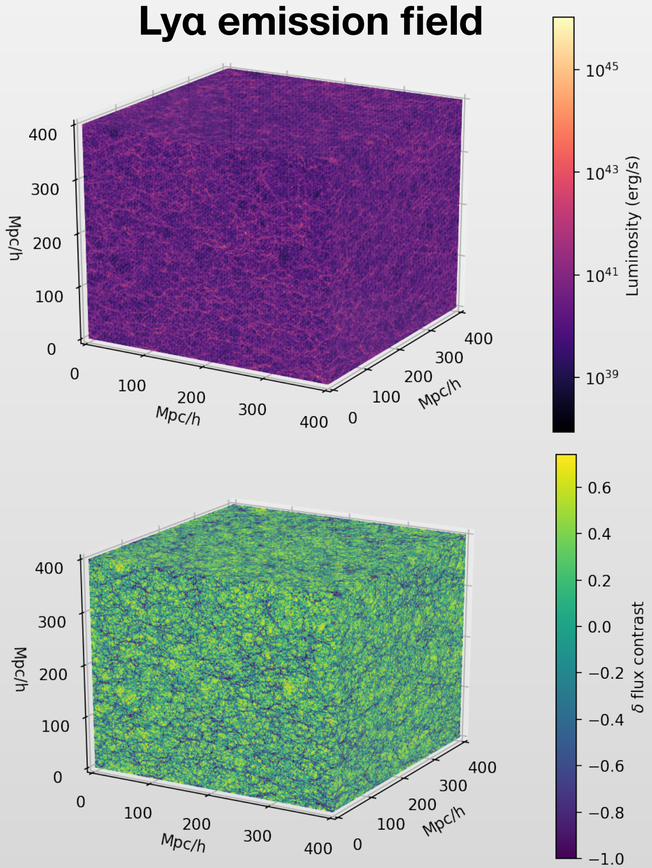
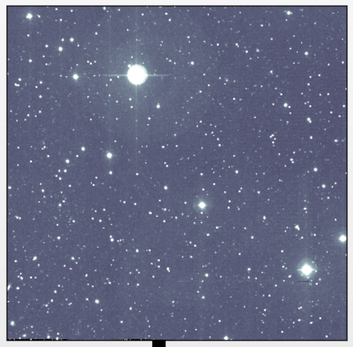


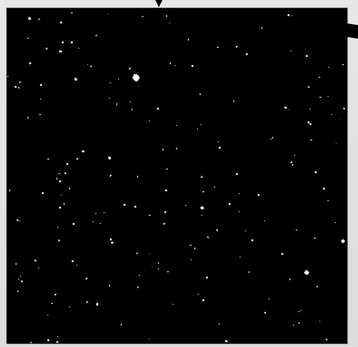
Image reduction

We reduce the noise images without erasing the Lyα signal (no background substraction)

Single epoch image



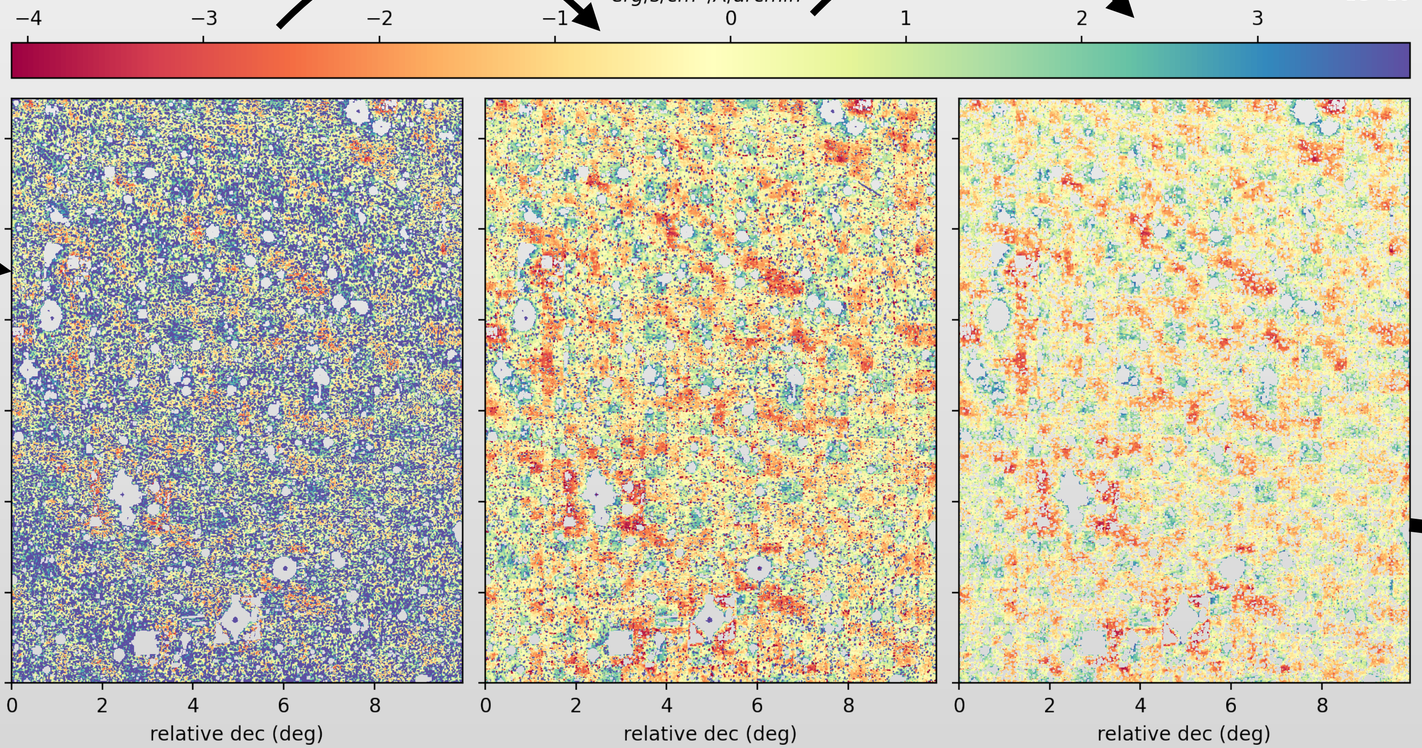
Subtract constant SKY value

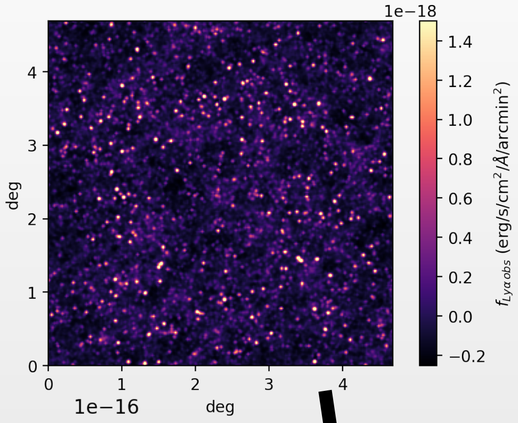


Low-res coadd

Foreground removal (g mag<19)

Sigma-clipping to remove outliers





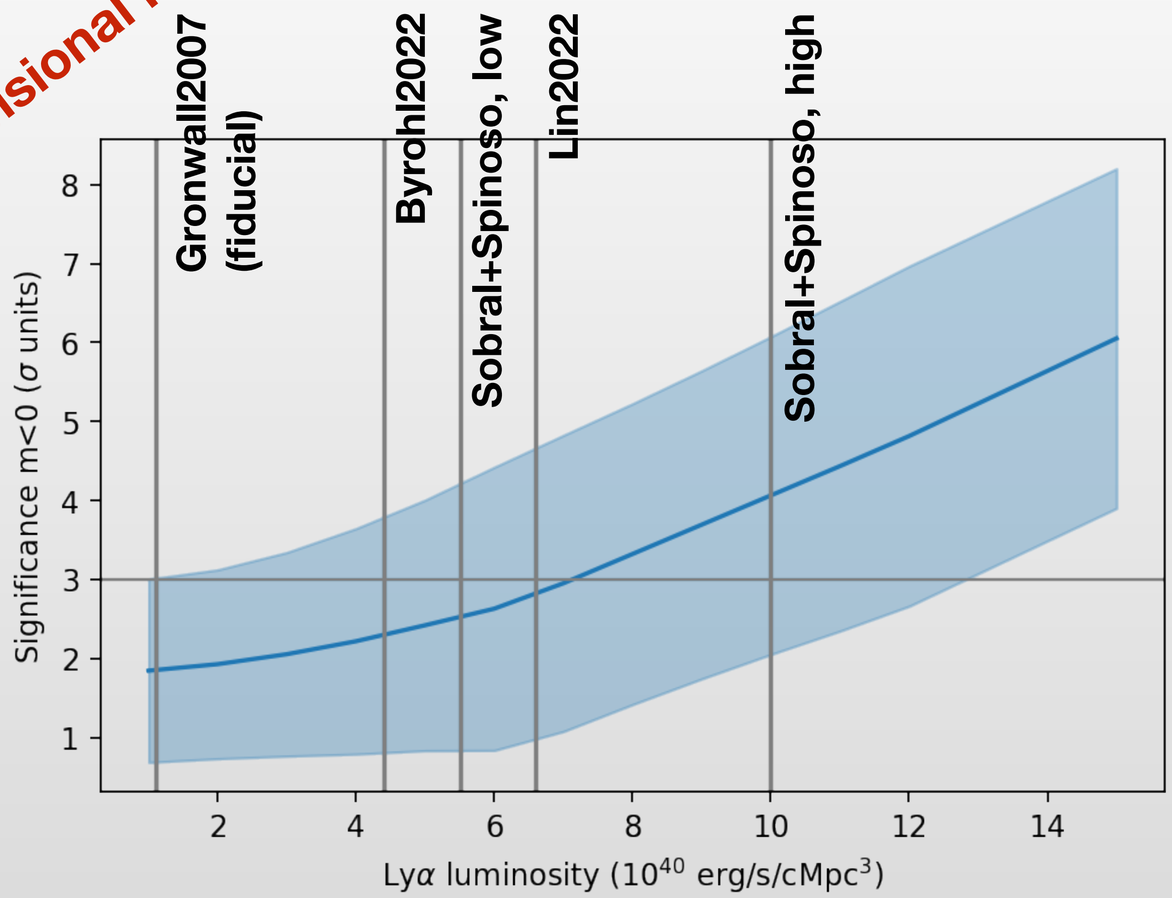
Combine with Lyα image (signal ~100 times smaller!)

Final noise image

Lyα luminosity constraints

Forecast results

Provisional results!



Significance of a detection vs average Lyα luminosity
(Error area corresponds to different realizations of QSO coordinates)

We **cross-correlate** our simulated data with a **custom** one-parameter **estimator**

We find a **>3σ detection** of correlation at an **average Lyα luminosity** of

$$\langle L_{Ly\alpha} \rangle \sim 7 \cdot 10^{40} \mathrm{erg/s/cMpc^3}$$

Without a detection, we may place the **upper limit**:

$$\langle L_{Ly\alpha} \rangle < 7 \pm 6 \cdot 10^{40} \mathrm{erg/s/cMpc^3}$$

Well into **literature values**!

What can we expect?

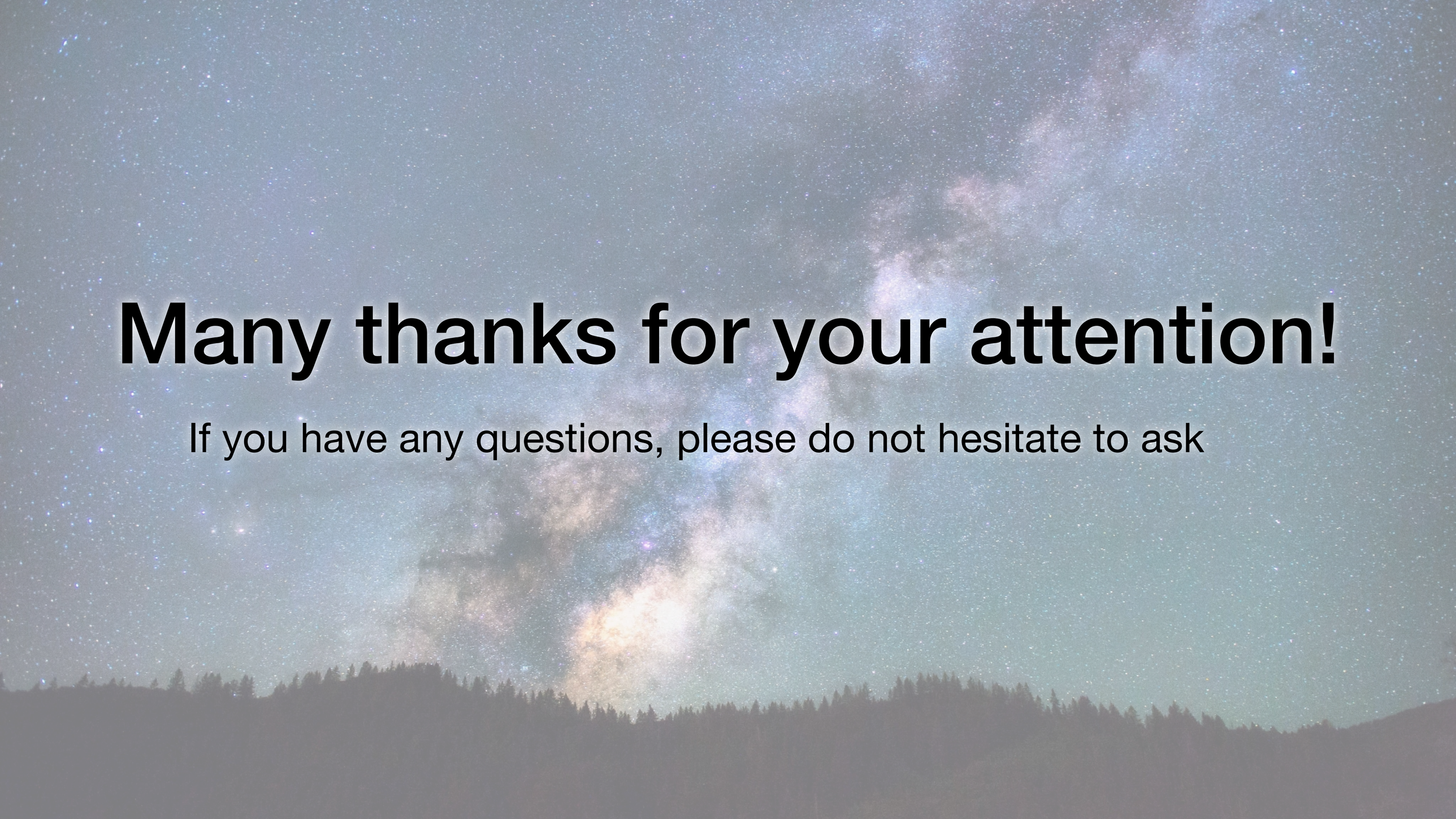
Current photometric surveys (DEcALS/BASS)

Future photometric surveys (LSST, JPAS, Euclid, CSST...)

No detection: Competitive **upper limits** on total **Lyα luminosity**

Low SNR detection: **Estimate** on total **Lyα luminosity**

High SNR detection: Explore use as a **cosmological probe**


Many thanks for your attention!
If you have any questions, please do not hesitate to ask