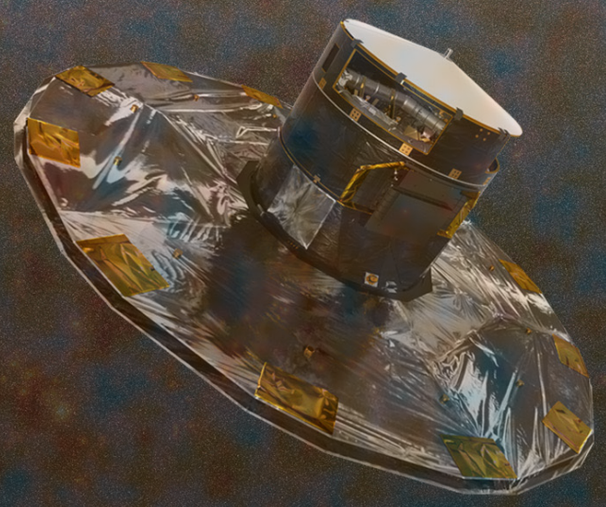
Cosmology with Gaia quasars (Quaia)

with D. Alonso, K. Storey-Fisher, D. Hogg, A. C. Eilers, H. W. Rix…



Giulio Fabbian

Marie Skłodowska Curie Global fellow

MARIE CURIE ACTIONS

FLATIRON INSTITUTE
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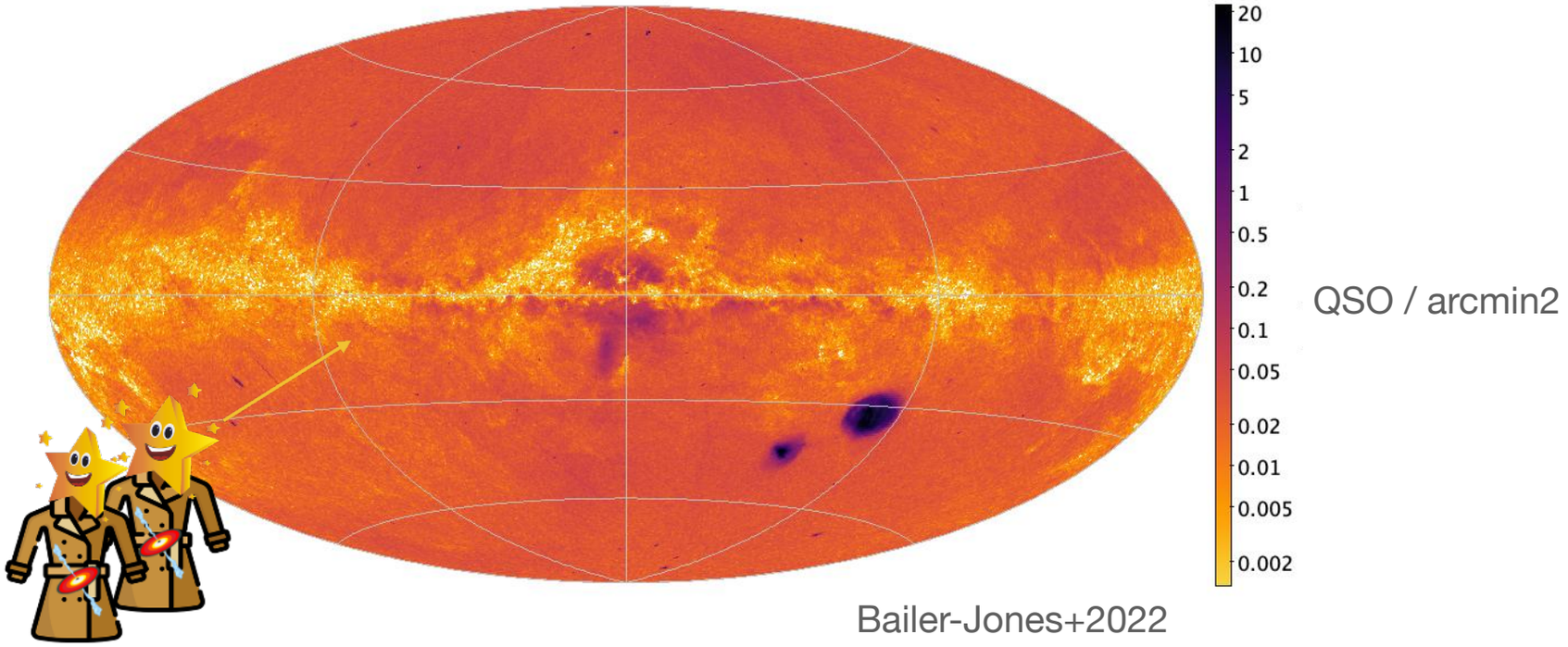
Gaia: more than astrometry

- Photometry, astrometry, slitless spectroscopy of point sources with $30 \leq \lambda/\Delta\lambda \leq 100$ resolution, 21 mag. limit in G band.

- DR3 released 6.6 million quasar candidates with redshifts!



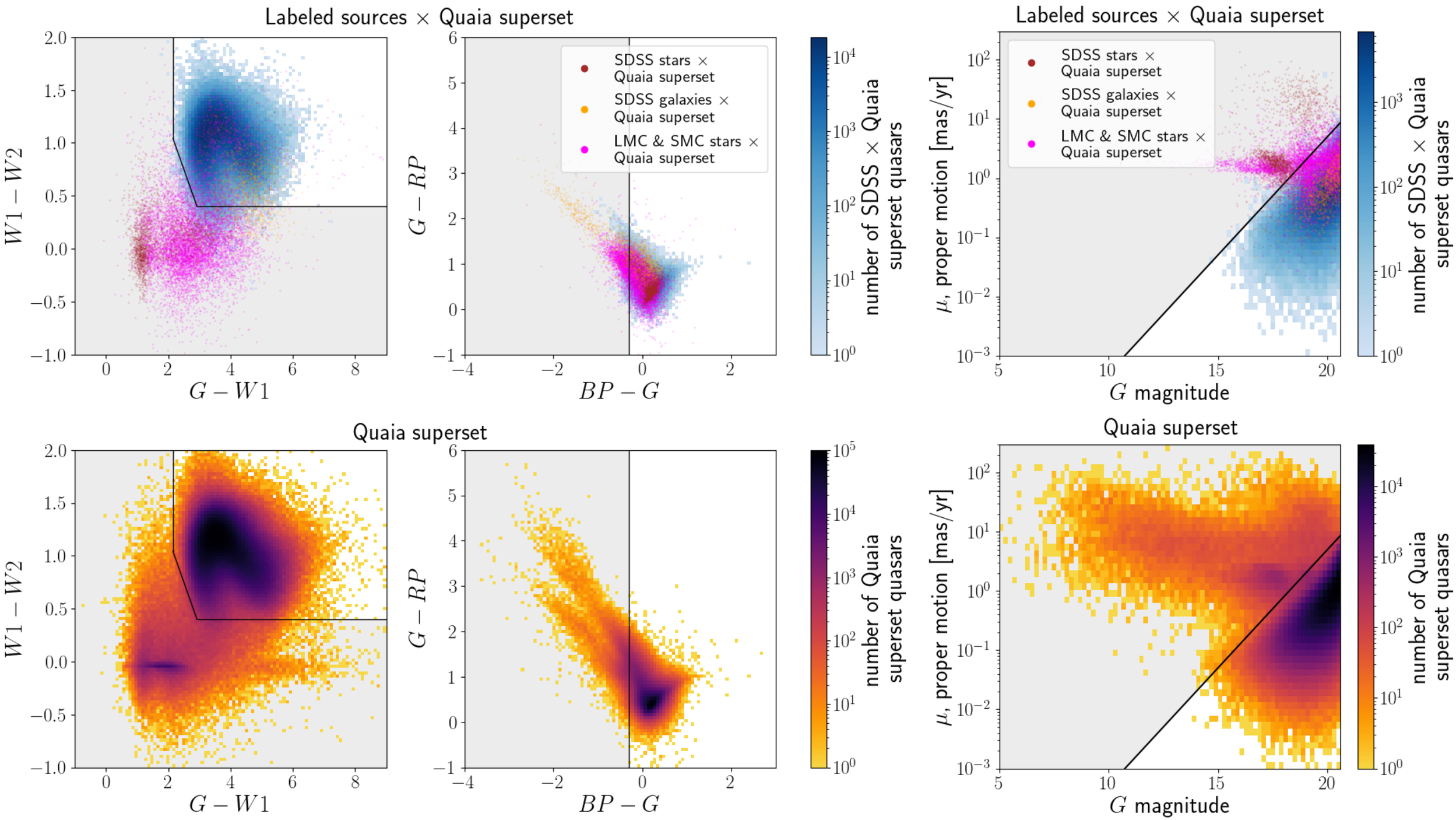
Bailer-Jones+2022

- Complete, low purity, as many are stars masquerading as QSO :/ but…

- Space-quality (e.g. no seeing, airmass): larger volume and cleaner selection function than any existing sample.

Quaia: the cosmological QSO sample of Gaia

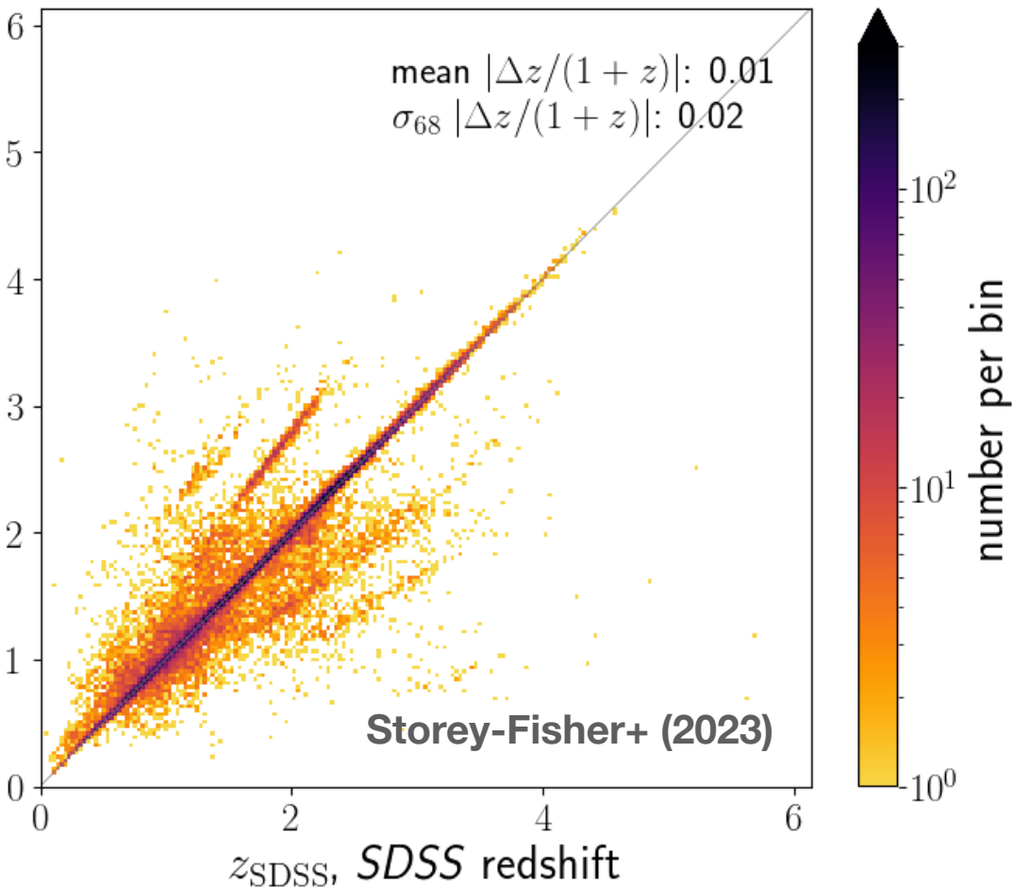
- unWISE + SDSS DR18 + cuts in color and proper motion = improved purity, low systematics

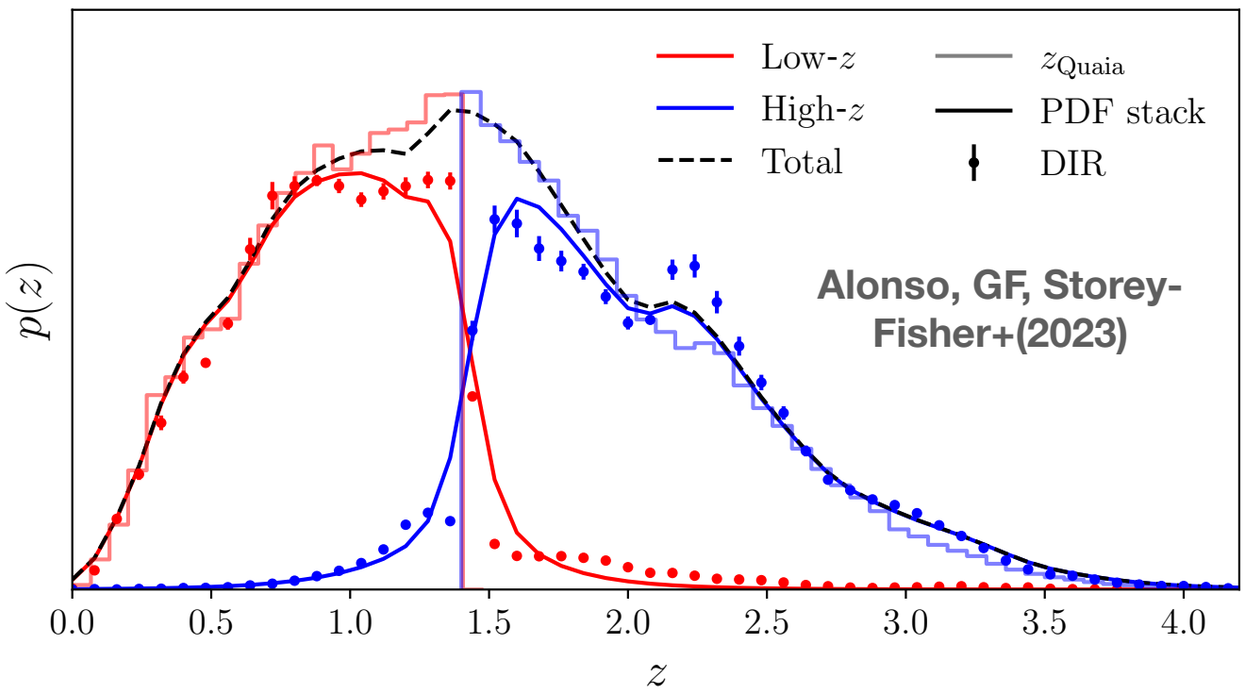


Storey-Fisher+ (2023)

Quaia: improved redshift and final properties

- Multi-band kNN-based correction of redshifts achieving $\sigma_z \approx 0.01(1+z)$

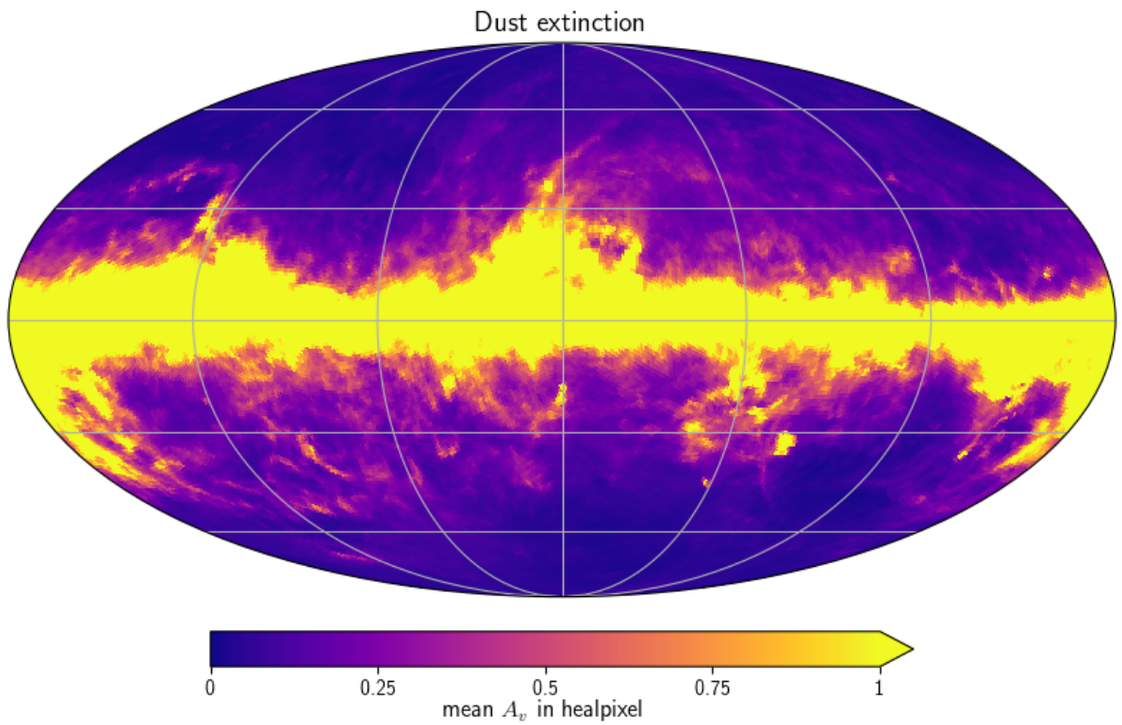


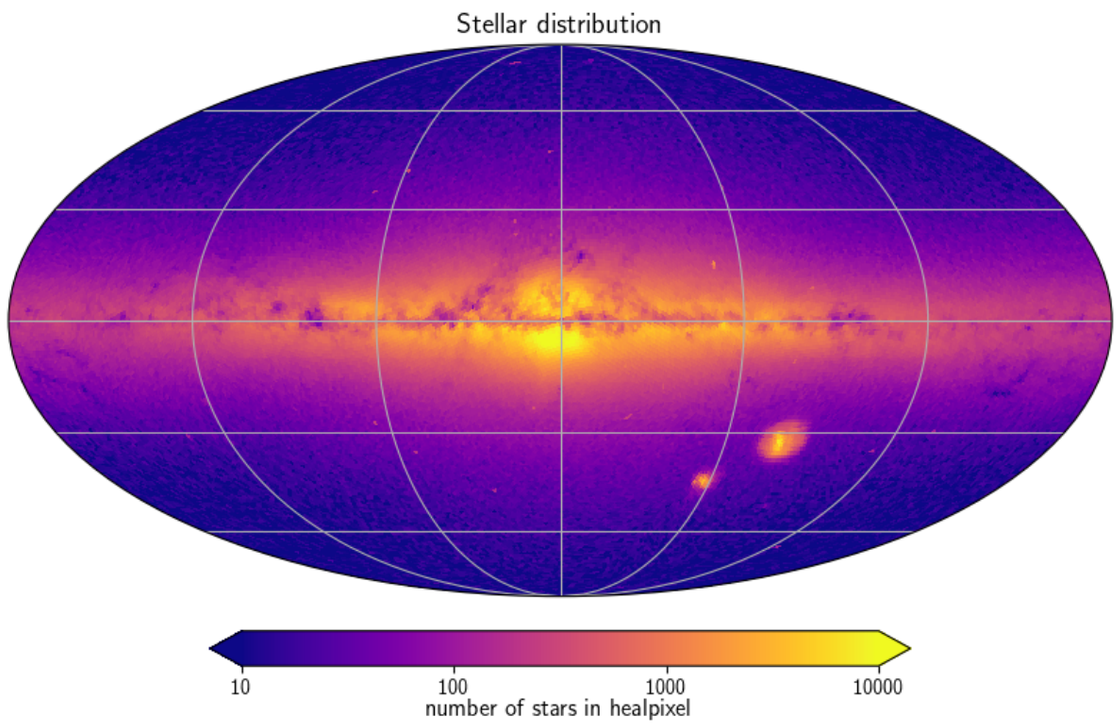


	N	$f_{\rm sky}$	$\bar{n}$, deg^{-2}	$V_{\rm span}$, $(h^{-1}\,{\rm Gpc})^3$	$V_{\rm eff}$, $(h^{-1}\,{\rm Gpc})^3$	$z_{\rm med}$	$f(\lvert\delta z\rvert < 0.01)$	$f(\lvert\delta z\rvert < 0.1)$
Quaia	**1,209,833**	**0.71**	**41.50**	**138.46**	**7.01**	**1.47**	**0.61**	**0.83**
Gaia Purer	1,261,884	0.71	43.29	138.44	6.43	1.61	0.62	0.70
WISE-PS1	1,106,010	0.54	49.81	105.45	7.21	1.43	0.12	0.76
eBOSS	190,194	0.14	34.03	26.55	1.01	1.49		

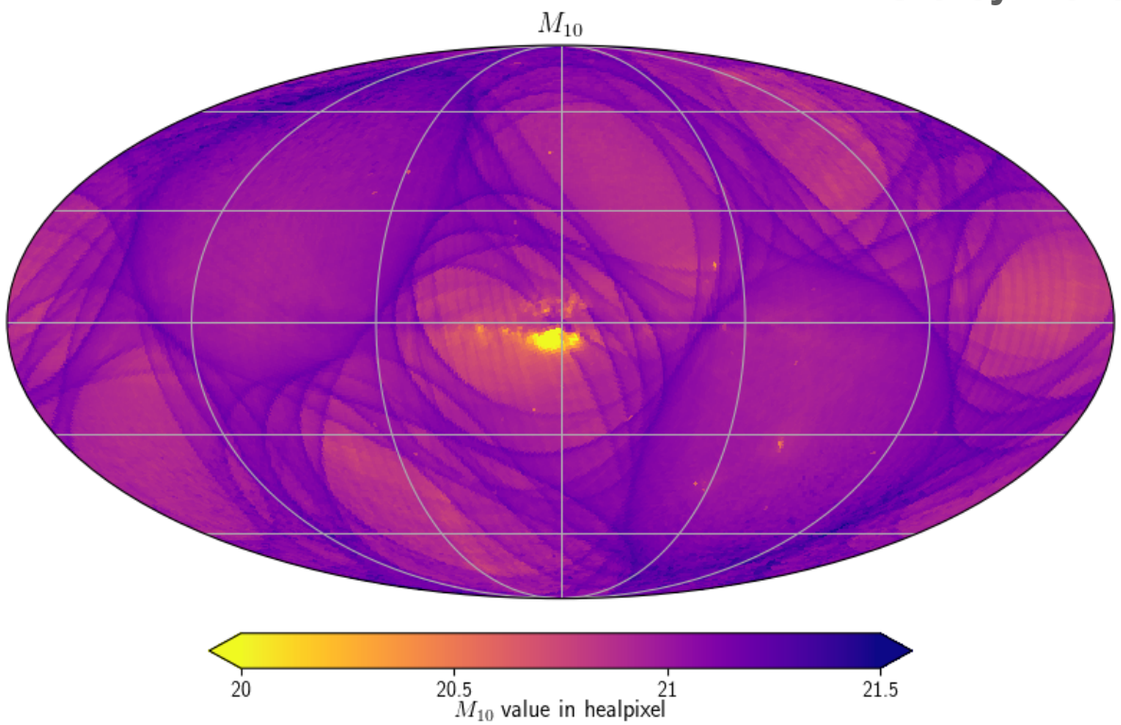
The selection function

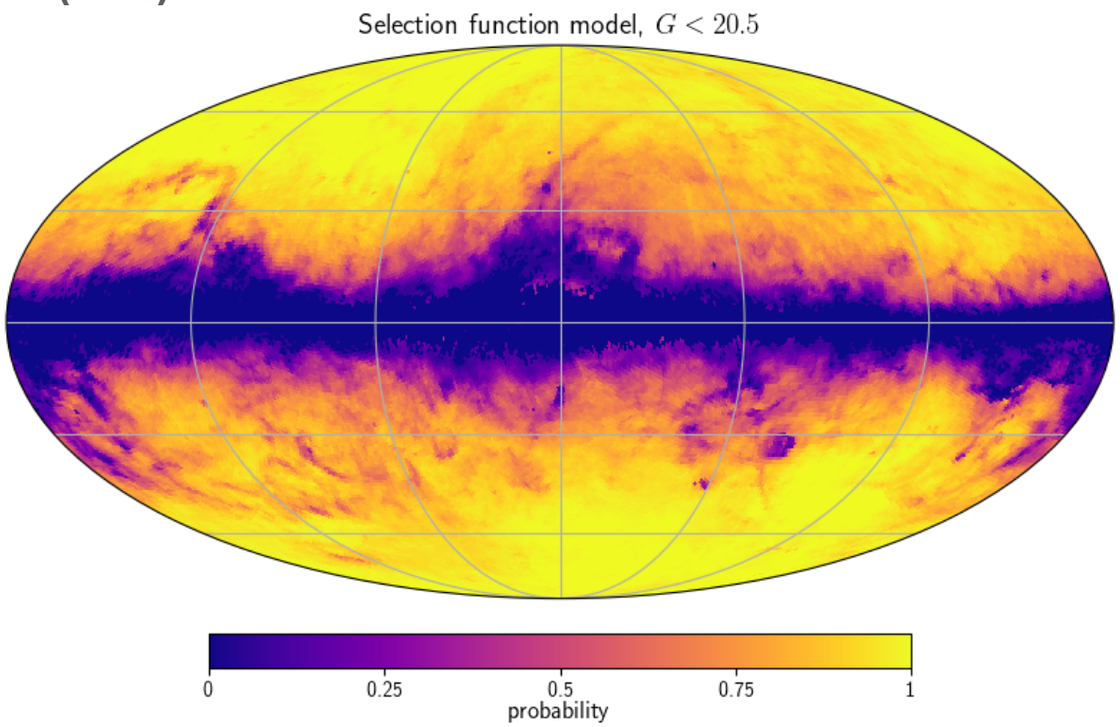
- Selection function corrects for scanning pattern, stars, extinction. Just a handful of templates!



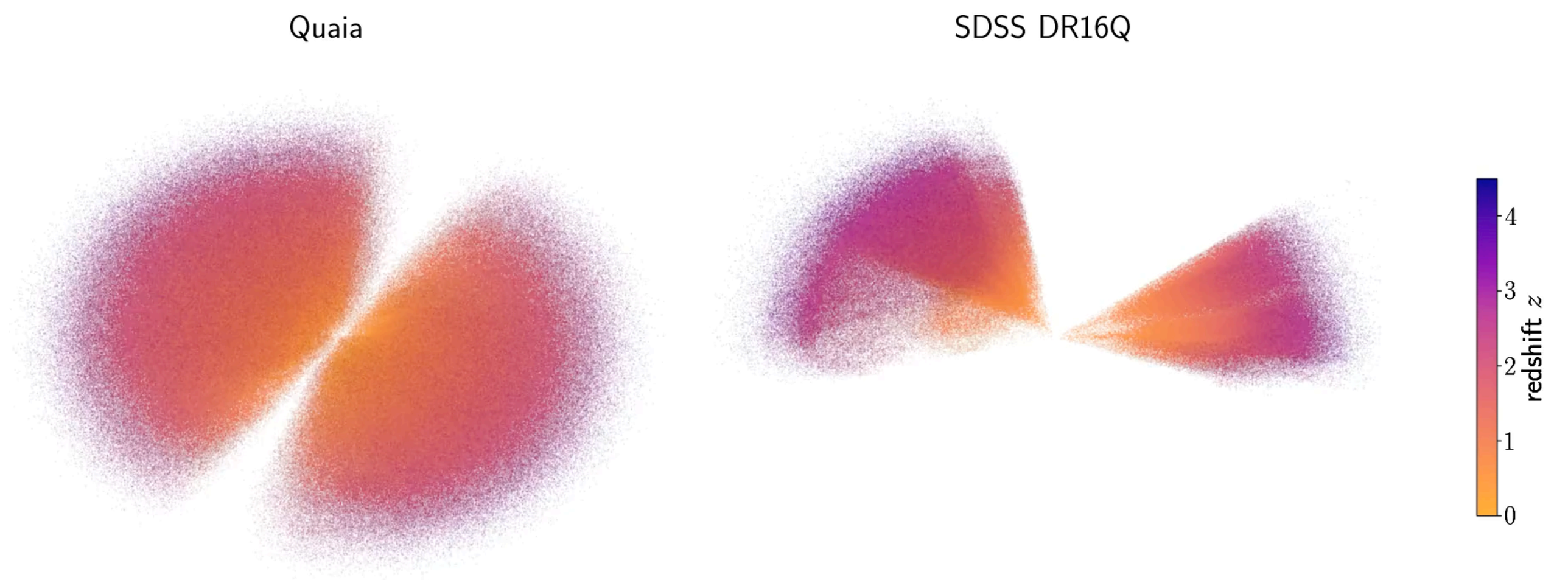


Storey-Fisher+ (2023)



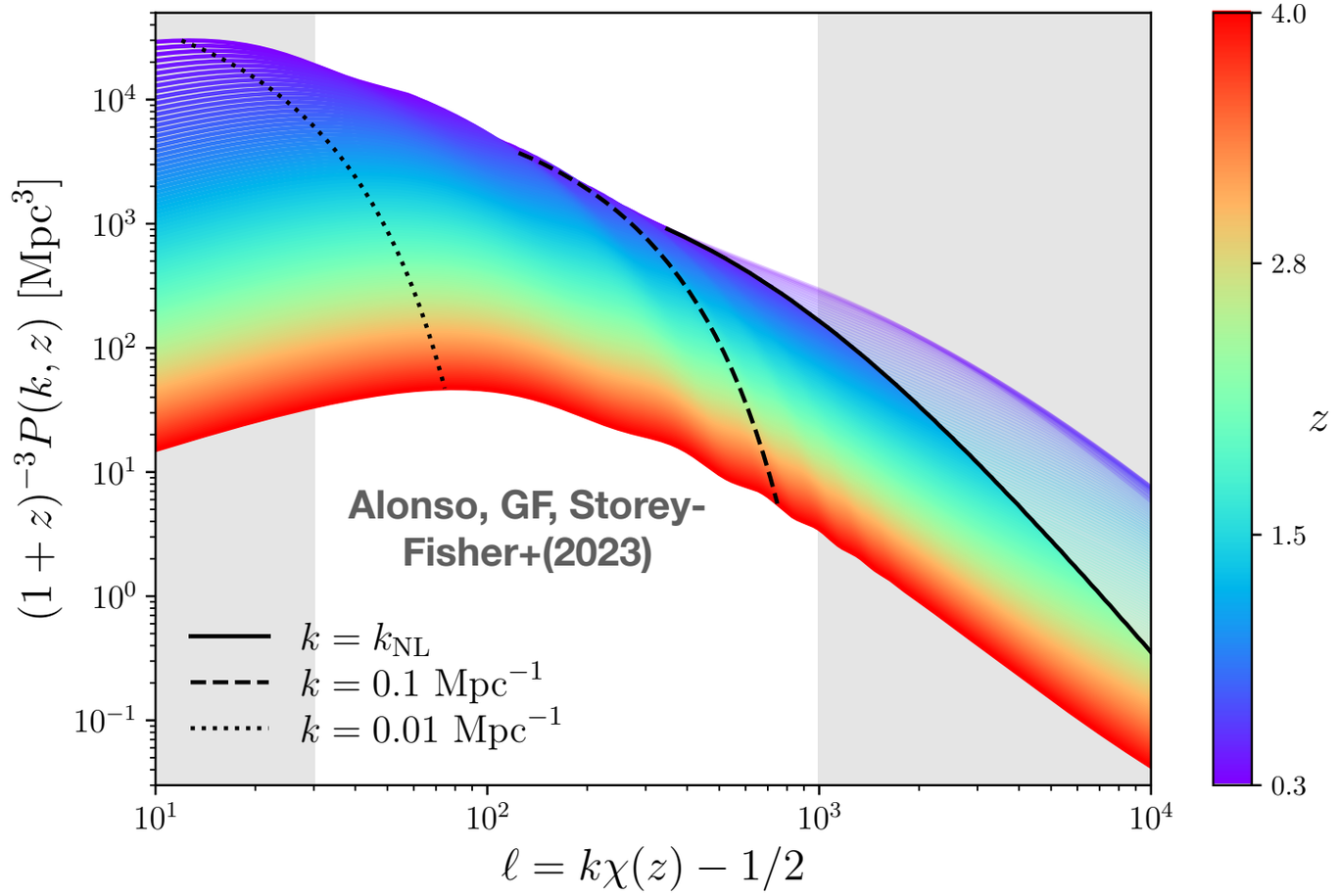


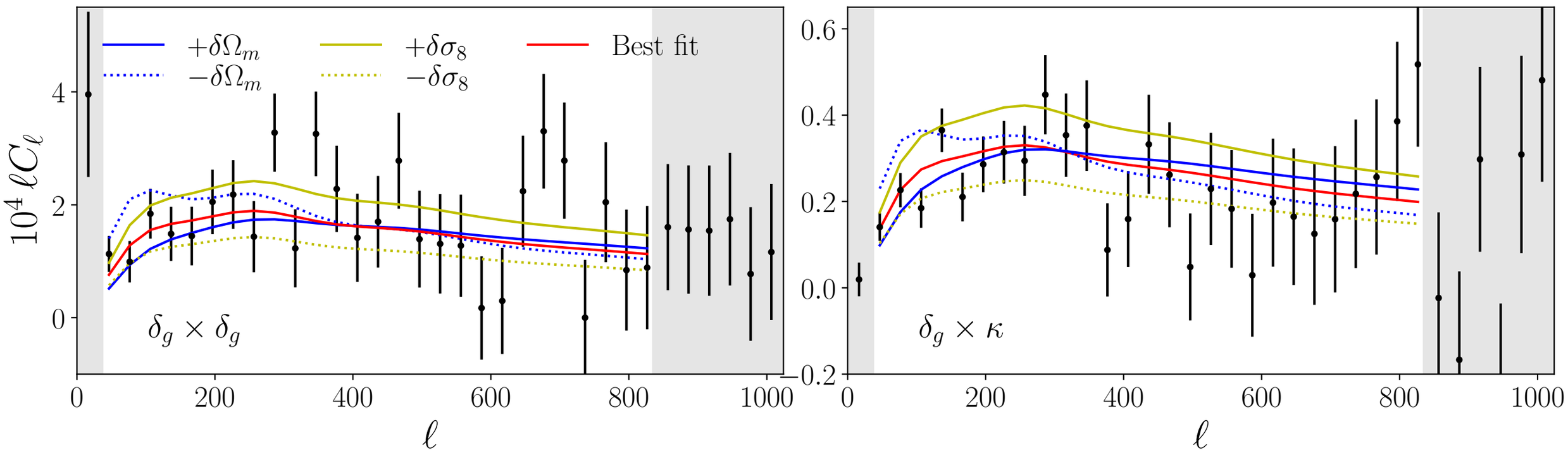
How it compares?



What Quaia can do for cosmology?

- Accurate redshifts and high redshift.
- Linear or quasi-linear scales.
- Non-degenerate σ_8, Ω_m measurement
- Large volume and highly-biased tracers are good for

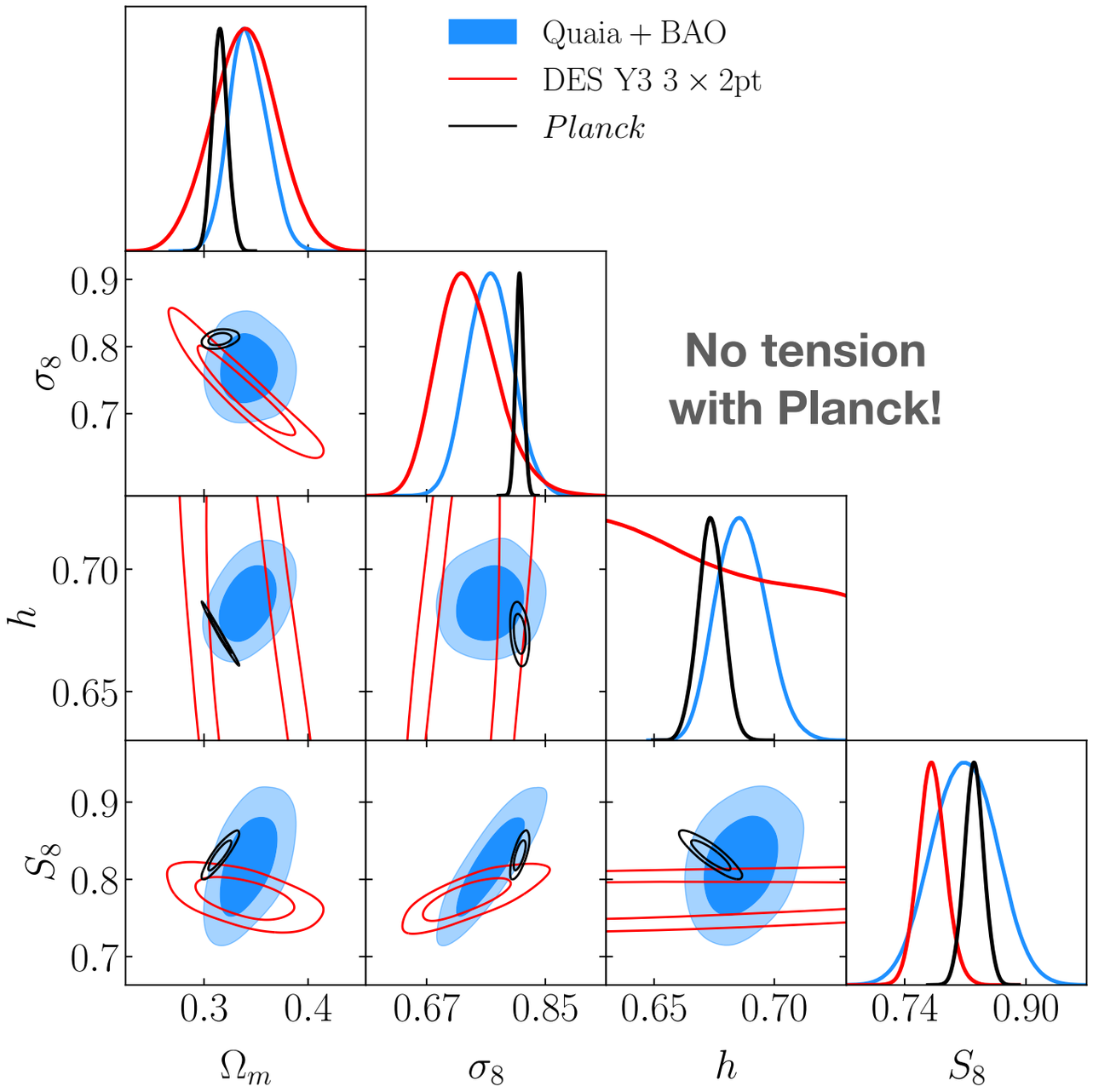




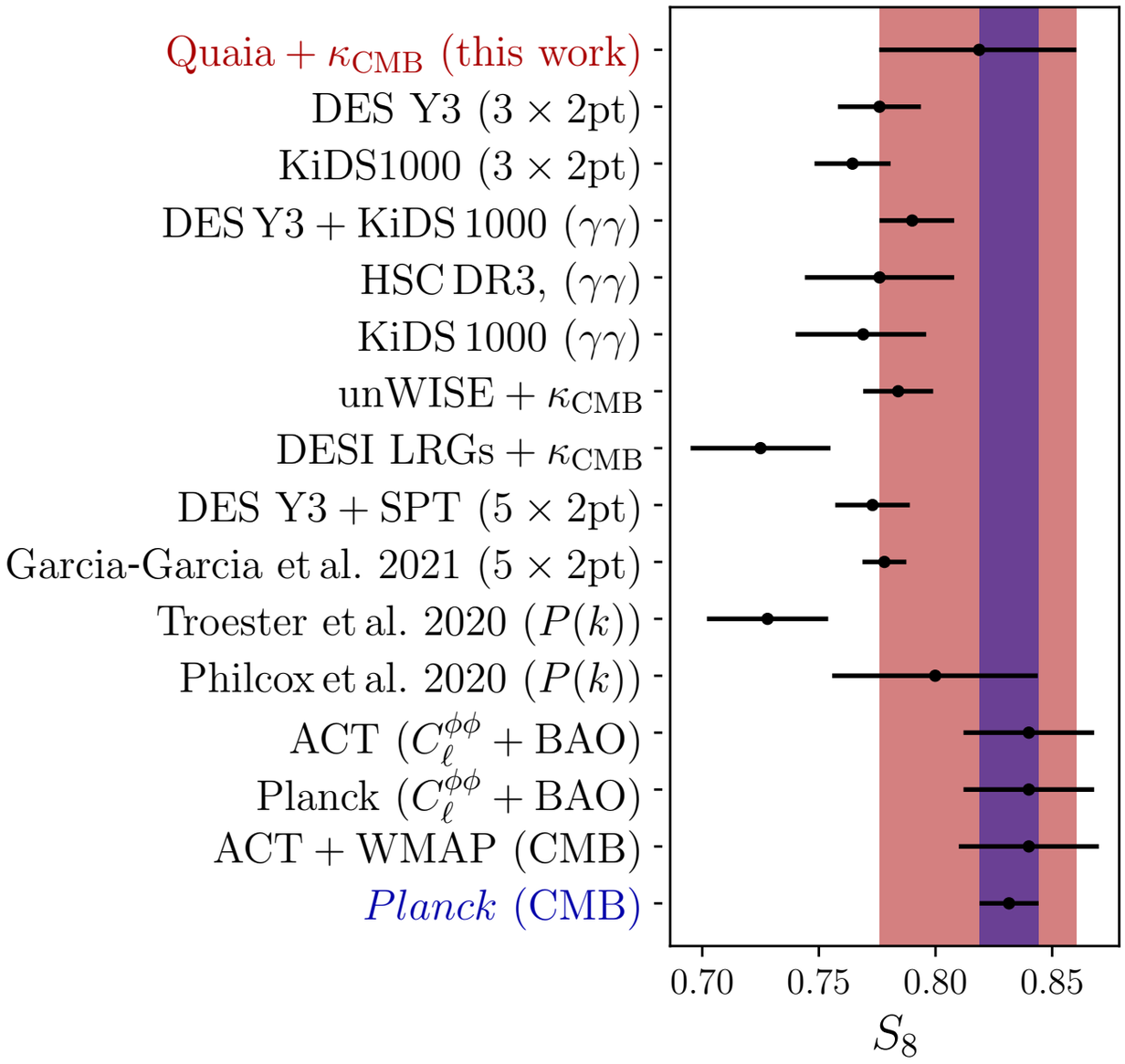
Cosmology results

- 2 redshift bins,cross-correlation with Planck PR4 lensing $C_\ell^{\kappa g}$ and auto-correlation C_ℓ^{gg}.

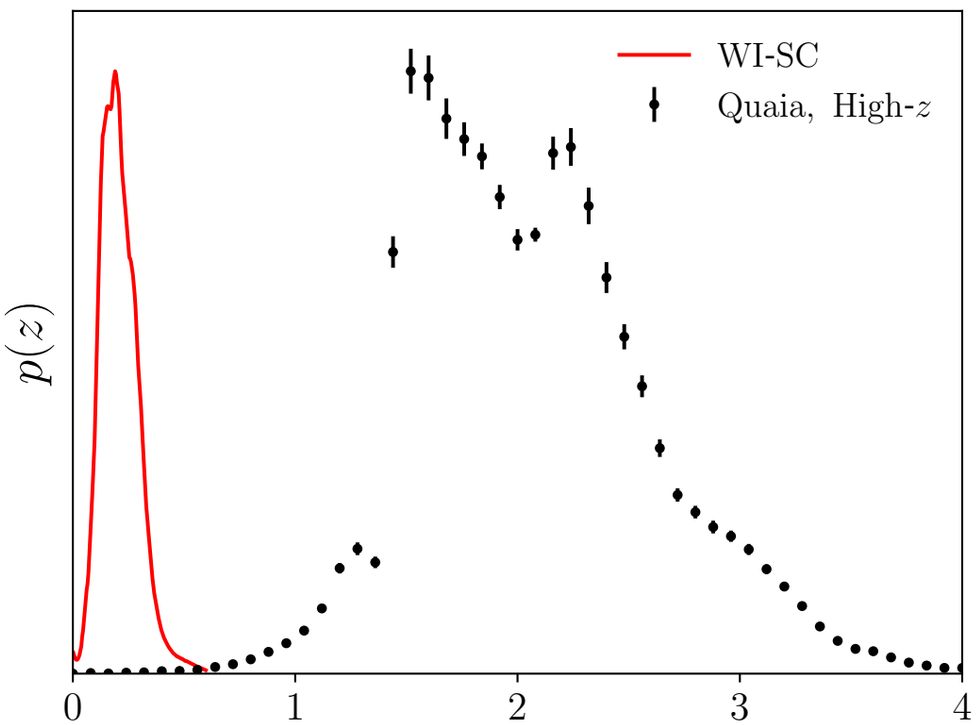
- Linear systematics deprojection (unimportant at $\ell \gtrsim 40$)



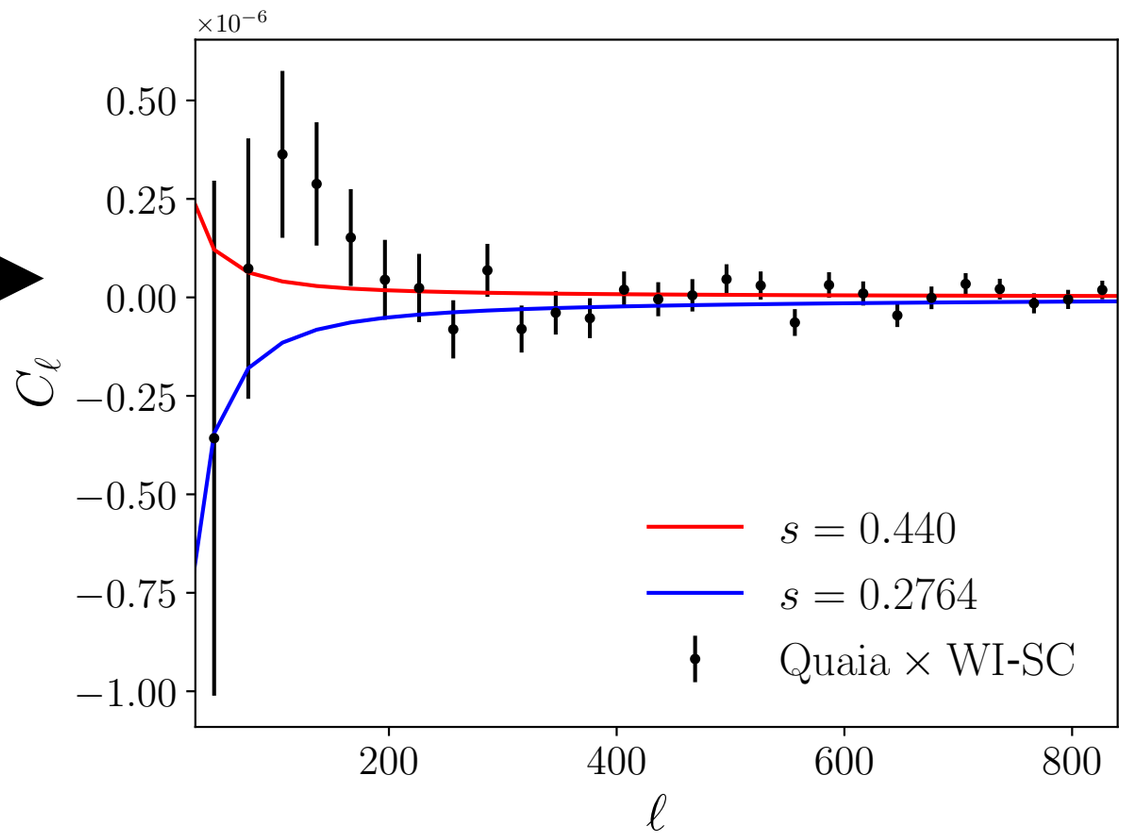
No tension with Planck!



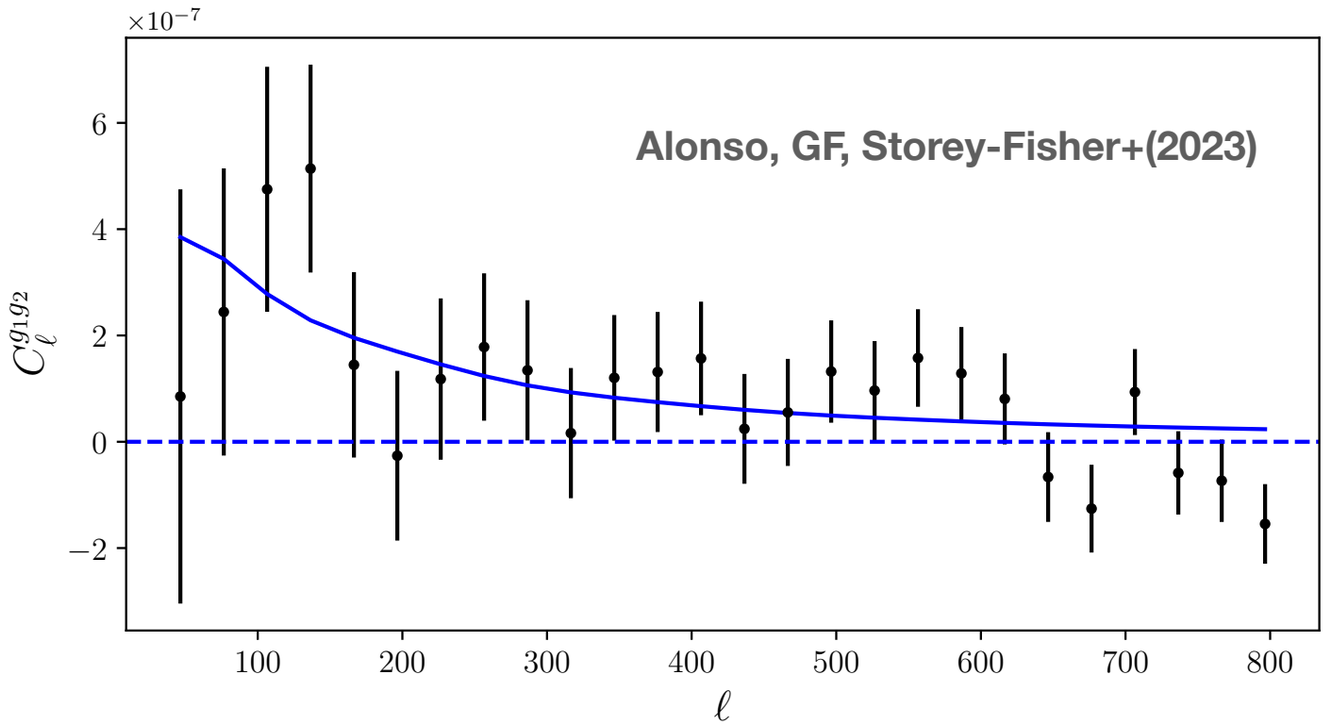
Some robustness tests



If QSO are magnified

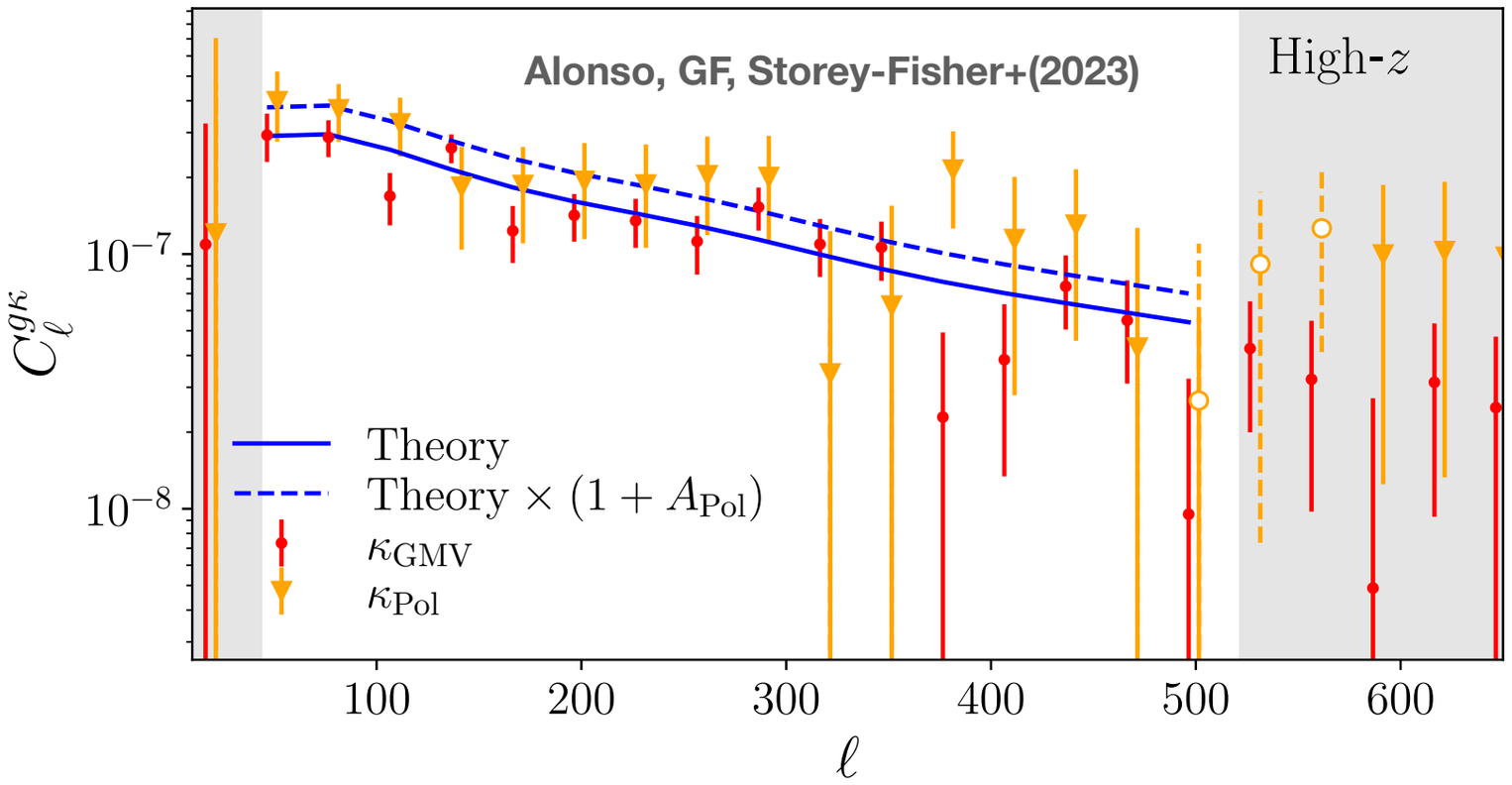


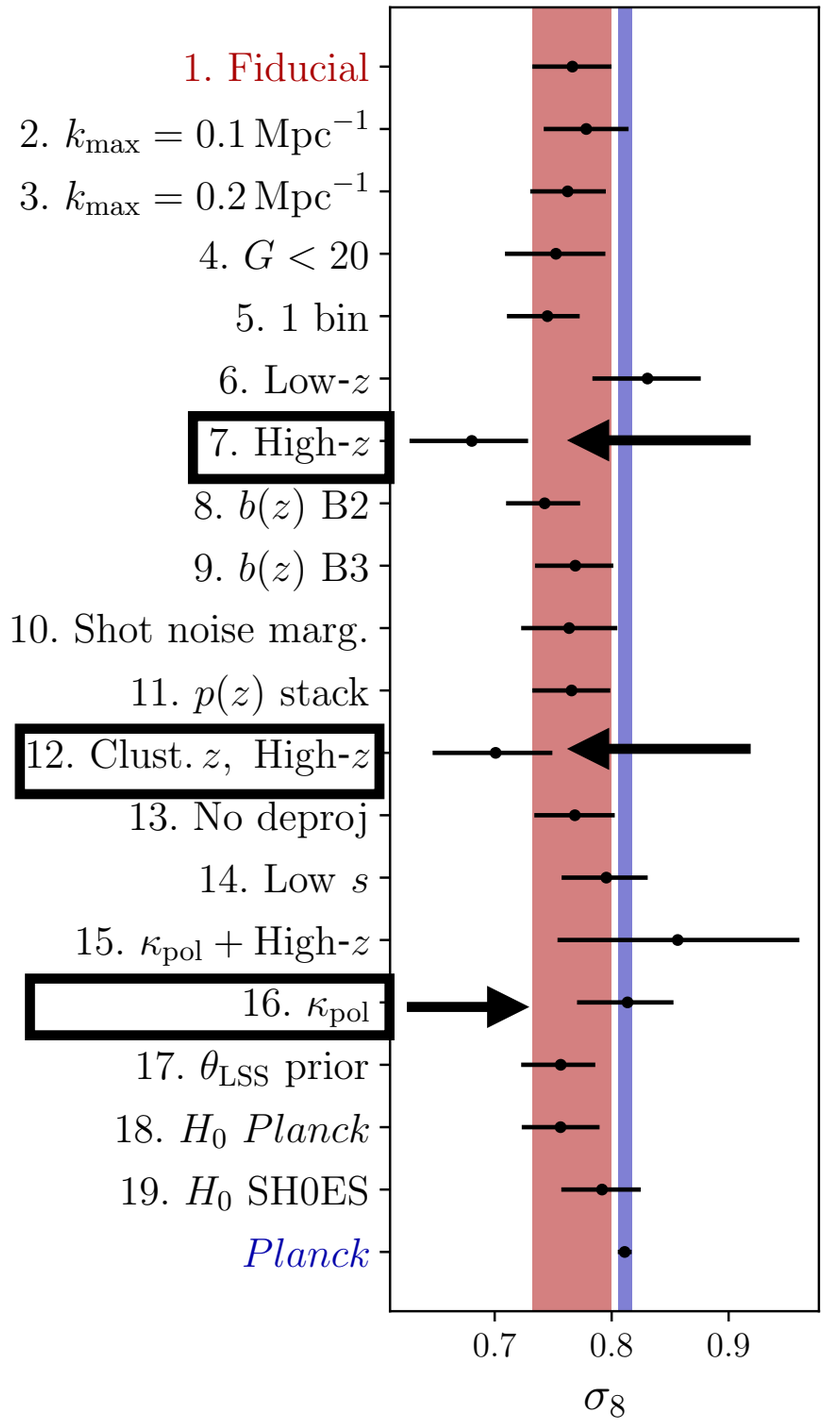
- Cross-correlation with low-z galaxies supports estimates of magnification bias.
- Cross-bin correlation consistent with redshift error estimates.



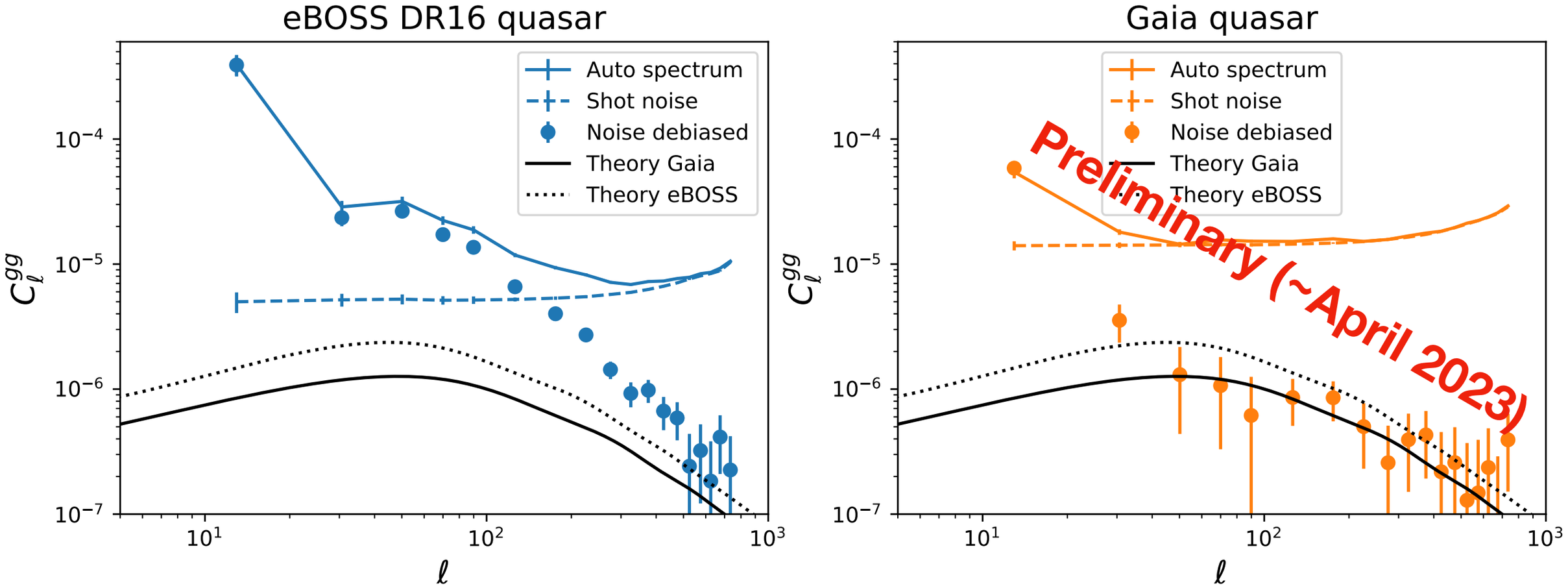
CIB and foregrounds are significant at high z!

- Lots of robustness tests passed but we see some inconsistency at high redshift.
- CIB bias is the most likely explanation, only affecting z>1.5 bin.
- Deep polarization data can save us (with some penalty)!





How it compares?



- Significantly lower systematics before any mitigation!
- Can we do better than state-of-the art analyses (QSO only):
  - 3D: Castorina+2019 $-51 < f_{\rm NL} < 21,\ \sigma(f_{\rm NL}) \approx 18$, eBOSS.
  - 2D: Leistedt+2015: $-49 < f_{\rm NL} < 31,\ \sigma(f_{\rm NL}) \approx 20$, tomography from SDSS photometric DR7.
  - **Quaia**: $\sigma(f_{\rm NL}) \approx 12$ (Fisher), $\sigma(f_{\rm NL}) \approx 40$ (conservative), $\sigma(f_{\rm NL}) \lesssim 30$ (optimal)

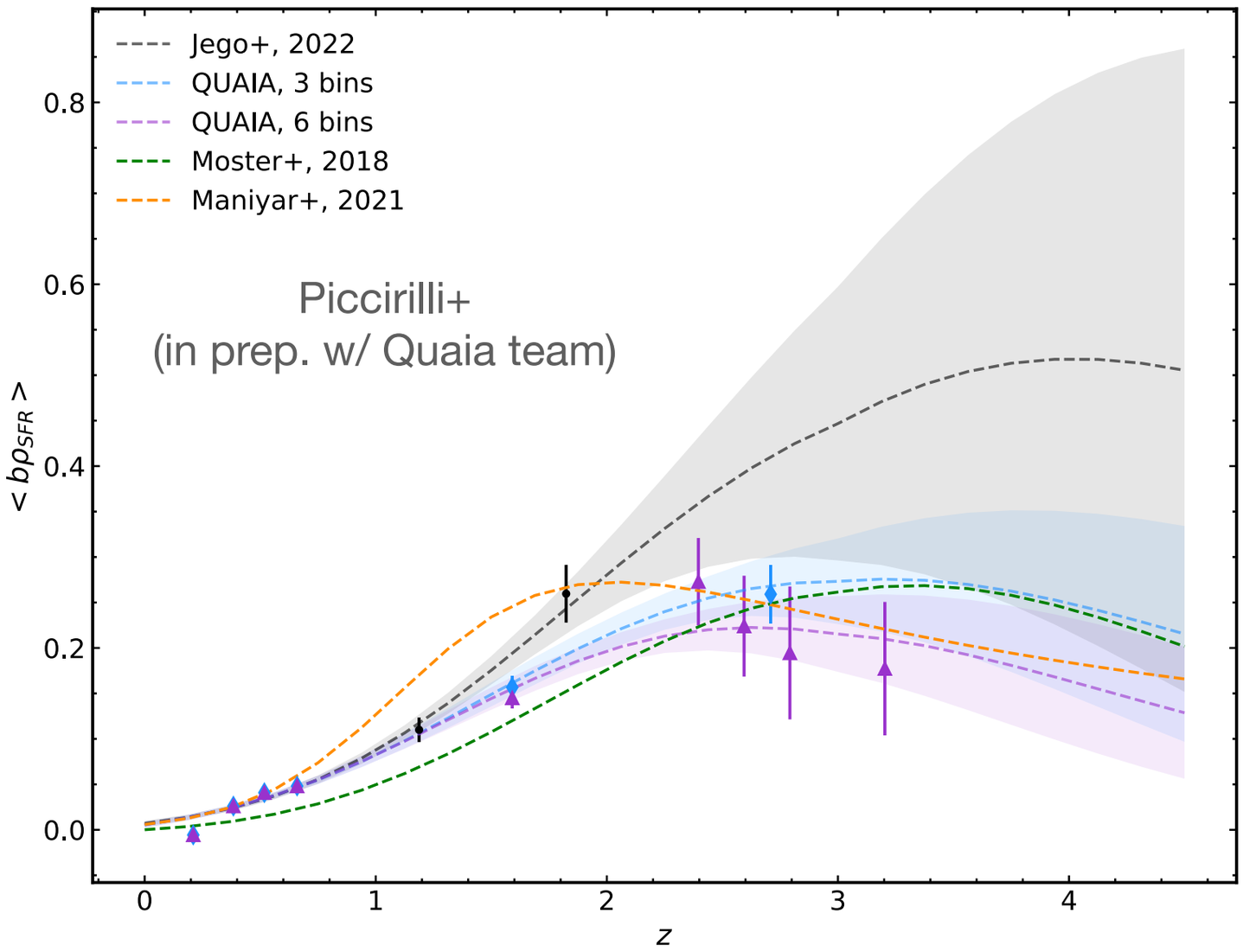
CIB constraints with Quaia

- QSO/AGN: perfect to study physics of star-formation contributing to the CIB, connected to their evolution.

- Quaia precise redshift measurement and sky coverage enable CIB (and SFR) tomography in a new regime.

- Polarization data crucial for this science!

Giulia Piccirilli
(U. Roma Tor Vergata)
On the job market !



Conclusions

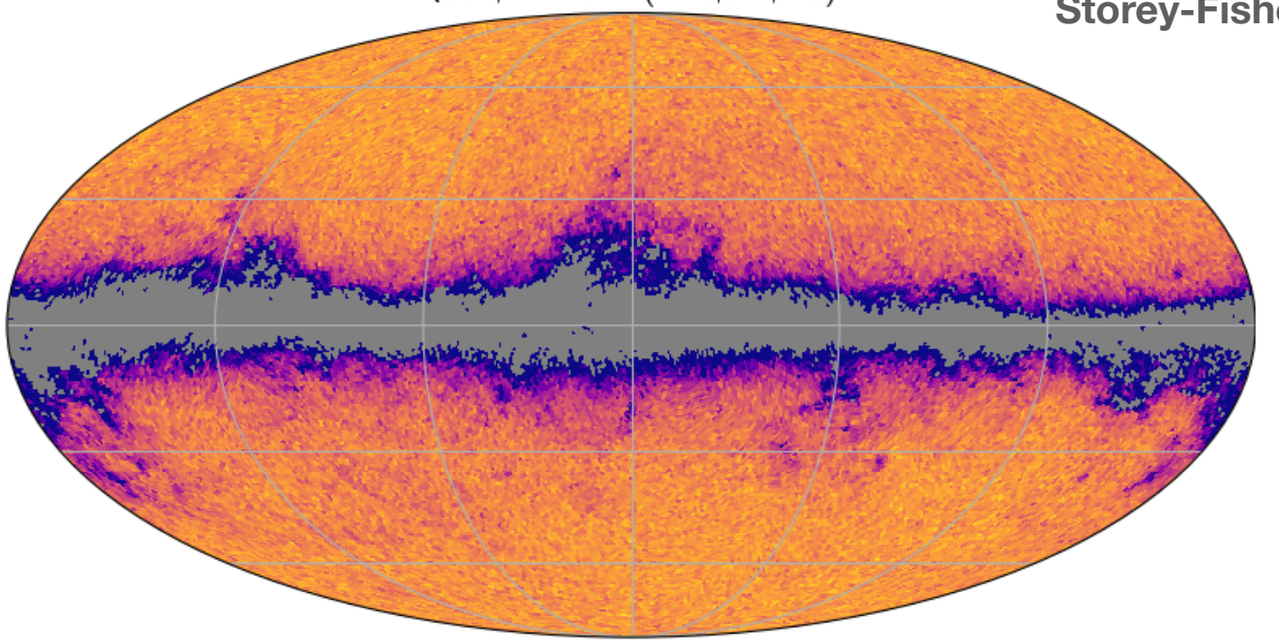
- **Quaia: a new QSO catalog for cosmology**
  - 1.2M objects, on full sky with accurate redshift measurements, covers ~largest volume to date.
  - Publicly available: catalog, selection function maps, random mocks and codes.
  - Low systematics contaminations allowed by space-based data.

- **Cosmological measurements with CMB cross-correlation are promising!**
  - Non-degenerate measurements of σ_8, Ω_m, S_8 consistent with Planck expectations at all z!
  - CIB residual it's hard to deal with: deep polarization data are of crucial importance!
  - Robust and competitive f_{NL} measurements from CMB lensing cross-correlation.

- **Stay tuned for**: CIB constraints, tests of homogeneity and isotropy, cosmology with voids, 3D $P(k), B(k_1, k_2, k_3)$ analysis, k_{eq} estimation….

How it compares?

Quaia, $G < 20.5$ (N=1,295,502)

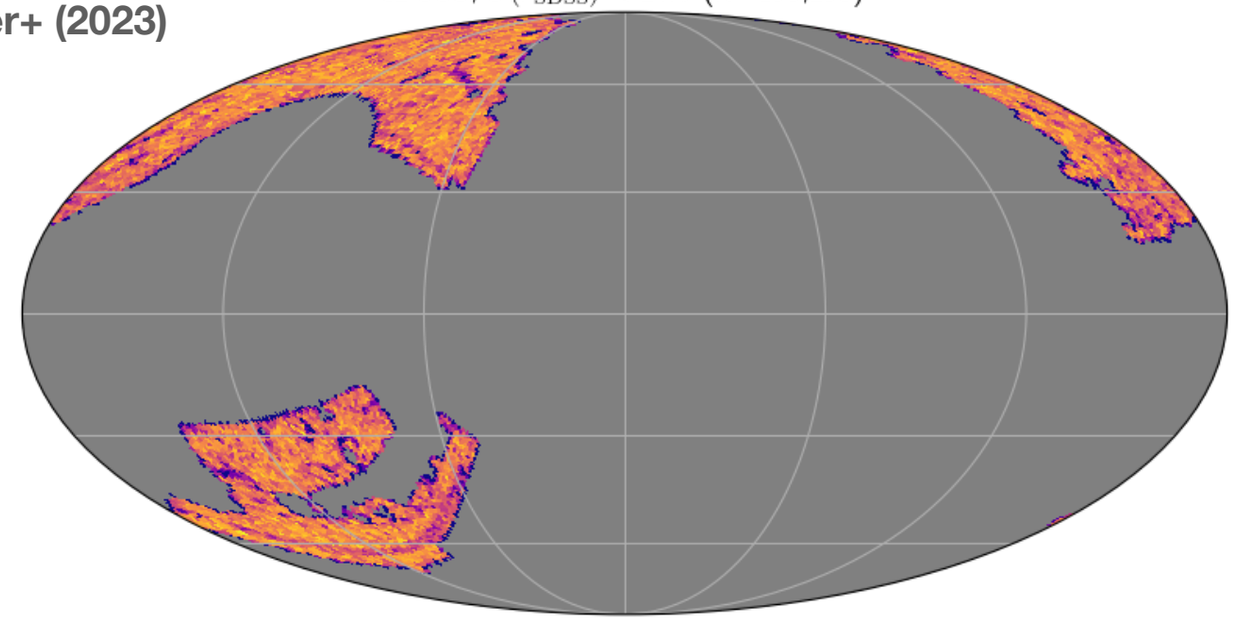


5 10 20 50 100

number density per healpixel ($\deg^{-2}$)

Storey-Fisher+ (2023)

eBOSS, $G(r_{\rm SDSS}) < 20.5$ (N=190,295)



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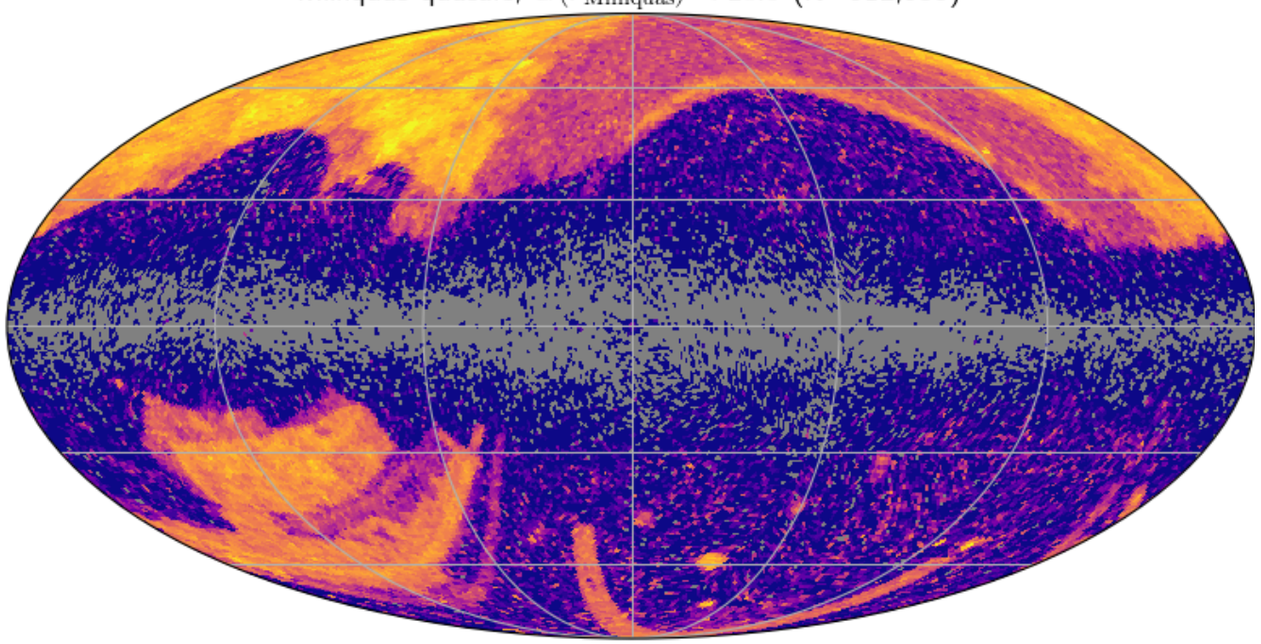
number density per healpixel ($\deg^{-2}$)

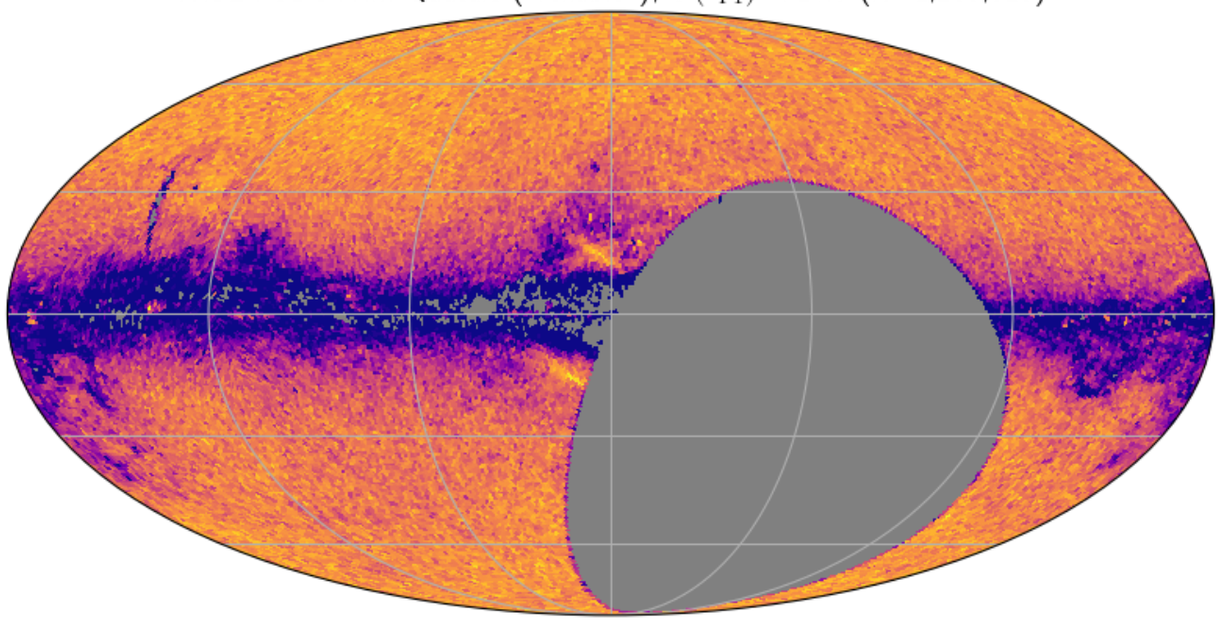
Milliquas quasars, $G(r_{\rm Milliquas}) < 20.5$ (N=912,050)



5 10 20 50 100 200

number density per healpixel ($\deg^{-2}$)

WISE-PS1-STRM Quasars ("reliable"), $G(r_{\rm P1}) < 20.5$ (N=1,266,828)



10 20 50

number density per healpixel ($\deg^{-2}$)