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Synergies with other cosmological surveys

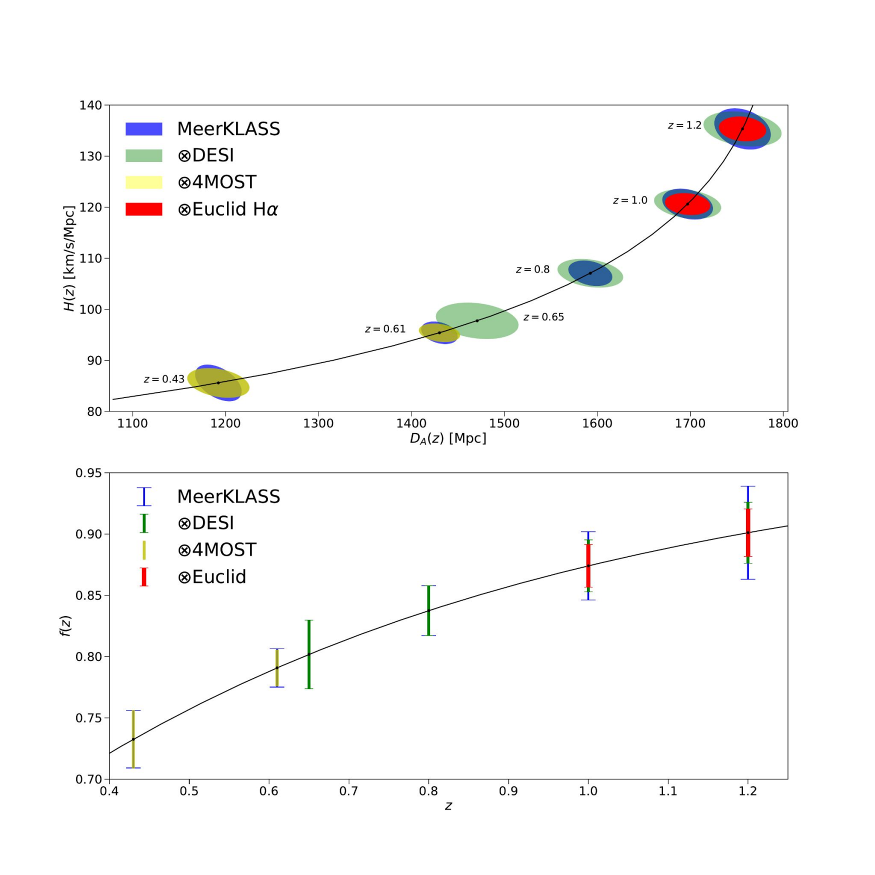
AKA,
my actual potential inputs
NOT proposed Chapters

In collaboration with many of you

JOSÉ FONSECA - IA U. PORTO

Synergies between Radio and Optical for standard cosmological parameters

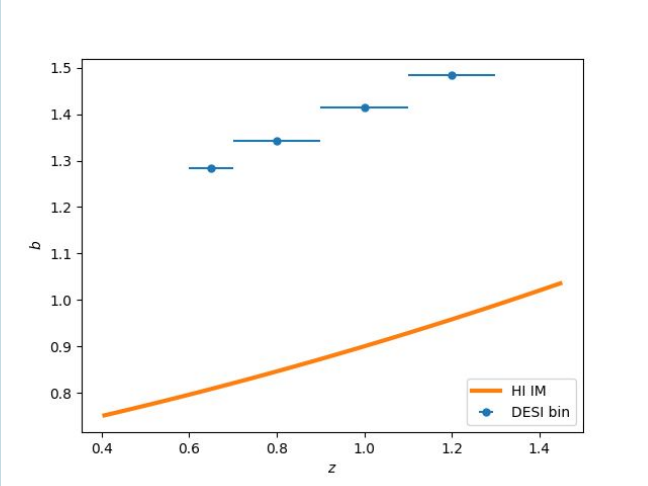
SKA Cosmology SWG - Niza - 6/11/2024

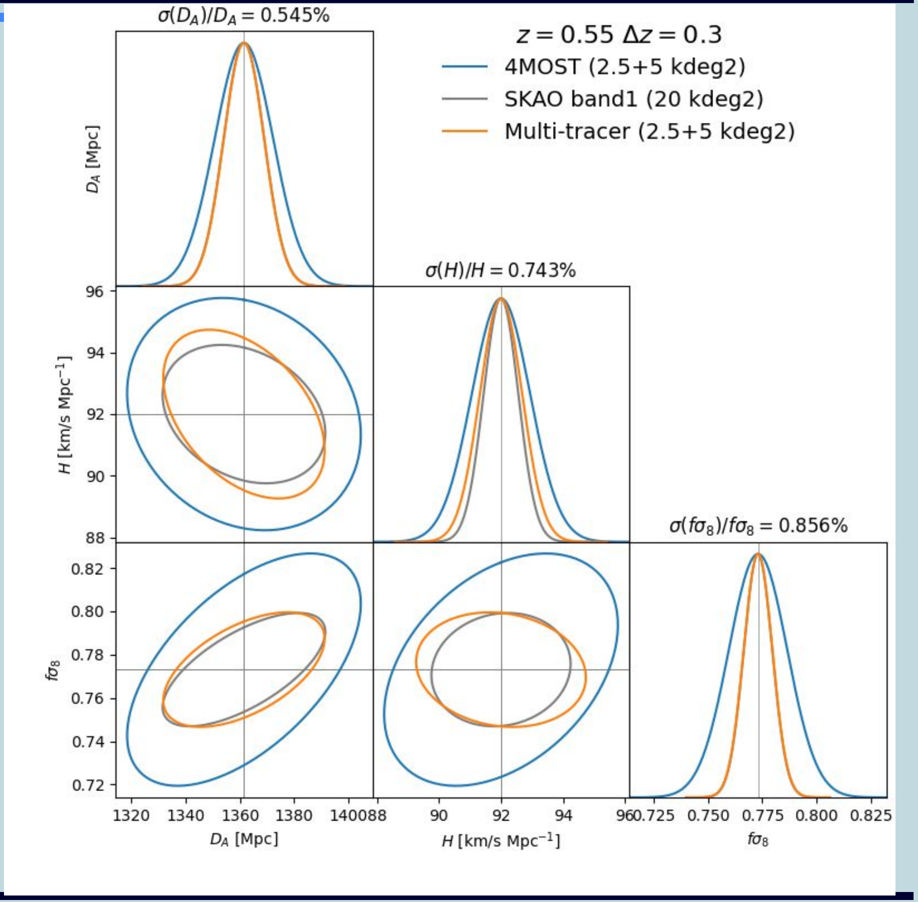


For cross-correlations only, we can achieve a BAO detectability of SNR= [4.8, 7.2] for z = [0.43, 0.61] with 4MOST and SNR=[3.7, 4.1] for z = [0.65, 0.8] with DESI. Combining DESI with Euclid, it will be even possible to make a detection at z = 1.0 and 1.2.

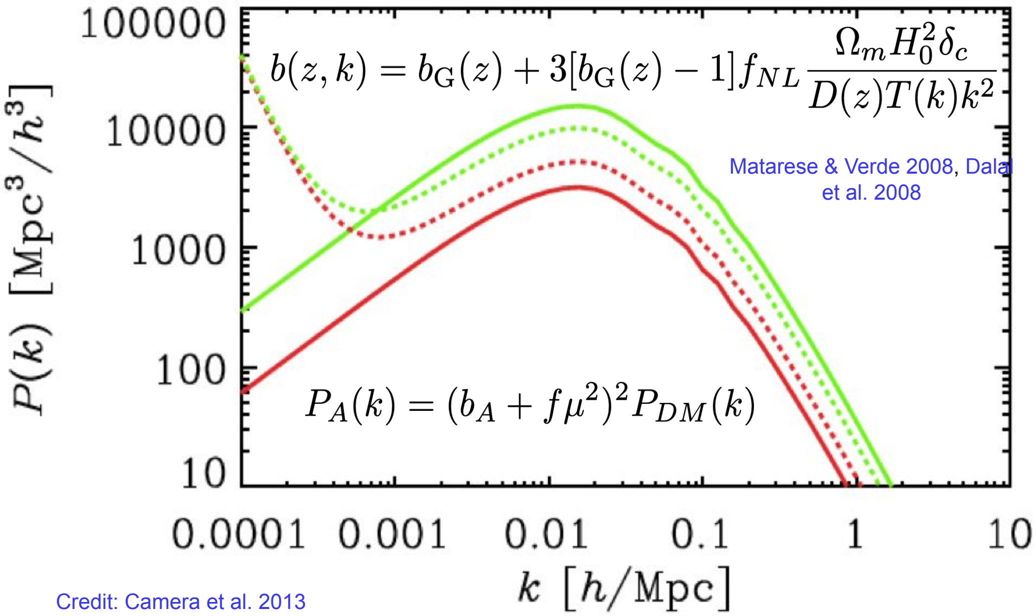
SKAO with 4MOST

Already done for short paper on synergies between SKAO and ESO

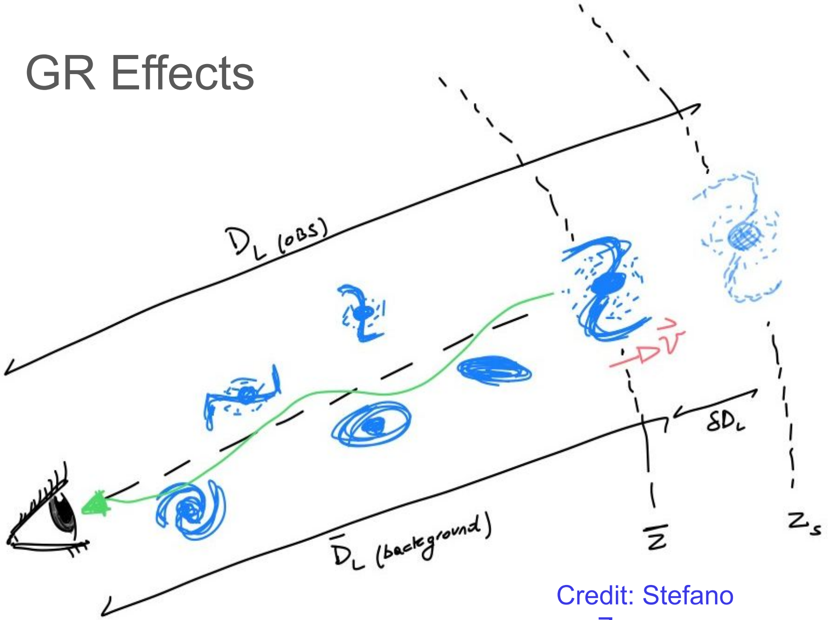




Extracting information on largest scales with synergies



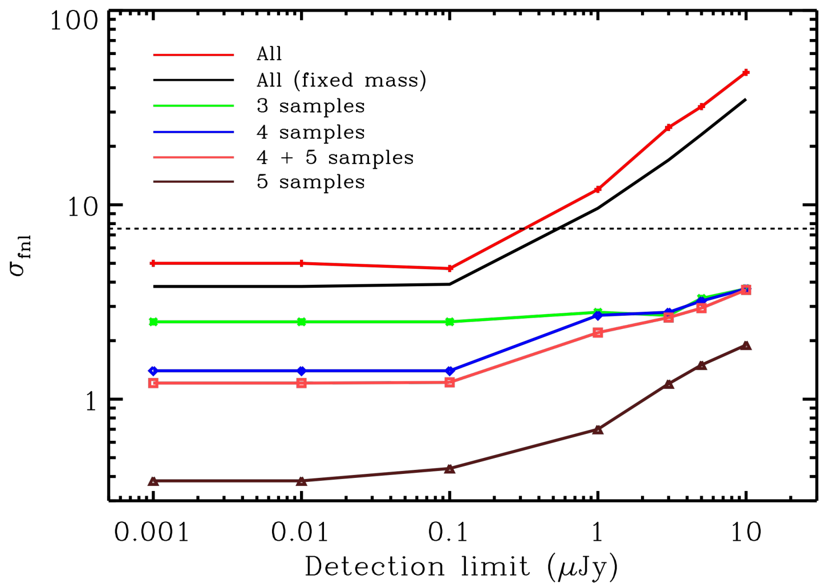
Credit: Camera et al. 2013



Credit: Stefano Zazzera

Constraints on Ultra Large Scale Effects

Continuum Galaxies SKAO



Ferramacho et al. 2014

	S^3 $N(z)$	T-RECS $N(z)$
S^3 biases	1.90	1.88
Hale biases	1.54	1.56

Table 2. Forecasts on $f_{\rm NL}$ $1-\sigma$ errors obtained using a multi-tracer Fisher analysis with redshift bins of size $\Delta z = 0.25$ and a range of $0 < z < 5$.

		SFG+SB MLAGN HLAGN	SFG+SB MLAGN	SFG+SB AGN
S^3 biases	S^3 $N(z)$	2.23	2.27	2.26
	T-RECS $N(z)$	2.35	2.47	2.46
Hale biases	S^3 $N(z)$	1.83	1.84	1.84
	T-RECS $N(z)$	1.98	1.99	1.98

Table 3. Forecasts on $f_{\rm NL}$ $1-\sigma$ errors obtained using a multi-tracer Fisher analysis with redshift bins of size $\Delta z = 1$ and a range of $0 < z < 5$.

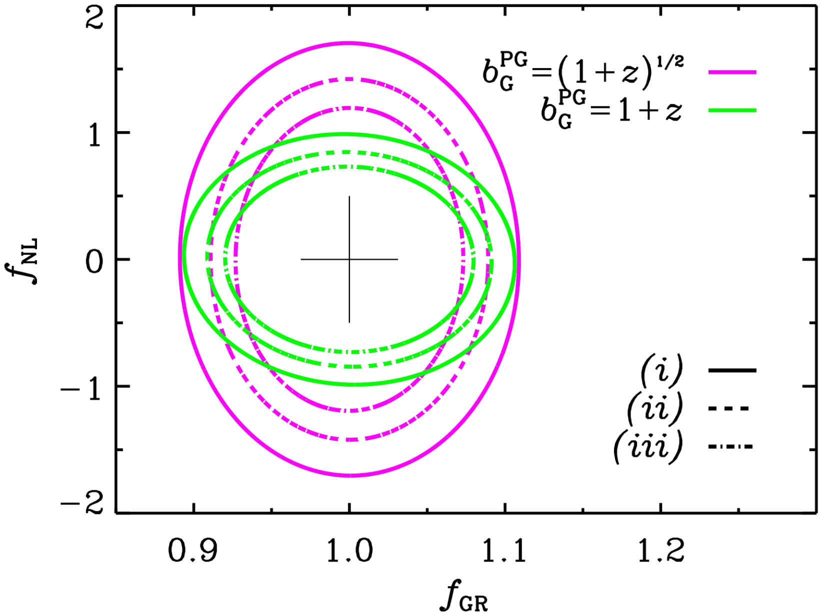
		SFG+SB MLAGN HLAGN	SFG+SB AGN
S^3 biases	S^3 $N(z)$	6.53	6.58
	T-RECS $N(z)$	5.39	5.82
Hale biases	S^3 $N(z)$	4.61	4.63
	T-RECS $N(z)$	4.07	4.08

Table 4. Forecasts on $f_{\rm NL}$ $1-\sigma$ errors obtained using a multi-tracer Fisher analysis with redshift bins of size $\Delta z = 0.25$ and a range of $0 < z < 2$.

Gomes et al. 2020

Constraints on Ultra Large Scale Effects

Photometric Galaxies x HI IM



Euclid-like
LSST-like

MARGINAL ERRORS FROM THE MT ANALYSIS FOR THE THREE PHOTO-z SCENARIOS WITH GAUSSIAN BIAS $\sqrt{1+z}$ (OR $1+z$) AND $\ell_{\rm max} = 300$.

	$\sigma(f_{GR})$		$\sigma(f_{NL})$	
(i)	0.071	(0.070)	1.12	(0.65)
(ii)	0.059	(0.060)	0.94	(0.56)
(iii)	0.048	(0.053)	0.79	(0.48)

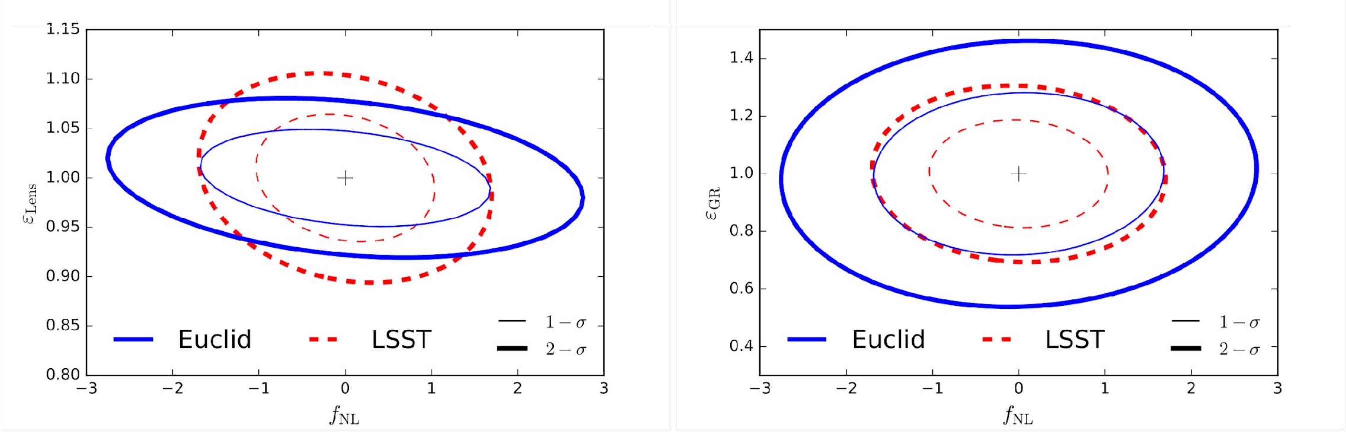
JF, Stefano Camera, Mário G. Santos & Roy Maartens ApJL 2015

Constraints on Ultra Large Scale Effects

Photometric Galaxies x HI IM

Updates for the SKA red book
Bacon et al 2020

Synergy	$\sigma(f_{NL})$	$\sigma(\varepsilon_{Lens})$	$\sigma(\varepsilon_{GR})$	$\sigma(\varepsilon_{Doppler})$	$\sigma(\varepsilon_{TD})$	$\sigma(\varepsilon_{SW})$	$\sigma(\varepsilon_{ISW})$
SKA1 HI IM × Euclid	1.1	-	-	-	-	-	-
	1.1	0.033	0.19	-	-	-	-
	1.3	0.033	-	0.19	5.3	5.5	16
SKA1 HI IM × LSST	0.67	-	-	-	-	-	-
	0.68	0.043	0.12	-	-	-	-
	0.96	0.043	-	0.13	5.7	4.0	7.5



Constraints on Ultra Large Scale Effects

Halpha IM (SPHEREx) x HI IM (SKAO)

Table 1. Marginal errors on $f_{\rm NL}$, $\varepsilon_{\rm Doppler}$, $\varepsilon_{\rm SW}$ and $\varepsilon_{\rm ISW}$ for different binnings Δz, for the two IM surveys separately and combined via MT analysis, assuming $f_{\rm sky} = 0.75$, $0.2 \leq z \leq 3$, and the instrumental noise given in §3.

Δz		$\sigma(f_{\rm NL})$	$\sigma(\varepsilon_{\rm Doppler})$	$\sigma(\varepsilon_{\rm SW})$	$\sigma(\varepsilon_{\rm ISW})$
	HI	5.0	5.9	14	11
0.2	Hα	3.9	8.1	30	22
	MT	1.2	0.64	6.0	9.7
	HI	4.3	4.9	12	11
0.1	Hα	3.5	6.8	27	22
	MT	1.1	0.39	5.6	9.5
	HI	3.5	4.3	11	9.5
$\Delta z_{\rm min}$	Hα	3.4	6.3	26	20
	MT	1.0	0.33	4.9	8.3

Table 2. As in Table 1, for conditional errors on $f_{\rm NL}$.

Δz	HI	Hα	MT
0.2	2.4	1.4	1.0
0.1	2.1	1.3	0.92
$\Delta z_{\rm min}$	1.8	1.3	0.86

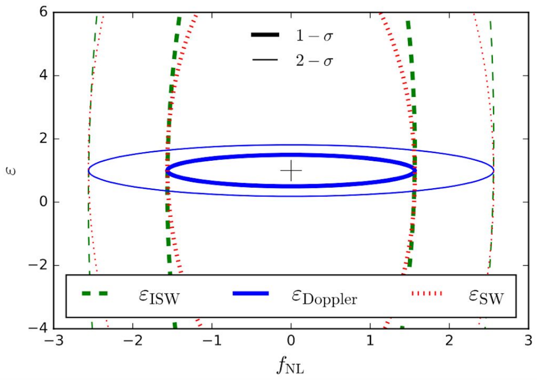


Figure 2. The 1σ (thick) and 2σ (thin) contours for the marginal errors of $f_{\rm NL}$ and the Doppler (solid blue), SW (dashed red) and ISW (dot-dashed green) GR effects. ($f_{\rm sky} = 0.75$, $0.2 \leq z \leq 3$ and redshift resolution $\Delta z_{\rm min}$.)

JF, Roy Maartens, Mário G. Santos, MNRAS 2018

Constraints on Ultra Large Scale Effects

Spectroscopic (Euclid or DESI) x HI IM (SKAO)

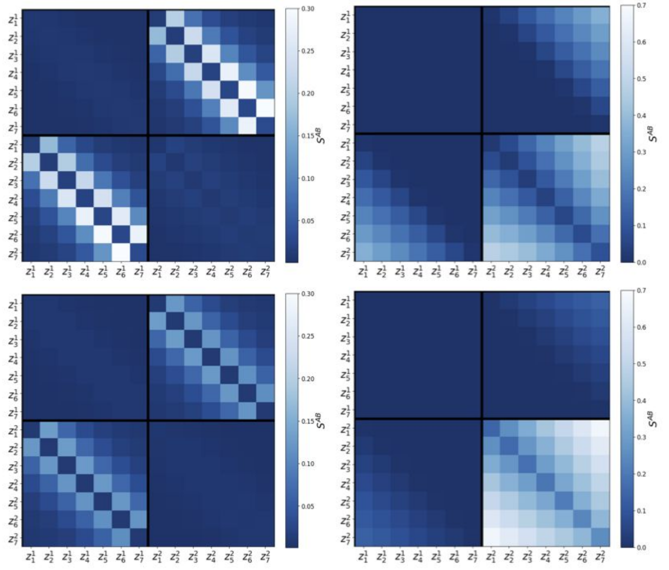
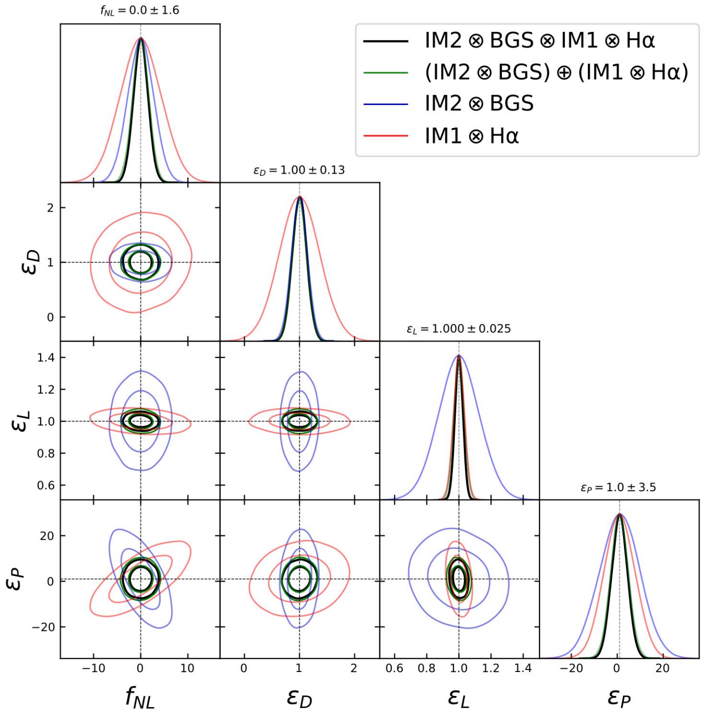


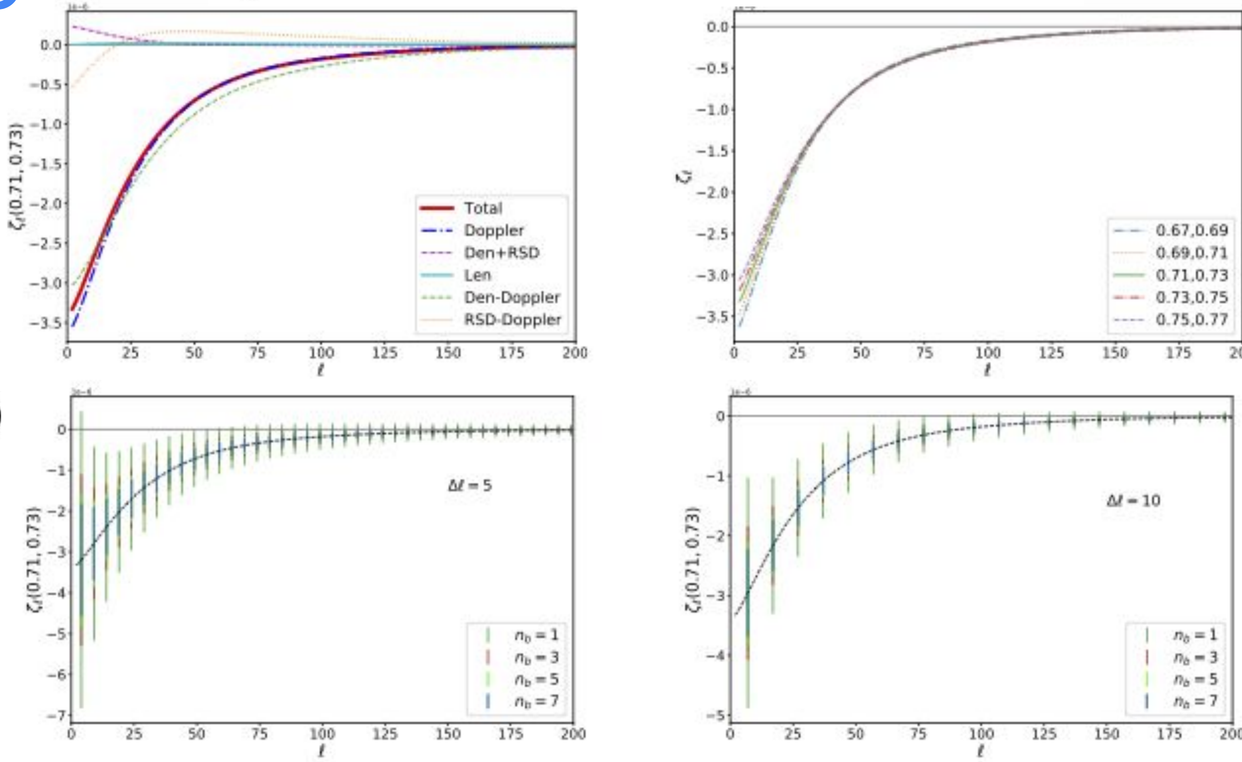
Figure 5. Signal-to-noise $S^{AB}(\theta, z_i^A, z_j^B)$ for the Doppler contribution ($\theta = \varepsilon_D$) (*left*) and the lensing magnification contribution ($\theta = \varepsilon_L$) (*right*). *Top panels:* $1 \otimes 2 =$ IM2 $\otimes$ BGS for $0.35 < z < 0.56$. *Bottom panels:* $1 \otimes 2 =$ IM1 $\otimes$ Hα for $0.90 < z < 1.15$. Colour bar shows the signal-to-noise.



Jan-Albert Viljoen, JF, Roy Maartens, JCAP 2021

Antisymmetric Clustering Signals

$$\zeta_{ij}^{AB} \equiv C_\ell^{AB}(z_i, z_j) - C_\ell^{AB}(z_j, z_i) = C_\ell^{AB}(z_i, z_j) - C_\ell^{BA}(z_i, z_j)$$



$$\zeta_{ij}^{AB,\ contiguous} \simeq \left(b^A - b^B\right)\left(C_\ell^{\delta R}(z_i, z_j) - C_\ell^{R\delta}(z_i, z_j)\right) + \left(A_D^A b^B - A_D^B b^A\right)\left(C_\ell^{D\delta}(z_i, z_j) - C_\ell^{\delta D}(z_i, z_j)\right) + \left(A_D^A - A_D^B\right)\left(C_\ell^{DR}(z_i, z_j) - C_\ell^{RD}(z_i, z_j)\right) .$$

JF, Chris Clarkson, JCAP 2021

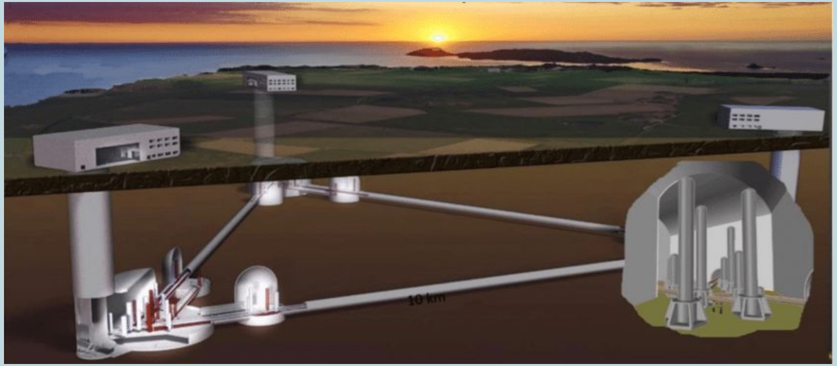
Table 1. Signal-to-noise ratio for different combinations of surveys. All considered a cut at $\ell_{\rm max} = 300$ with $\Delta\ell = 5$, and $\Delta z = 0.02$, and for $\Delta z = 0.01$ inside brackets.

	BGS - Full	BGS - Bright	Hα	SKAO2 Faint
SKAO MID HI gal	3.5 (4.6)	2.7 (3.4)	-	-
SKAO MID HI IM	4.8 (5.4)	3.4 (4.9)	6.7 (5.4)	-
SKAO2 Full	9.2 (11.4)	8.5 (12.4)	17.2 (15.5)	-
SKAO2 Bright	-	-	-	41.9 (53.3)

Then one can test the Euler Eq.

JF, Chris Clarkson, JCAP 2021

Synergies between Radio and GWs



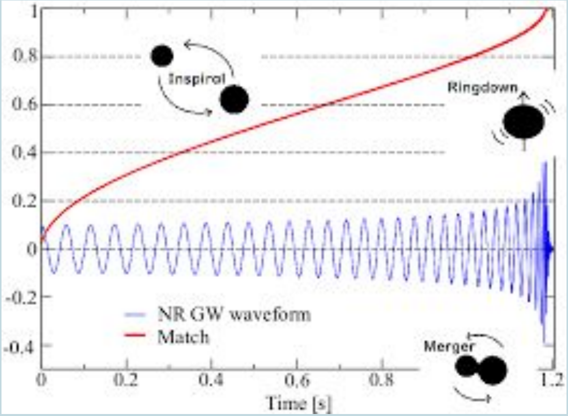
Credits: Einstein Telescope

Next Generation surveys:

$$N_{ET} \sim \mathcal{O}(10^5)$$
$$z_{ET} \sim 10$$

GW

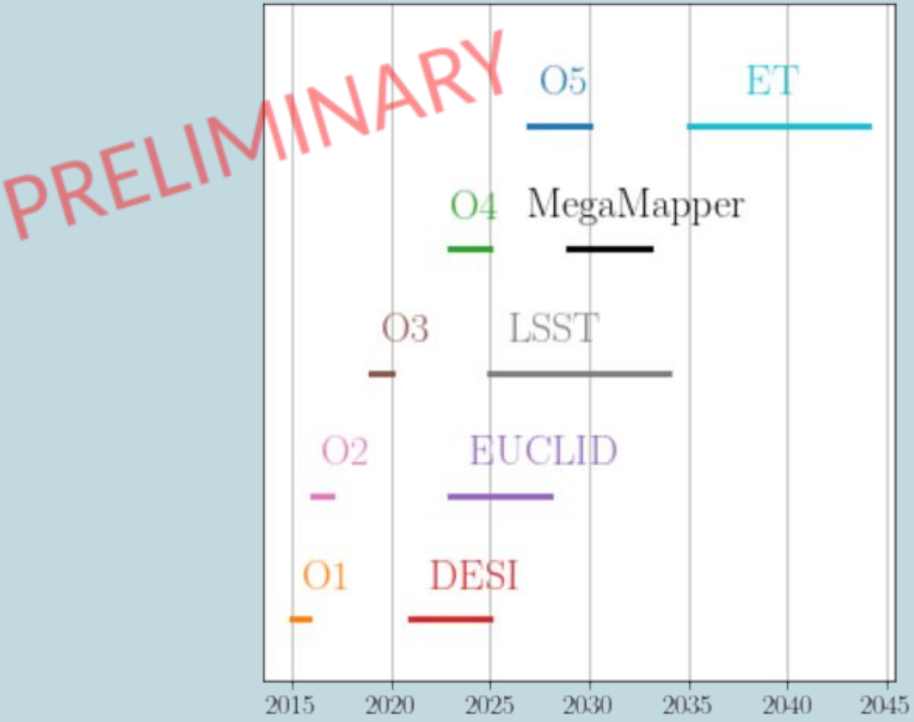
$$h \propto \frac{\mathcal{M}_z^{5/3}}{d_L}$$

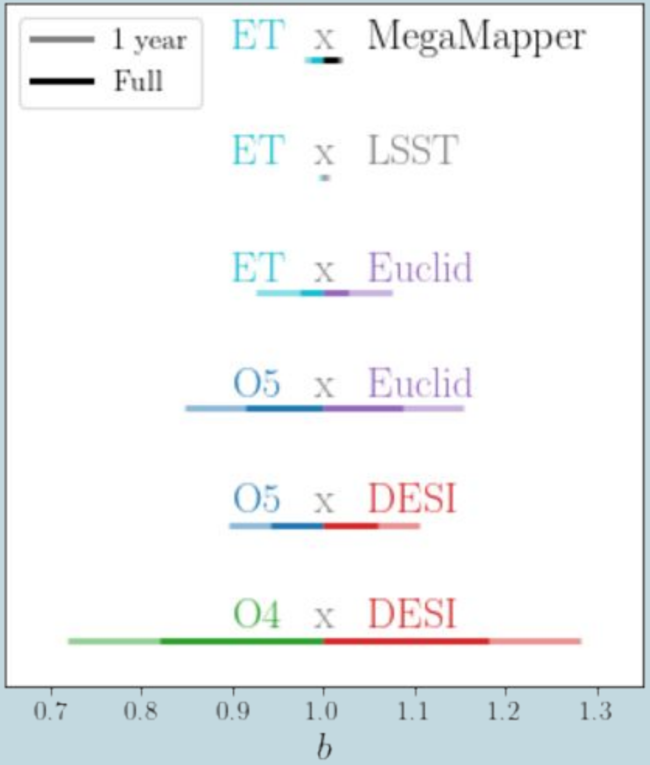


YES!

- Several works have done for when redshift is known (see eg Scelfo et al 2018, etc);
- Libanore et al (2021), angular power spectra with first corrections to the density contrast;
- Namikawa et al (2021), in 3D space;

Cross-correlations with galaxy surveys

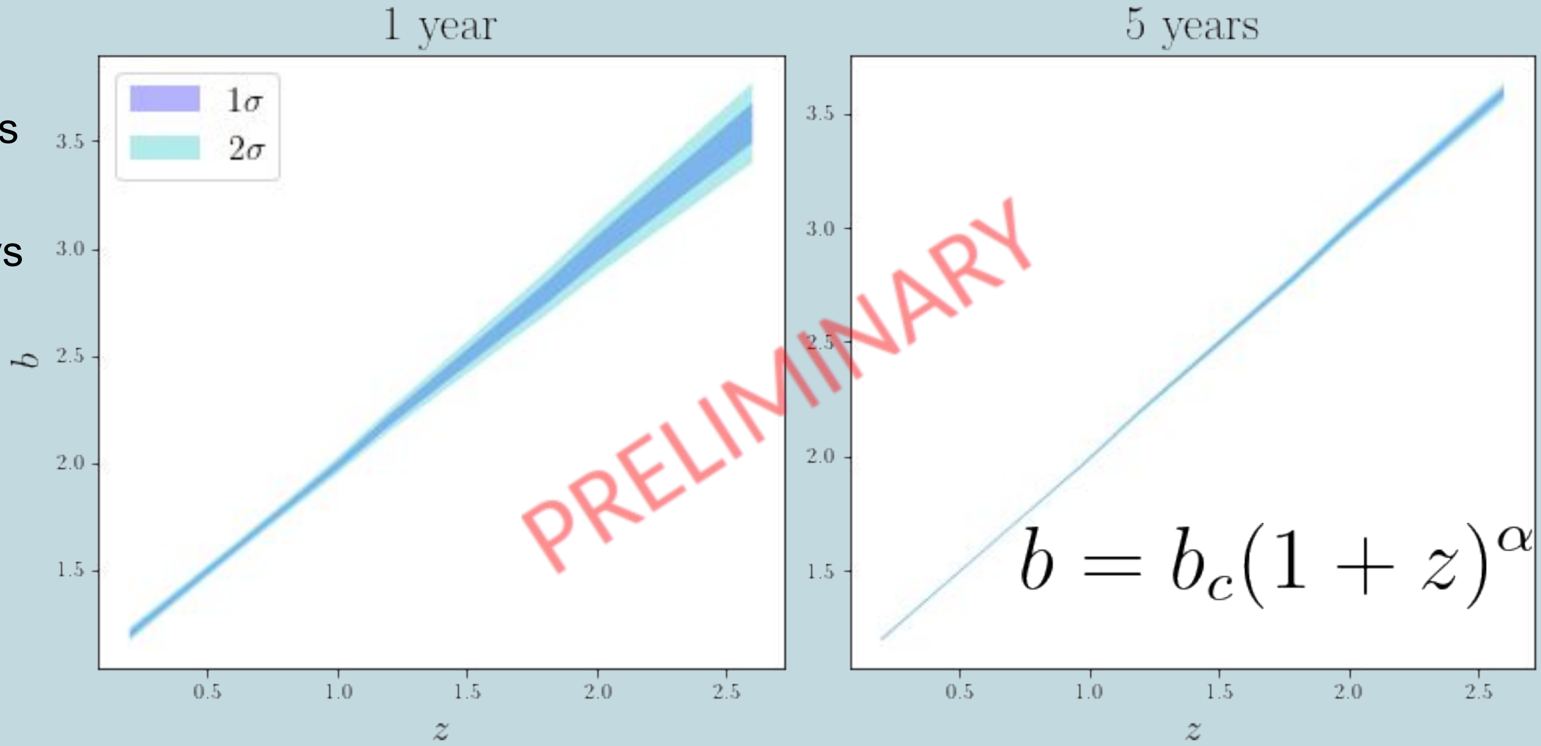




Zazzera et al., to appear

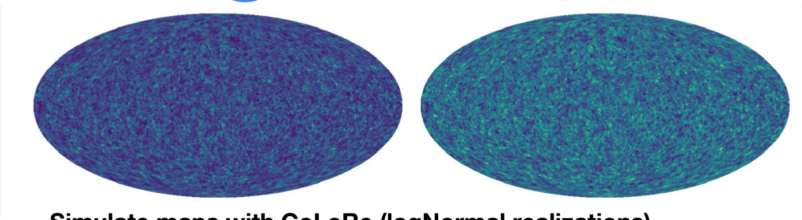
Clustering bias

Constraints from cross-correlations between an ET-like and LSST-like surveys



Zazzera et al., to appear

Doing HI IM MT in practice



Simulate maps with CoLoRe (logNormal realizations)

- Define estimators

$$\epsilon_{\mathrm{A},\ell} \equiv \sqrt{\frac{\hat{C}_\ell^{\mathrm{HH}} - N_\ell^{\mathrm{HH}}}{(T_\ell B_\ell)^2 \left(\hat{C}_\ell^{gg} - N_\ell^{gg}\right)}},$$

- Include beam

$$\epsilon_{\mathrm{X},\ell} \equiv \frac{\hat{C}_\ell^{\mathrm{H}g}}{T_\ell\, B_\ell \left[\hat{C}_\ell^{gg} - N_\ell^{gg}\right]},$$

$$\epsilon_{\mathrm{opt}} = \frac{\sum_{i,j} \mathsf{C}_{ij}^{-1} \epsilon_j}{\sum_{ij} \mathsf{C}_{ij}^{-1}},$$

- do foreground removal using PCA (7 components)
- Correct for transfer function of the fg_rm

$$T_\ell = \frac{\langle C_\ell^{\tilde{\mathrm{H}}\mathrm{H}} \rangle - N_\ell^{\tilde{\mathrm{H}}\mathrm{H}}}{\langle C_\ell^{\mathrm{HH}} \rangle - N_\ell^{\mathrm{HH}}}$$

Mask

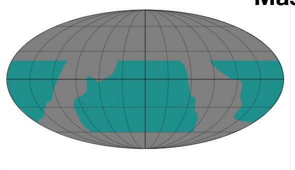
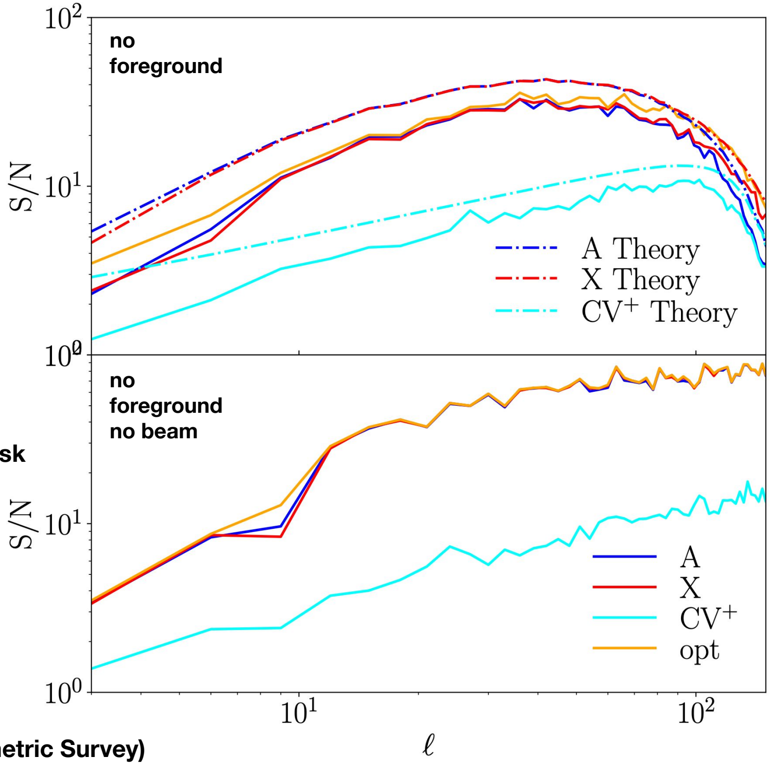
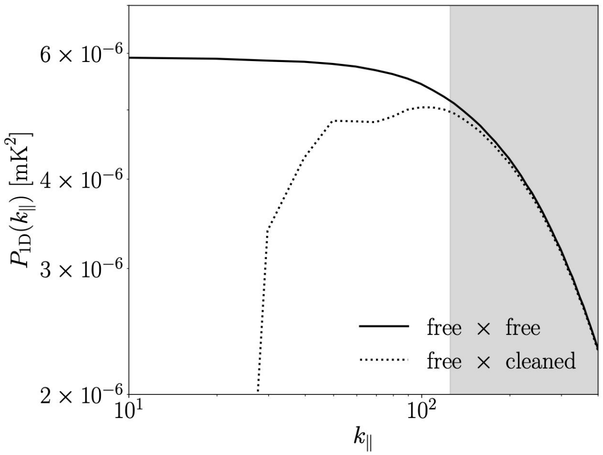
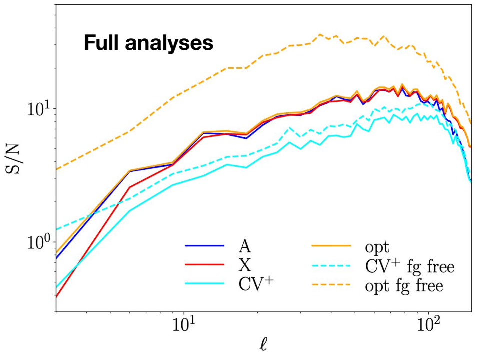


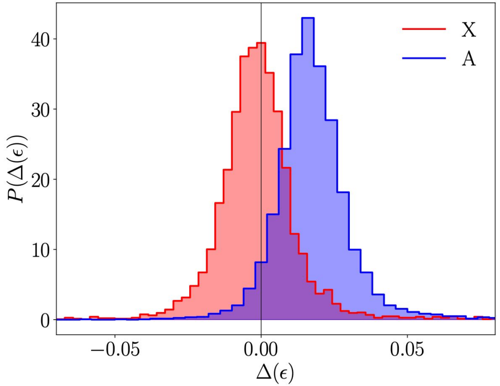
Figure 1. Sky mask used in our analysis, shown in Mollweide's projection and equatorial coordinates. The masked area is shown in grey. The footprint corresponds to the sky observable from the LSST and SKA with the regions of highest galactic emission (both in synchrotron and dust) removed. The total unmasked area is 16900 deg^2 ($f_{\mathrm{sky}} = 0.41$.)



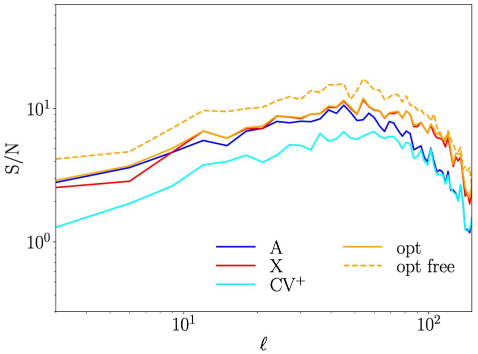
Amadeus Witzemann, David Alonso, JF, Mário G. Santos, MNRAS 2019 (HI IM with Photometric Survey)

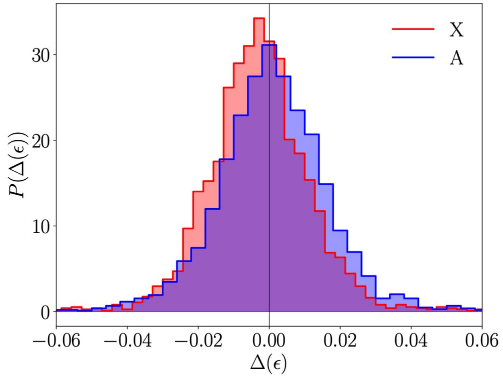






Thinner bins (a la spectroscopic survey)





Amadeus Witzemann, David Alonso, JF, Mário G. Santos
MNRAS 2019 (HI IM with Photometric Survey)

Summary (Potential main contributions)

- Physics beyond standard cosmological model (Non-Gaussianity, GR effects, null tests of GR);
- Synergies with Optical;
- Synergies with GW:
- Exploration of way to explore the multitracer.