SORBONNE UNIVERSITÉ

FLATIRON INSTITUTE

SPHEREx: the X-machine

Benjamin D. Wandelt

CCA/Flatiron

Institut d'Astrophysique, Paris (IAP)

Lagrange Institute, Paris (ILP)

Sorbonne University

SPHEREx is the X-machine

- SPHEREx a unique data set for cross-correlations
  - All-sky coverage
  - Wide redshift range

- X-correlations are robust to potential large-angle systematics (zodi, star-galaxy confusion)
- Will give cleaner results for subtle signals such as primordial NG.

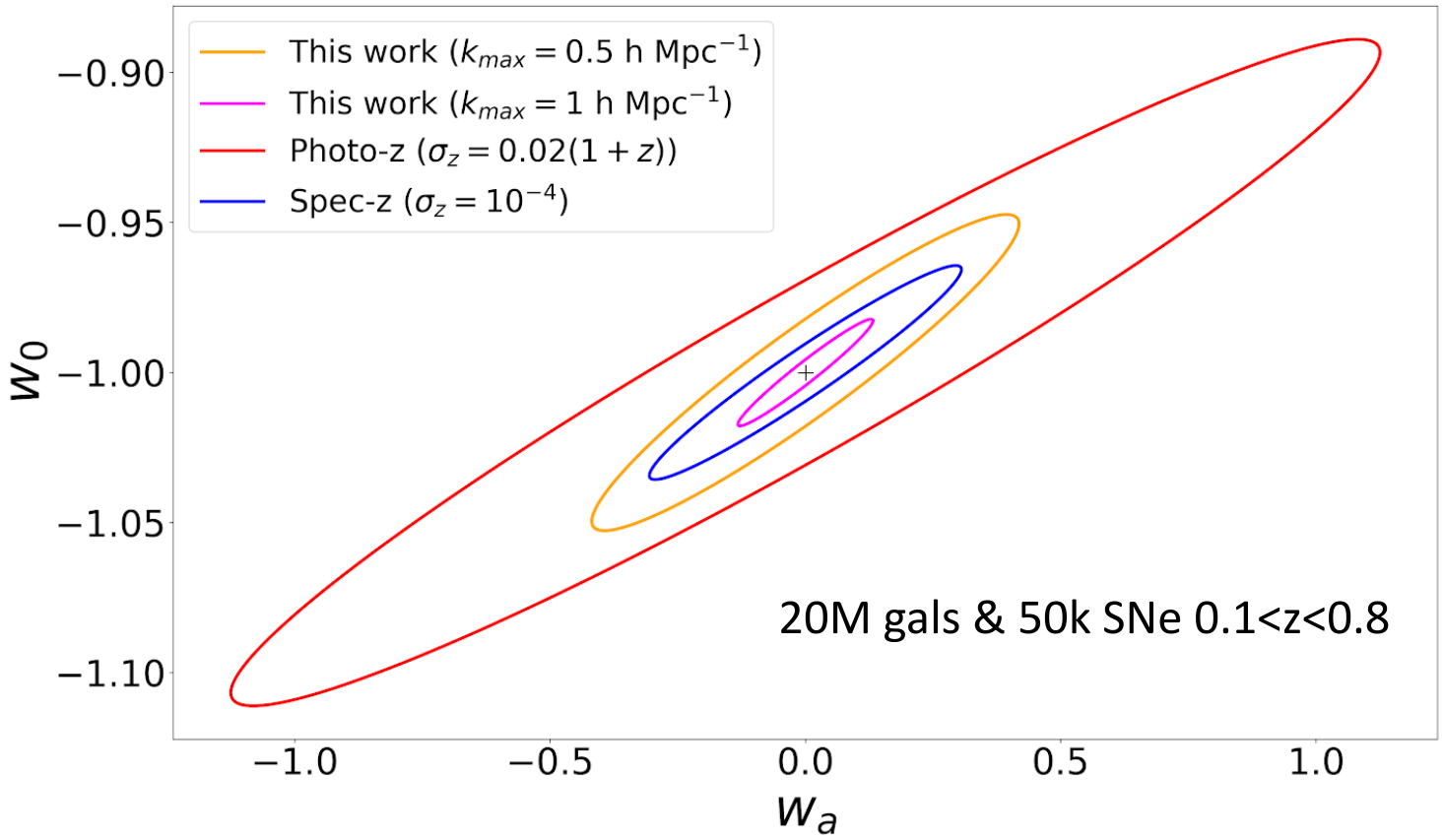
Many exciting X-correlation opportunities with other data sets

- Use global X-correlation AP to probe dark energy through expansion history (Mukherjee & Wandelt, arXiv:1808.06615)
  - Standard candles
  - Cosmic sirens
  - (Your favorite distance tracer here)
- Other redshift surveys (e.g. for 2 & 3-point functions)
  - PFS, DESI
  - Euclid
  - WFIRST

$$f_{NL} \sim < \delta_K^{X} \delta_k^{Y} \delta_k^{Z} >$$

- CMB (see other talks)
- Long-term: Use GW-galaxy correlations to probe GR
  - GW-lensing will cross-correlate with galaxy distribution (Mukherjee, Wandelt & Silk, arXiv: 1908.08951)

Example: Global Alcock-Paczynski in cross-correlation



Mukherjee & Wandelt arXiv:1808.06615

SPHEREx *internal* cross-correlations

- Compressing the SPHEREx data "cube" into $d^{\lambda}(\hat{n})$

$$C_{\ell}^{\lambda_1 \lambda_2} = \int d^{\lambda_1}(\hat{n}_1) P_{\ell}(\hat{n}_1 . \hat{n}_2) d^{\lambda_2}(\hat{n}_2) d\hat{n}_1 d\hat{n}_2$$

will strongly compress the data (by ~10^3)* while maintaining all cosmological two-point information.

Advantages:

- Exploits isotropy of cosmological data.
- Close to the data: simple noise properties.

* Npix x Nbands ~ 10^{12} ➔ Sqrt(Npix)*Nbands^2 ~ 10^9

Modeling $C_\ell^{\lambda_1 \lambda_2}$

- These wavelength cross-spectra can be modeled in terms of a sum of populations of biased redshift tracers of the underlying density field.
- *Alternatively*, can model generically (e.g. using principal component analysis) and "discover" powerful tracer combinations, e.g.

$$d^\lambda(\hat{n}) = \sum_i \int s_i(\lambda a_e) n_i(\hat{n}, a_e) da_e$$

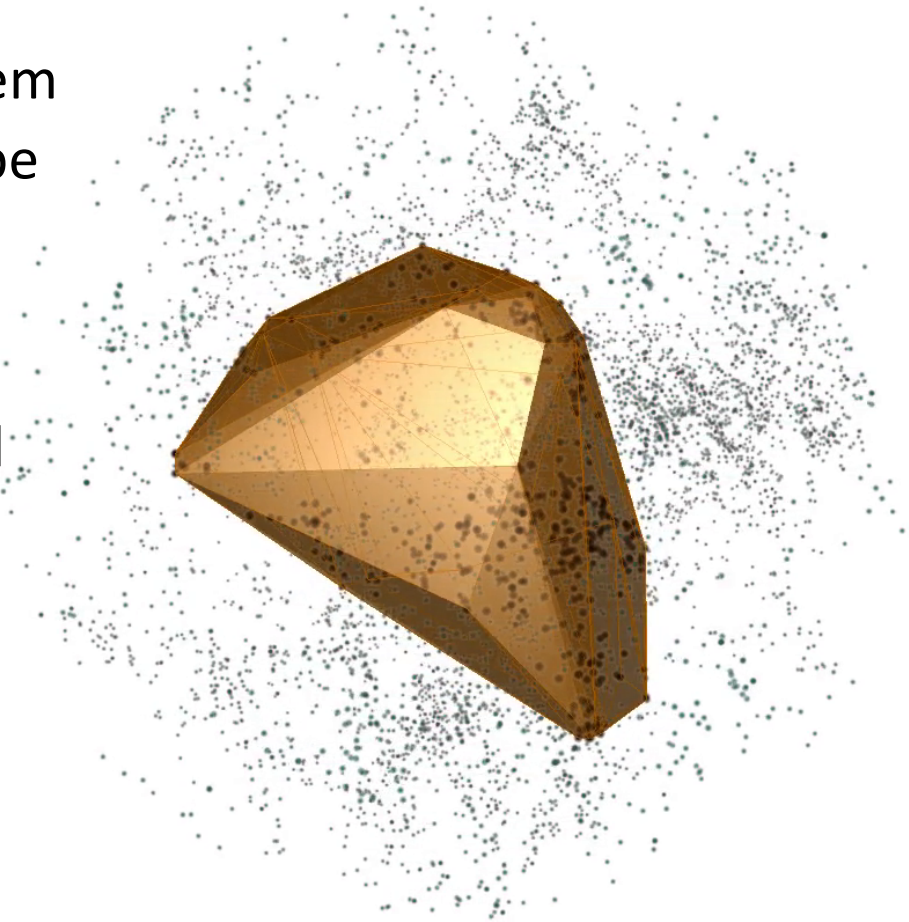
$$s_i(\lambda) \sim p_i(s(\lambda))$$

$$n_i(\hat{n}, a_e) = \bar{n}_i \left(\delta_i(\hat{n}, a_e) + 1\right)$$

$$\delta_i = b_i \delta_m \text{ +...}$$

SPHEREx is a void machine

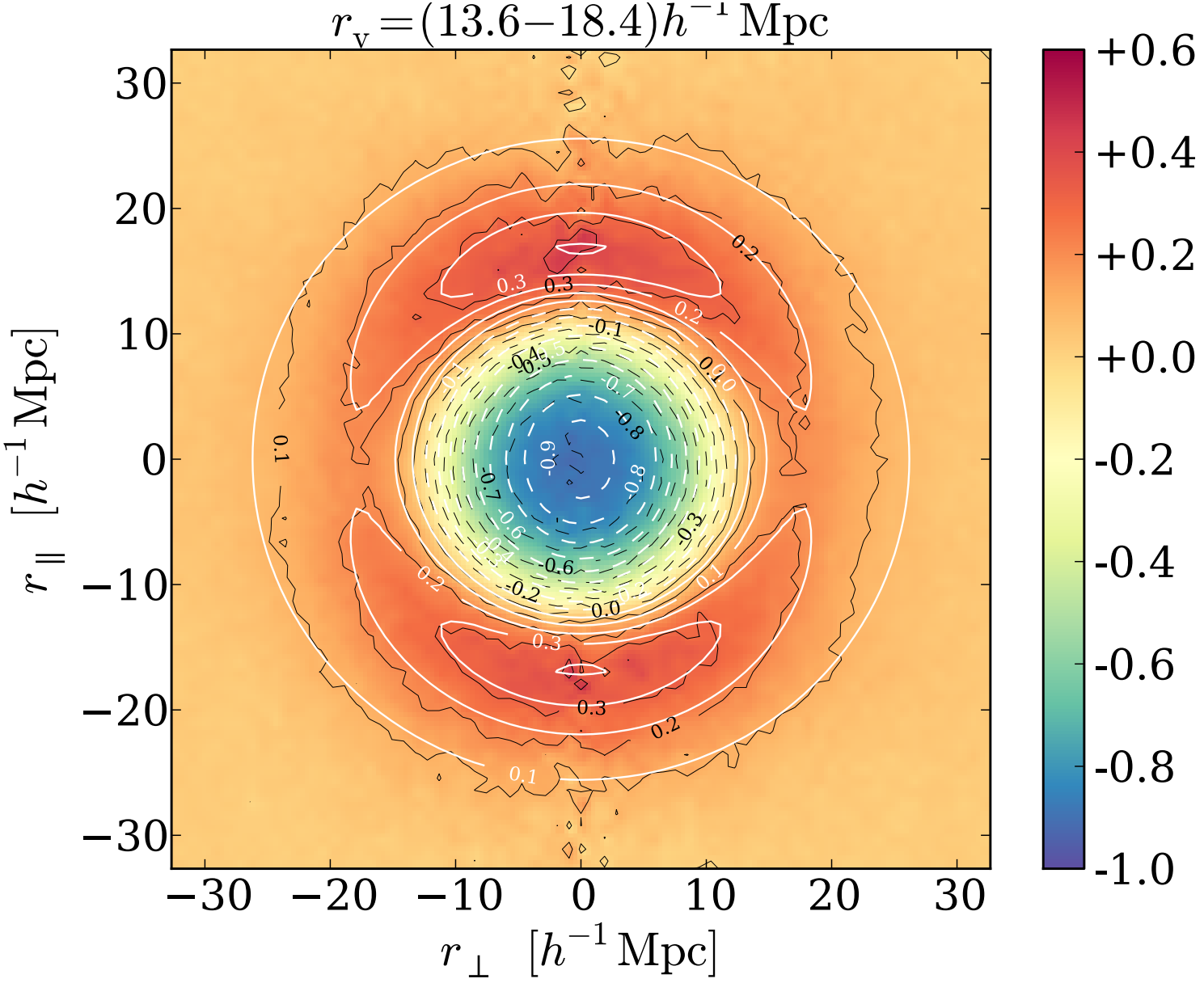
- Biggest "objects" in the Universe – pseudo-spectral data can resolve them
- A free, additional observational probe in current and future surveys: ~10^5 voids in SPHEREx!
- The first regions in the universe that are dominated by dark energy; most sensitive to modifications of General Relativity
- Void bias carries information about neutrinos (Kreisch et al. arXiv: 1808.07464)
- Contrast high at low-z



An active community and a rapidly growing body of work

Google “VIDE bitbucket”

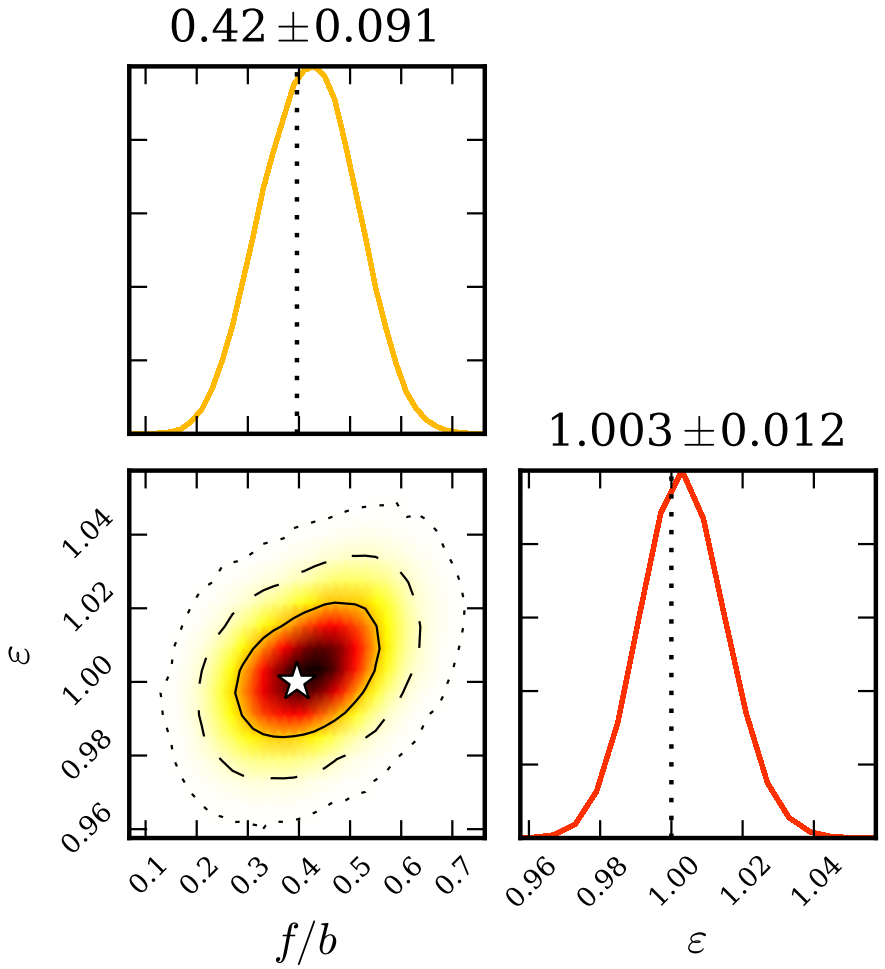
Void-galaxy correlation function in redshift space



Joint measurement of growth of structure and of expansion geometry

Using BOSS data. AP measurement is 4 times tighter than galaxy clustering analysis!

(Gil-Marin *et al.* arXiv:1509.06386)



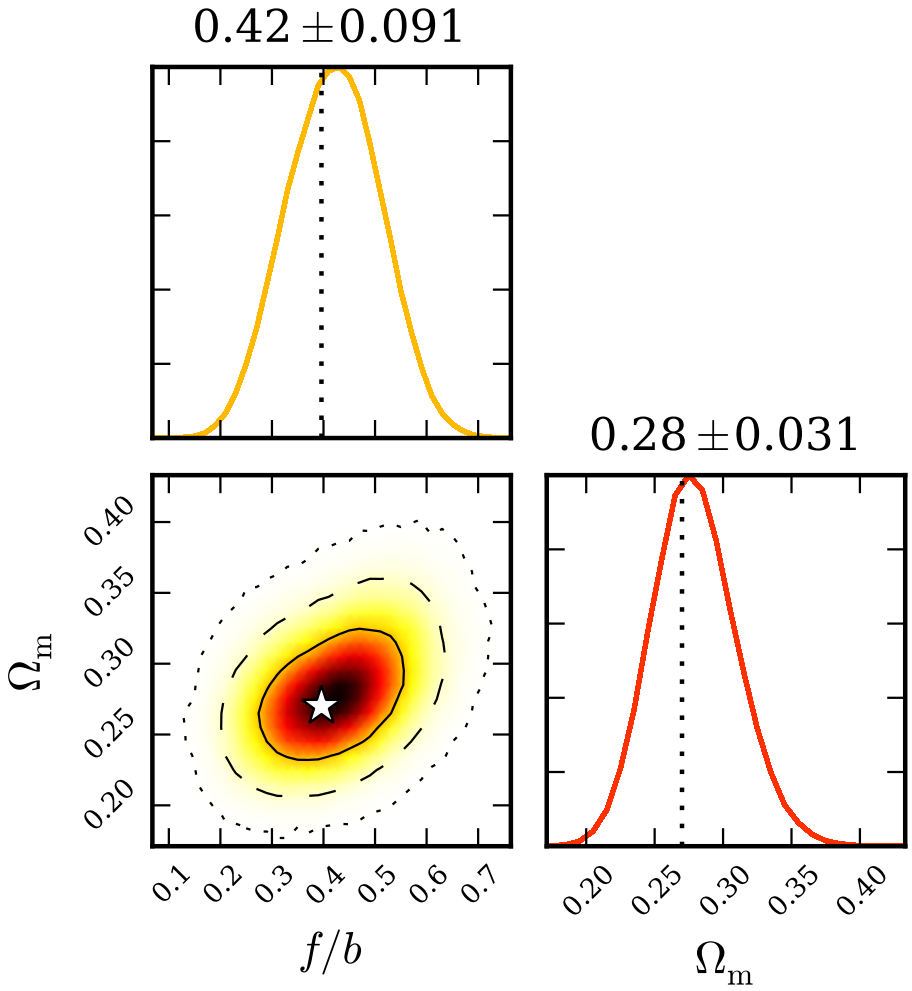
Preliminary Euclid forecasts => 30 times higher Figure of merit than standard BAO

Hamaus, BDW et al. arXiv:1602.01784

Joint constraint on growth f/b and on matter density

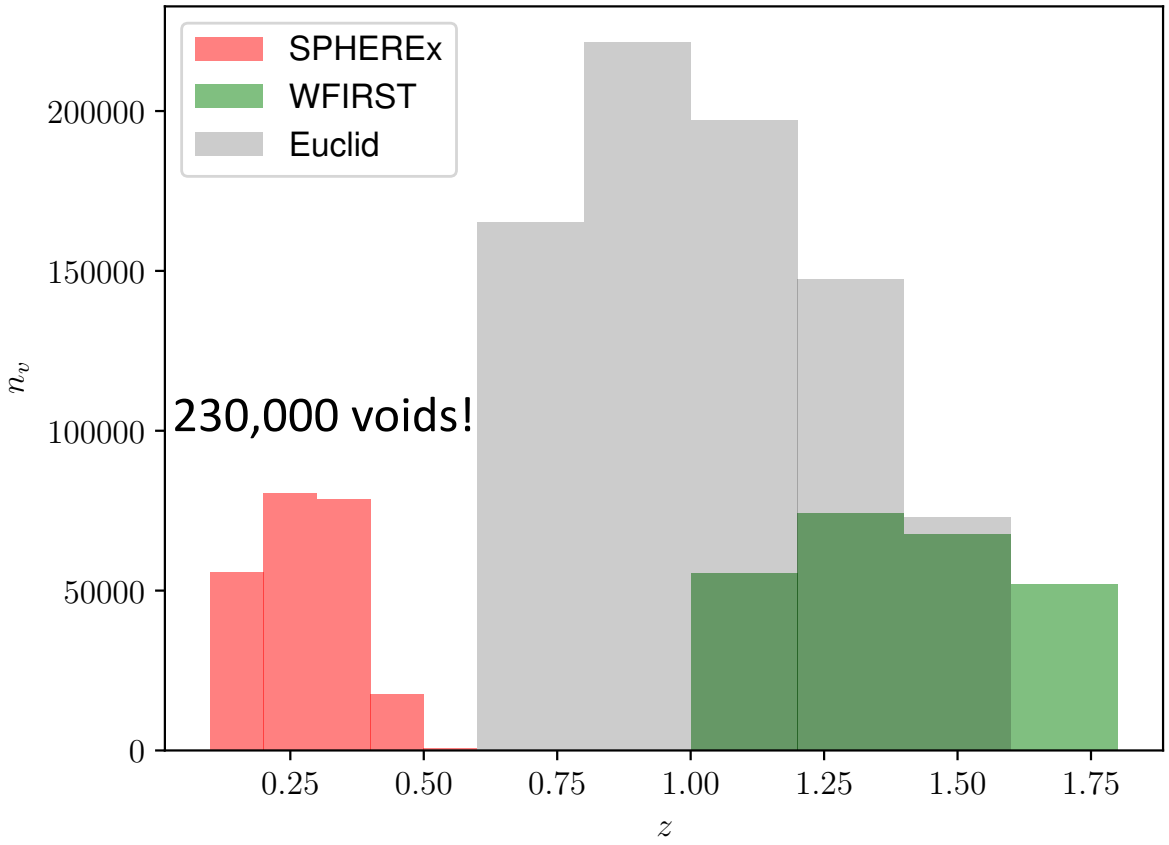
for $w_{DE} = -1$

3457 voids from SDSS



Hamaus, BDW et al. arXiv:1602.01784

SPHEREx voids probe low-z, Dark Energy dominated universe



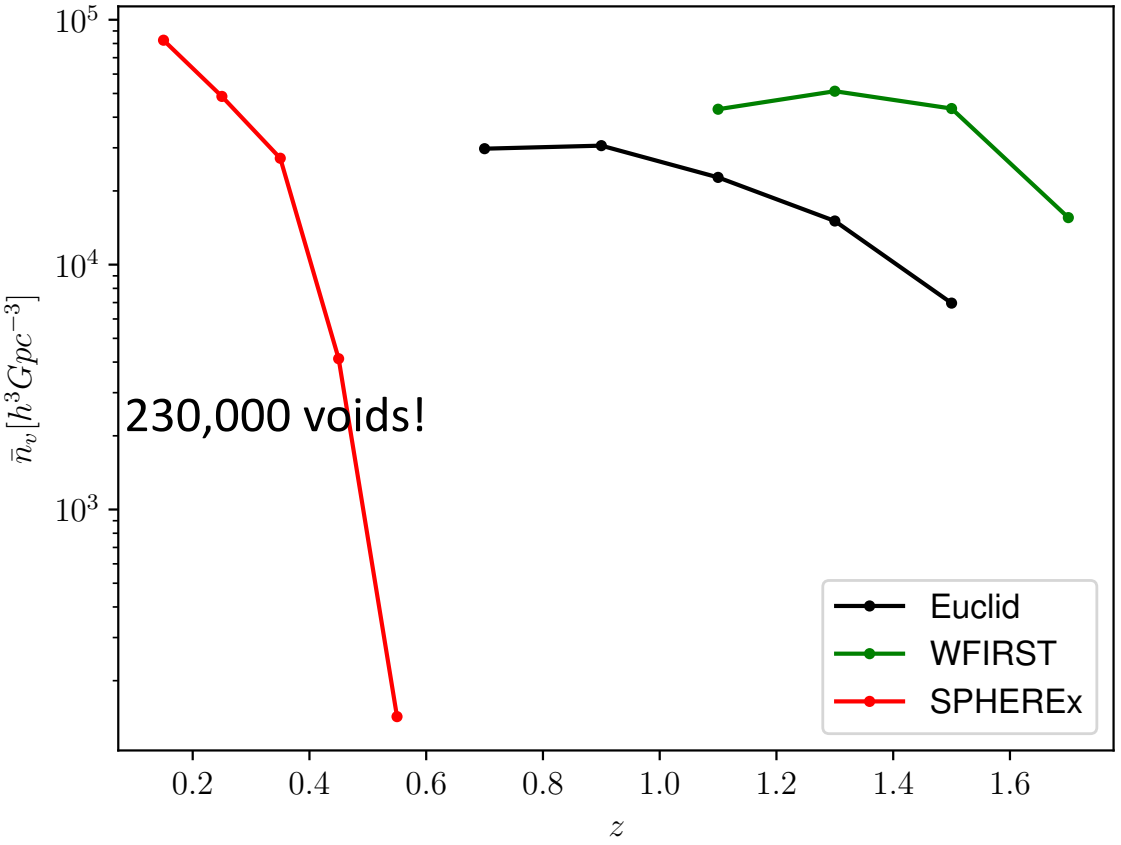
Old specs,

Using dz~0.003 only

Forecast by Alice Pisani

Complementarity: expect SPHEREx LH contours to be rotated wrt Euclid, WFIRST

SPHEREx will get higher number density of voids at low z; sensitive to cosmic acceleration



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Complementarity: expect SPHEREx LH contours to be rotated wrt Euclid, WFIRST

Conclusions

- SPHEREx's unique strengths are well-matched to
  - **X-correlations**
  - **Low-z void cosmology**
- Project 1: forecasts for global X-AP for SPHEREx
- Project 2: study $C_\ell^{\lambda_1 \lambda_2}$
- Project 3: develop a SPHEREx void pipeline
- *Let's discuss: likelihood-free, simulation-based inference for PNG "f_{NL}" (c.f., DELFI: Alsing, Charnock, Feeney & Wandelt arXiv:1903.00007)*