Cosmology with the Square Kilometre Array

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SKA cosmology

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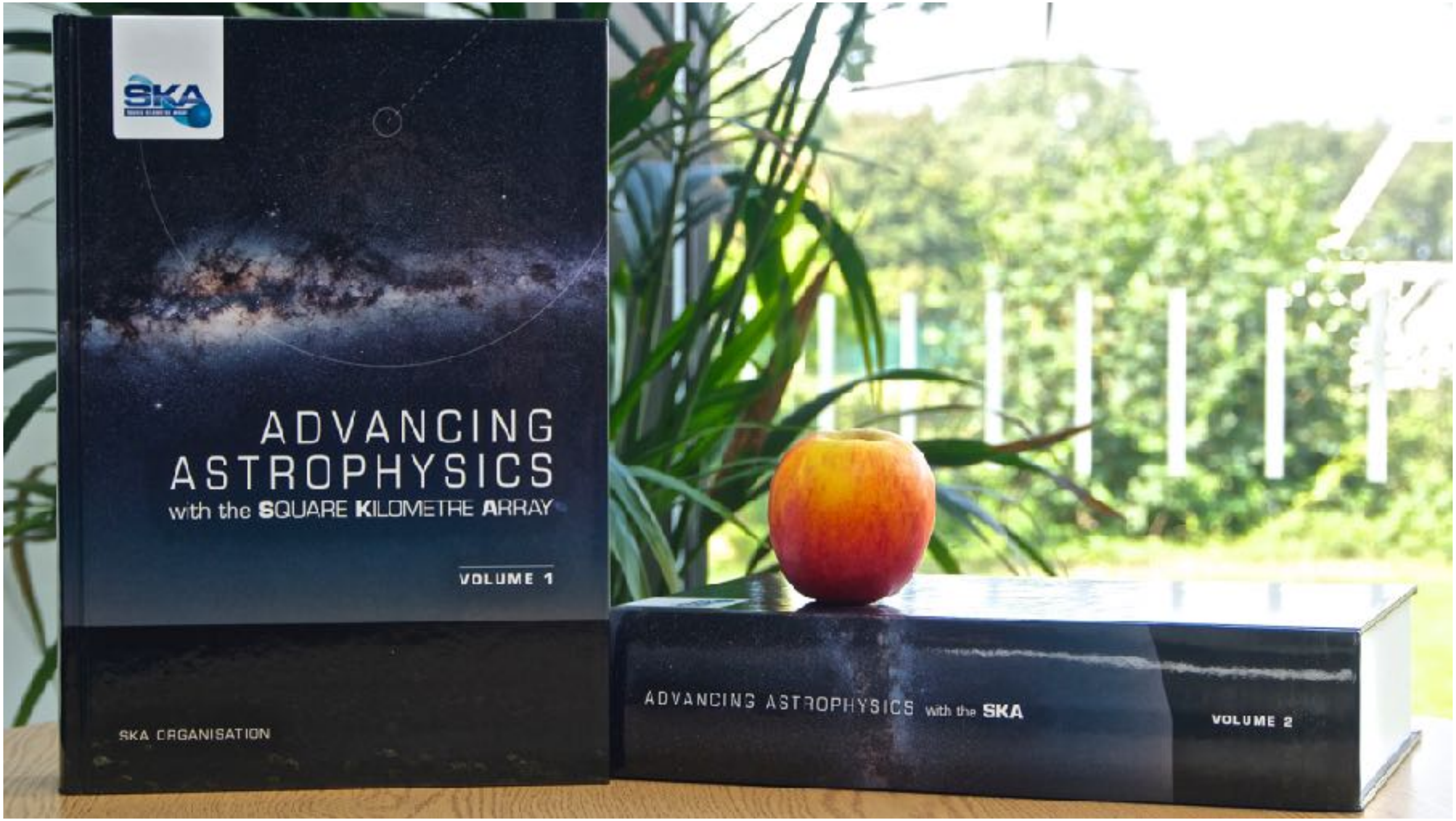


[arXiv:1811.02743]

Cosmology with Phase 1 of the Square Kilometre Array

Red Book 2018: Technical specifications and performance forecasts

David J. Bacon[1], Richard A. Battye[2], Philip Bull[3,4,5], Stefano Camera[6,7,8,2], Pedro G. Ferreira[9], Ian Harrison[2,9], David Parkinson[10], Alkistis Pourtsidou[5,1], Mário G. Santos[11,12], Laura Wolz[13], Filipe Abdalla[14,15], Yashar Akrami[16], David Alonso[9], Sambatra Andrianomena[11,12,17], Mario Ballardini[11], José Luis Bernal[18,19], Daniele Bertacca[20,36], Carlos A.P. Bengaly[11], Anna Bonaldi[21], Camille Bonvin[22], Michael L. Brown[2], Emma Chapman[23], Song Chen[11], Xuelei Chen[24], Steven Cunnington[1], Tamara M. Davis[26], Clive Dickinson[2], José Fonseca[11], Keith Grainge[2], Stuart Harper[2], Matt J. Jarvis[9,11], Roy Maartens[1,11], Natasha Maddox[27], Hamsa Padmanabhan[28], Jonathan R. Pritchard[23], Alvise Raccanelli[18], Marzia Rivi[14,29], Sambit Roychowdhury[2], Martin Sahlén[30], Dominik J. Schwarz[31], Thilo M. Siewert[31], Matteo Viel[32], Francisco Villaescusa-Navarro[32], Yidong Xu[24], Daisuke Yamauchi[34], Joe Zuntz[35]

[arXiv:1810.02680]

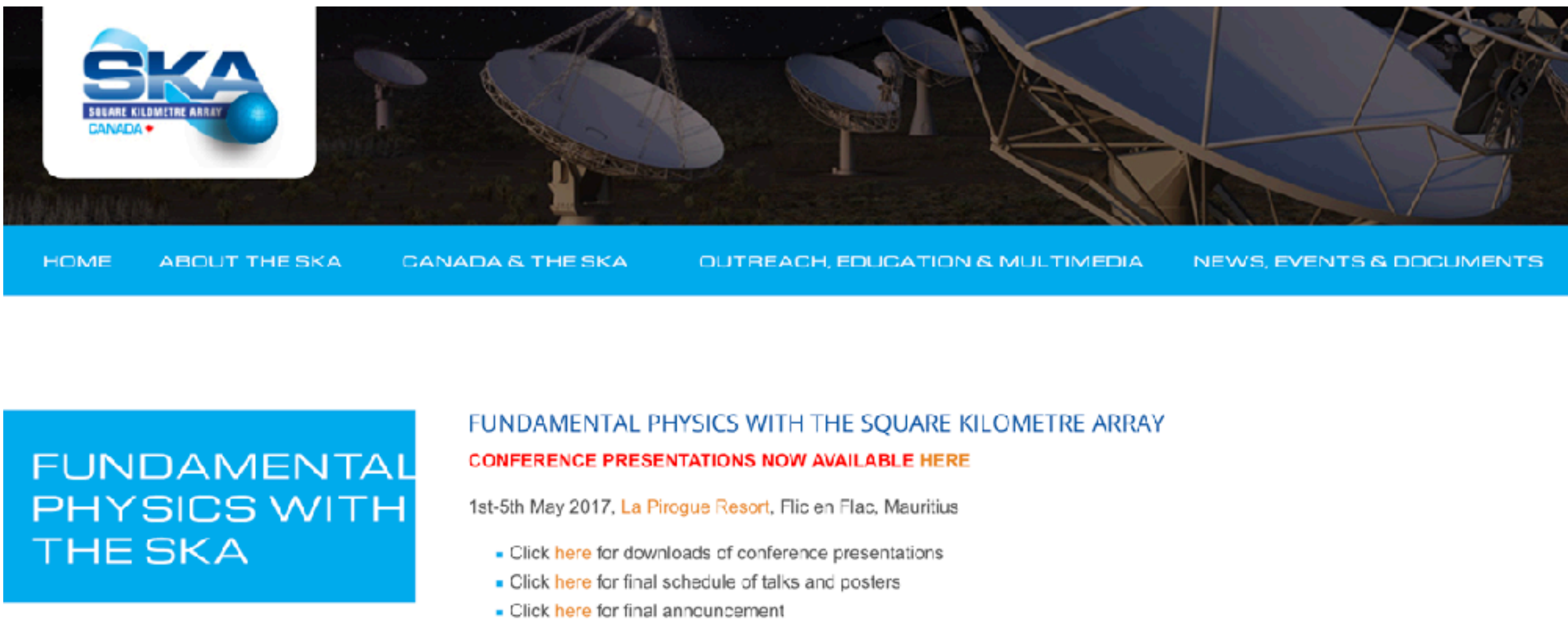
Fundamental Physics with the Square Kilometre Array

P. Bull,* S. Camera,* K. Kelley,* H. Padmanabhan,* J. Pritchard,* A. Raccanelli,* S. Riemer-Sørensen,* L. Shao,* S. Andrianomena, E. Athanassoula, D. Bacon, R. Barkana, G. Bertone, C. Bonvin, A. Bosma, M. Brüggen, C. Burigana, C. Bœhm, F. Calore, J. A. R. Cembranos, C. Clarkson, R. M. T. Connors, Á. de la Cruz-Dombriz, P. K. S. Dunsby, N. Fornengo, D. Gaggero, I. Harrison, J. Larena, Y.-Z. Ma, R. Maartens, M. Méndez-Isla, S. D. Mohanty, S. G. Murray, D. Parkinson, A. Pourtsidou, P. J. Quinn, M. Regis, P. Saha, M. Sahlén, M. Sakellariadou, J. Silk, T. Trombetti, F. Vazza, T. Venumadhav, F. Vidotto, F. Villaescusa-Navarro, Y. Wang, C. Weniger, L. Wolz, F. Zhang, B. M. Gaensler,† A. Weltman†

SKA cosmology

[arXiv:1810.02680]

Fundamental Physics with the Square Kilometre Array



SKA cosmology

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- SKA Cosmology SWG (R. Battye & L. Wolz)
  - Continuum Focus Group (M. Jarvis & D. Parkinson)
  - HI galaxy surveys Focus Group (P. Bull & N. Maddox)
  - HI intensity mapping Focus Group (M. Santos & L. Wolz)
  - Simulations Focus Group (D. Alonso & F. Villaescusa-Navarro)
  - SKA1-LOW cosmology Focus Group (A. Pourtsidou & J. Pritchard)
  - Synergies Focus Group (D. Bacon & S. Camera)
  - Weak lensing Focus Group (M. Brown & I. Harrison)

SKA cosmology

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[arXiv:1811.02743]

Cosmology with Phase 1 of the Square Kilometre Array

Red Book 2018: Technical specifications and performance forecasts

- Main scientific goals
  - Dark energy equation of state up to $z = 3$ from geometry (BAOs)
  - Measurements of the growth of perturbations in linear and nonlinear regimes
  - Accessing the largest cosmic scales (isotropy, homogeneity, non-Gaussianity, GR)
  - Measuring the HI density and bias up to $z = 6$ to high accuracy

3 surveys proposed

1) a medium deep band2 SKA1-MID 5000 deg^2(z<0.5) with weak lensing and low redshift spetroscopy, t=10000 hrs.

2) a wide band1 SKA1 MID 20000 deg^2 continuum galaxy and intensity mapping at z=0.35-3, t=10000 hrs.

3) a deep SKA1-LOW survey HI Intensity Mapping over 100deg^2 at z=3-6, t=5000 hrs

Modelling of the continuum sky is crucial.
Source of systematics is the bias of the radio galaxy populations.
Still some binning in redshift will be possible (photometric or statistical)
Cross identifications from optical surveys like DES for medium deep, while for wide poor optical/IR information.

Medium deep will be significantly oversampled at z<0.2 (multi tracing techniques)
N_gal=2-3,5x1.e6 - number density of about 3 gal/sq. arcmin for WL measurement

Wide band good for angular clustering and CMB cross-correlations

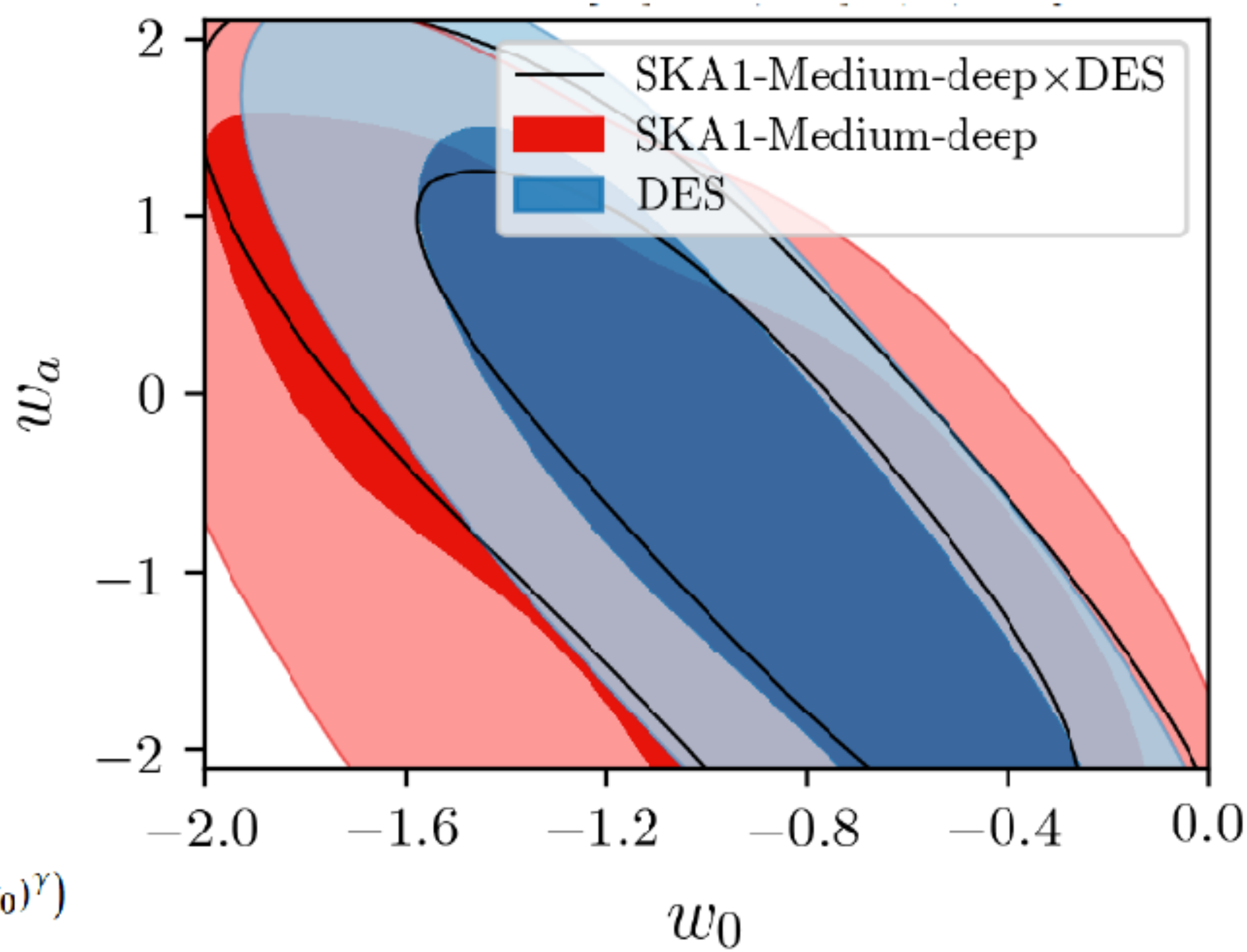
Weak lensing sinergies - I

GOAL: **measure galaxy shapes** requirements that have to be obtained in the radio are similar to those of present optical surveys. Ellipticities measured to O(1.e-4).

Cross-correlations will be crucial to get rid of wavelength dependent systematics (multiplicative and additive biases will be removed - Camera+17), while constraining power will be preserved

Medium deep survey with DES 5yrs - WEAK LENSING

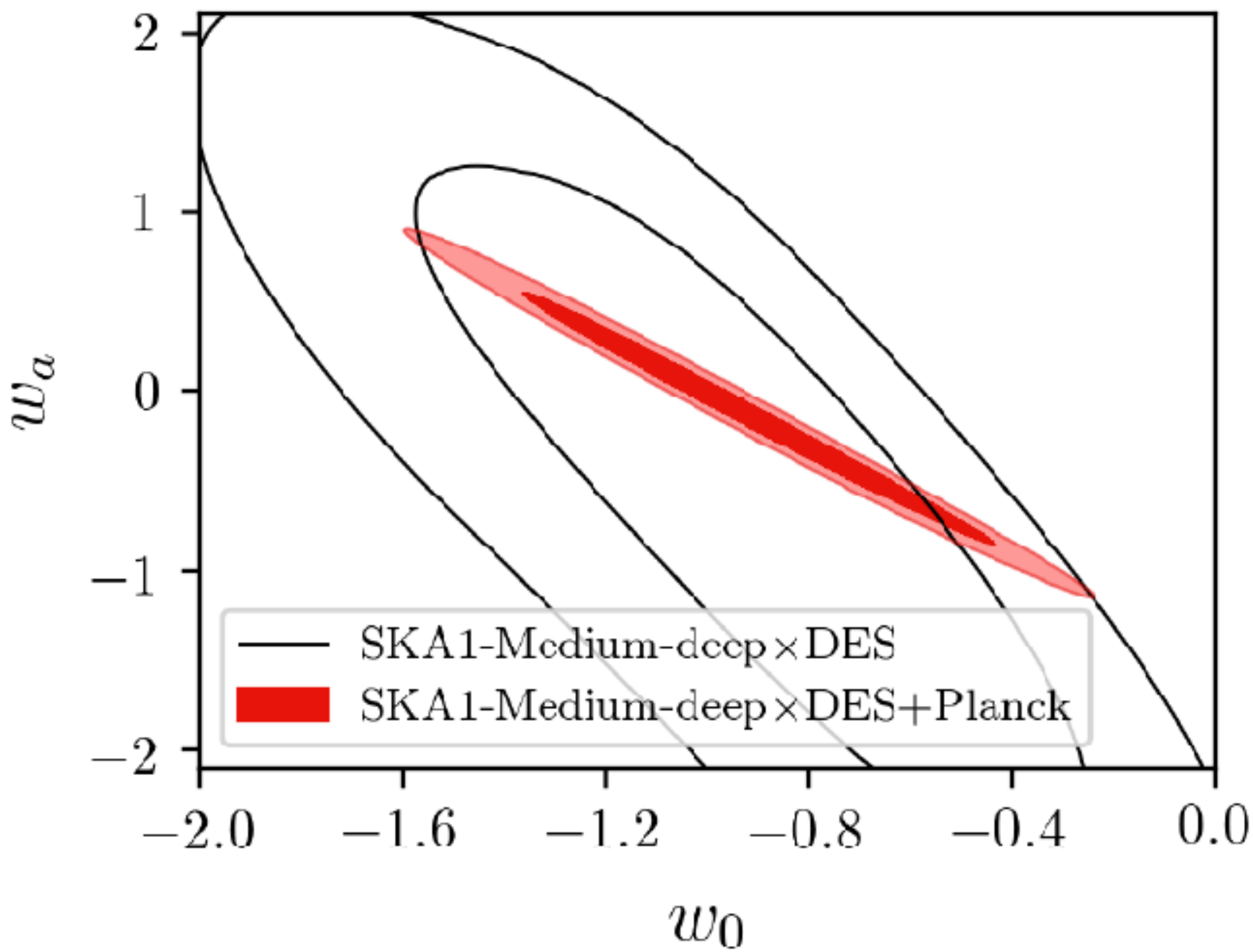
$$P/\rho = w(a) = w_0 + (1-a)w_a$$



$$\frac{dn}{dz} \propto z^2 \exp\left(-(z/z_0)^\gamma\right)$$

Weak lensing experiment	A_{sky} [deg^2]	n [arcmin^{-2}]	z_m	γ	$f_{spec\text{-}z}$	$z_{spec\text{-}max}$	$\sigma_{photo\text{-}z}$	$z_{photo\text{-}max}$	$\sigma_{no\text{-}z}$
SKA1 Medium-Deep	5,000	2.7	1.1	1.25	0.15	0.6	0.05	2.0	0.3
DES	5,000	12	0.6	1.5	0.0	N/A	0.05	2.0	0.3

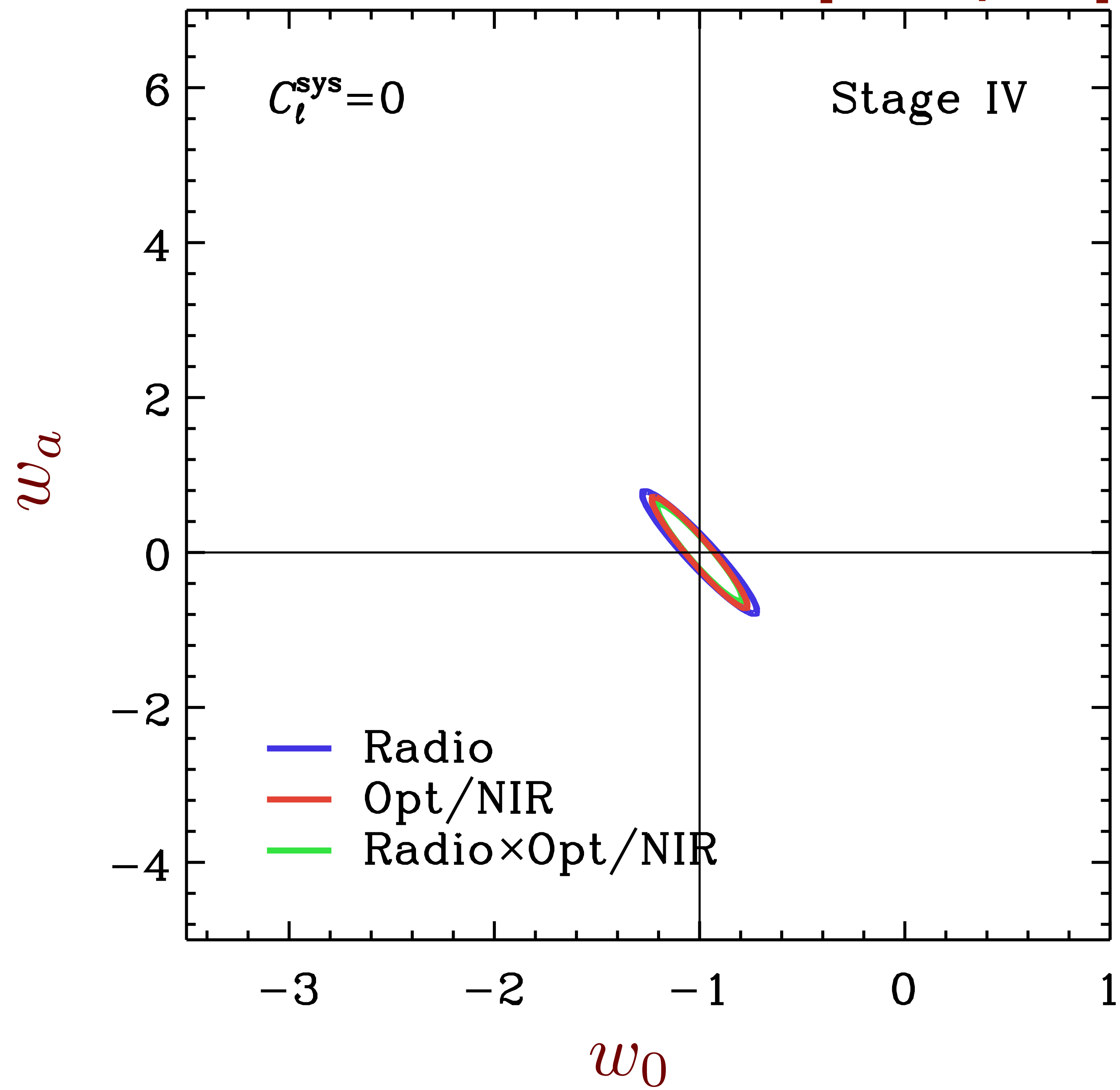
Weak lensing sinergies - II



Still Planck and CMB experiments will be driving the constraints, but cross-correlation important

SKA radio weak lensing

[SC et al., 2017]



SKA radio weak lensing

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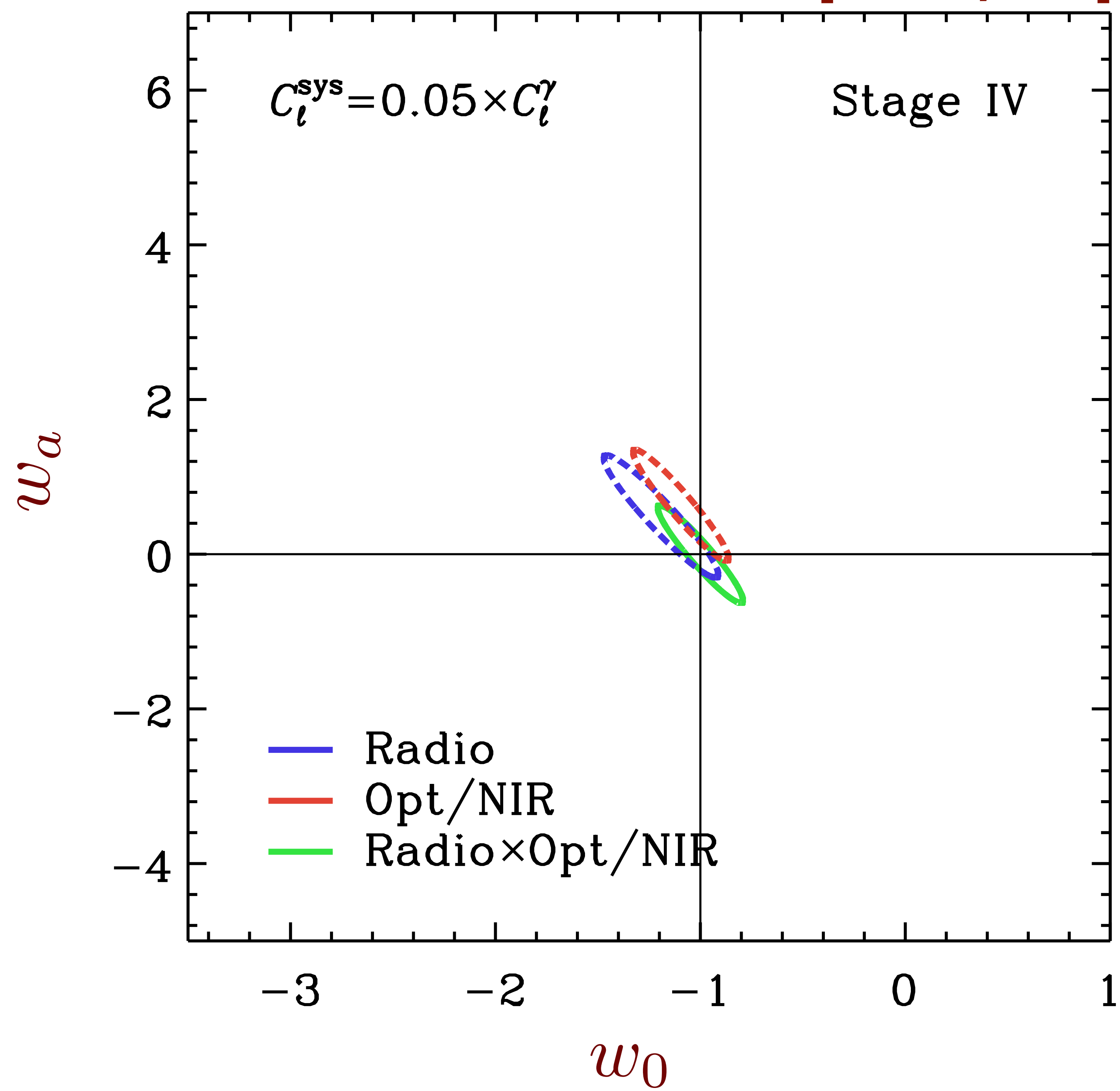
[SC et al., 2017]



SKA radio weak lensing

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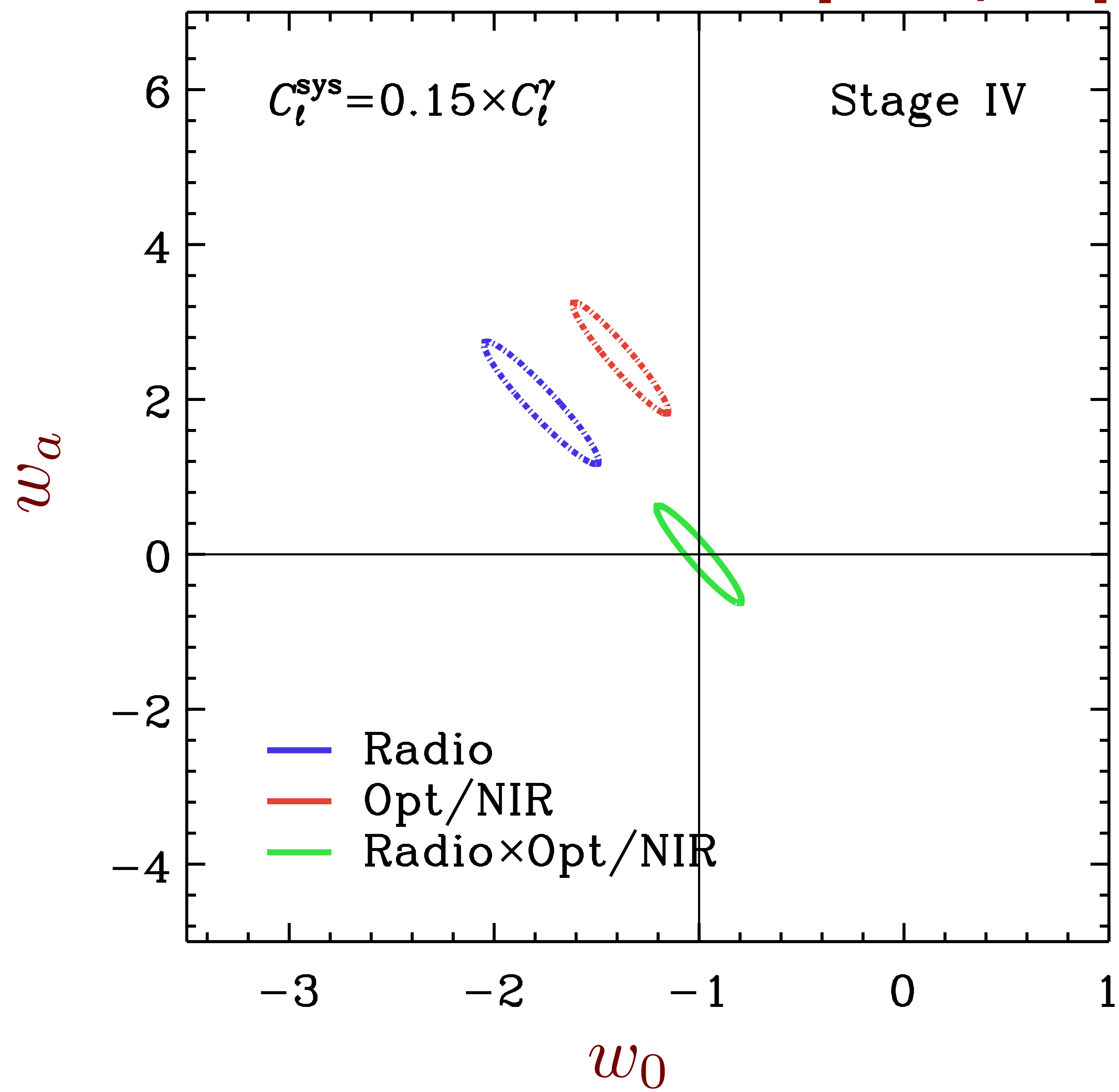
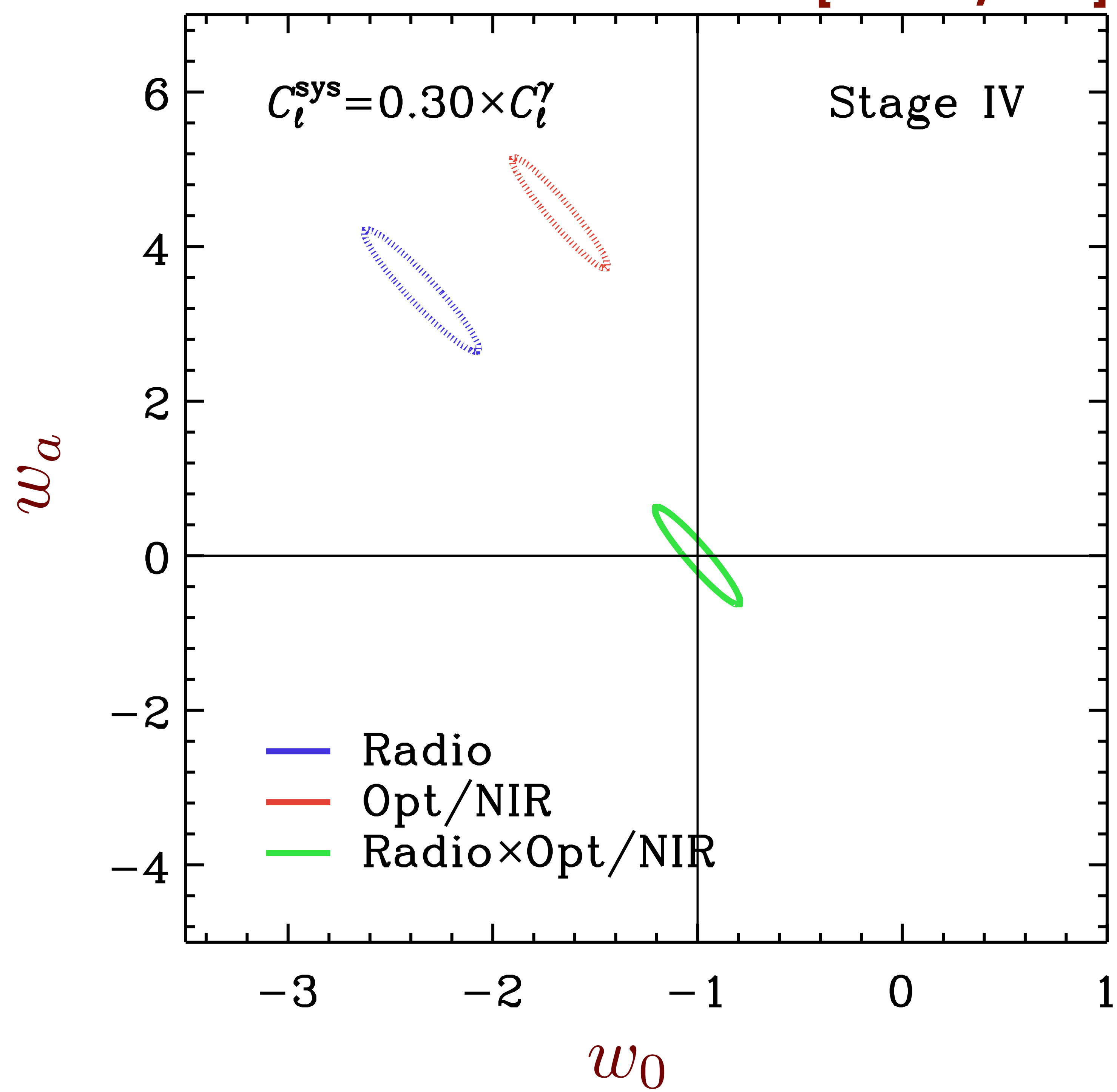
[SC et al., 2017]



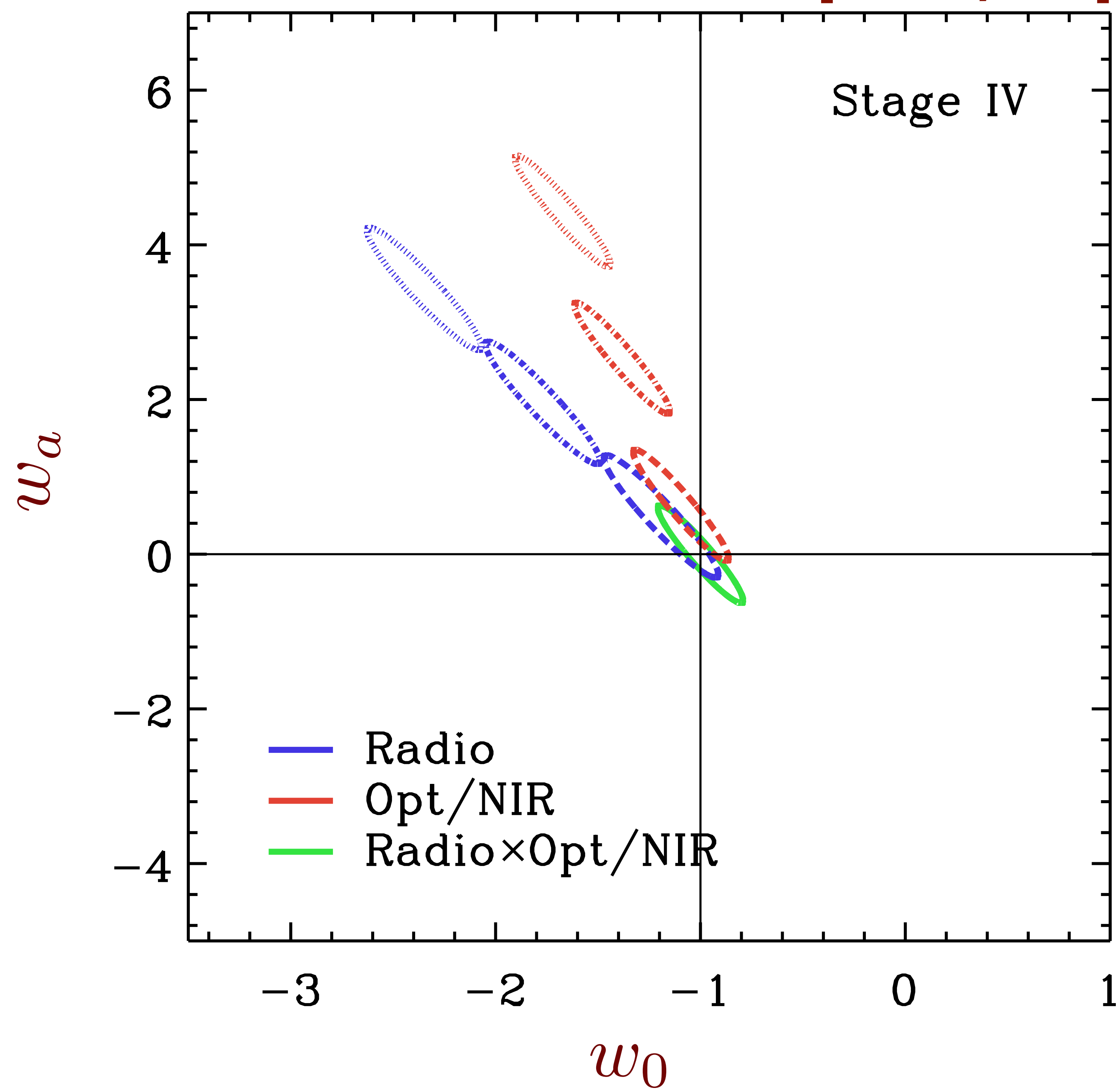
SKA radio weak lensing

[SC et al., 2017]



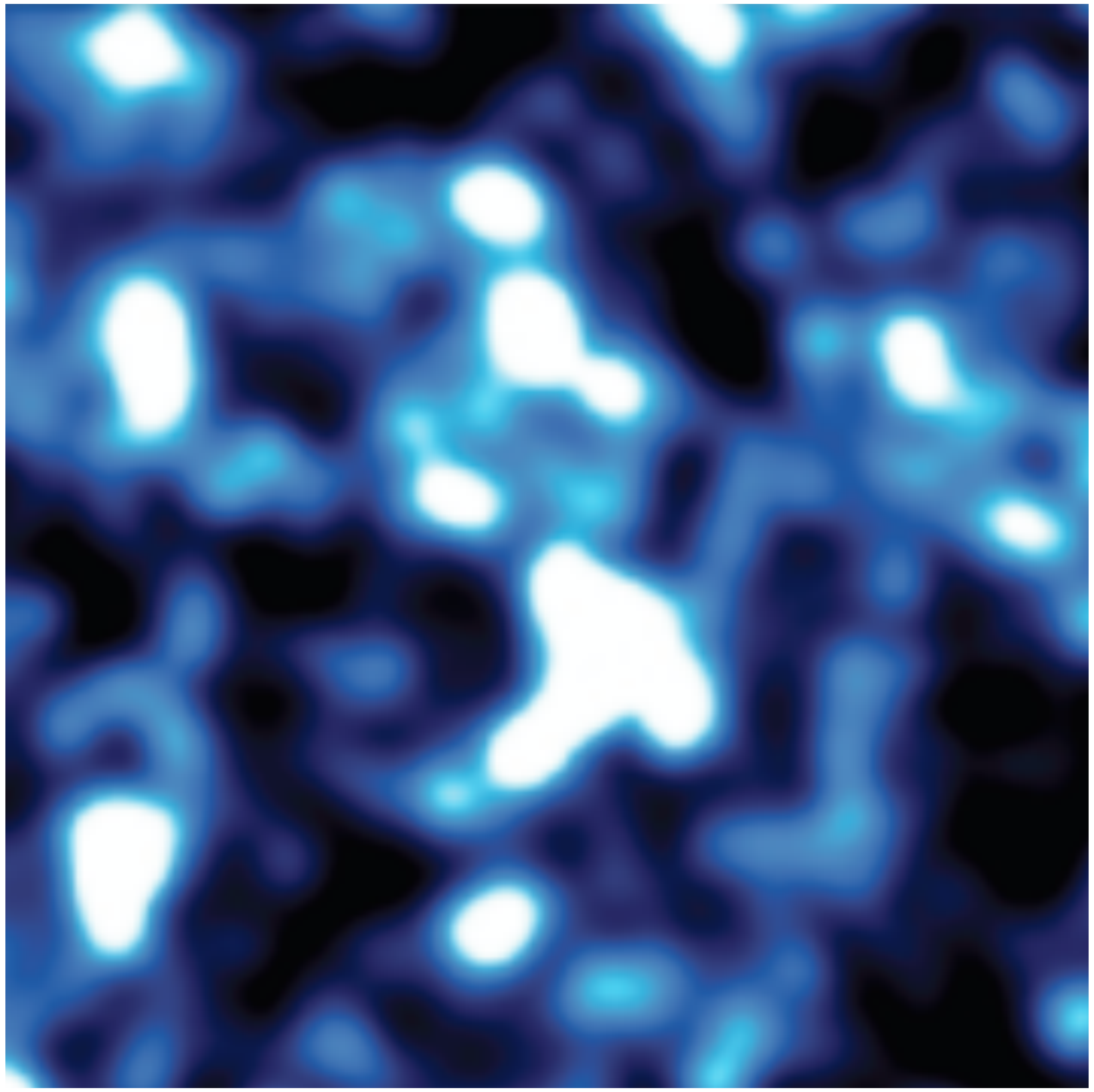
SKA radio weak lensing

[SC et al., 2017]



HI intensity mapping

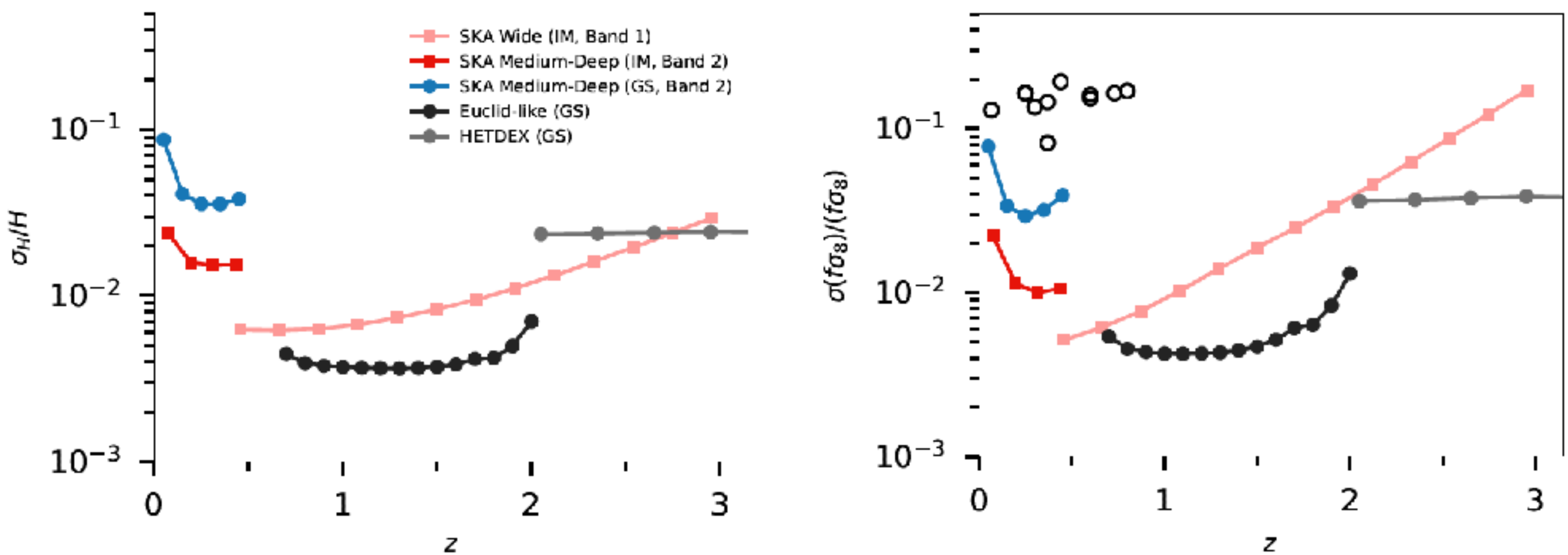
[Bharadwaj et al., 2001; Battye et al., 2004; Loeb & Whyte, 2008]



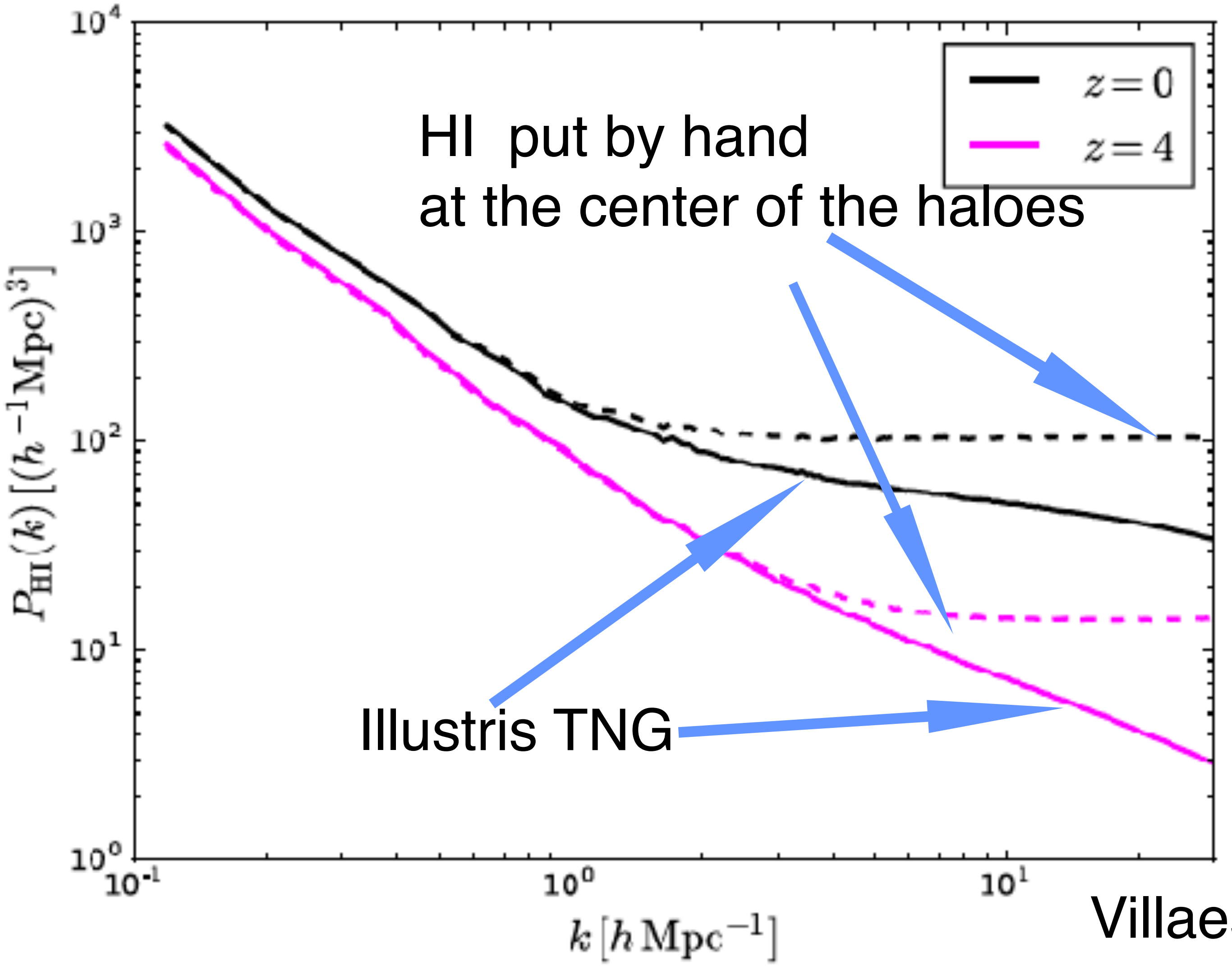
- Redshift for free: $\nu_{obs} = 1420\ \mathrm{MHz} / (1+z)$

HI intensity mapping

- HI **intensity mapping** and **galaxy** Med-Deep Band 2 surveys



Simulating intensity mapping signal: small scales



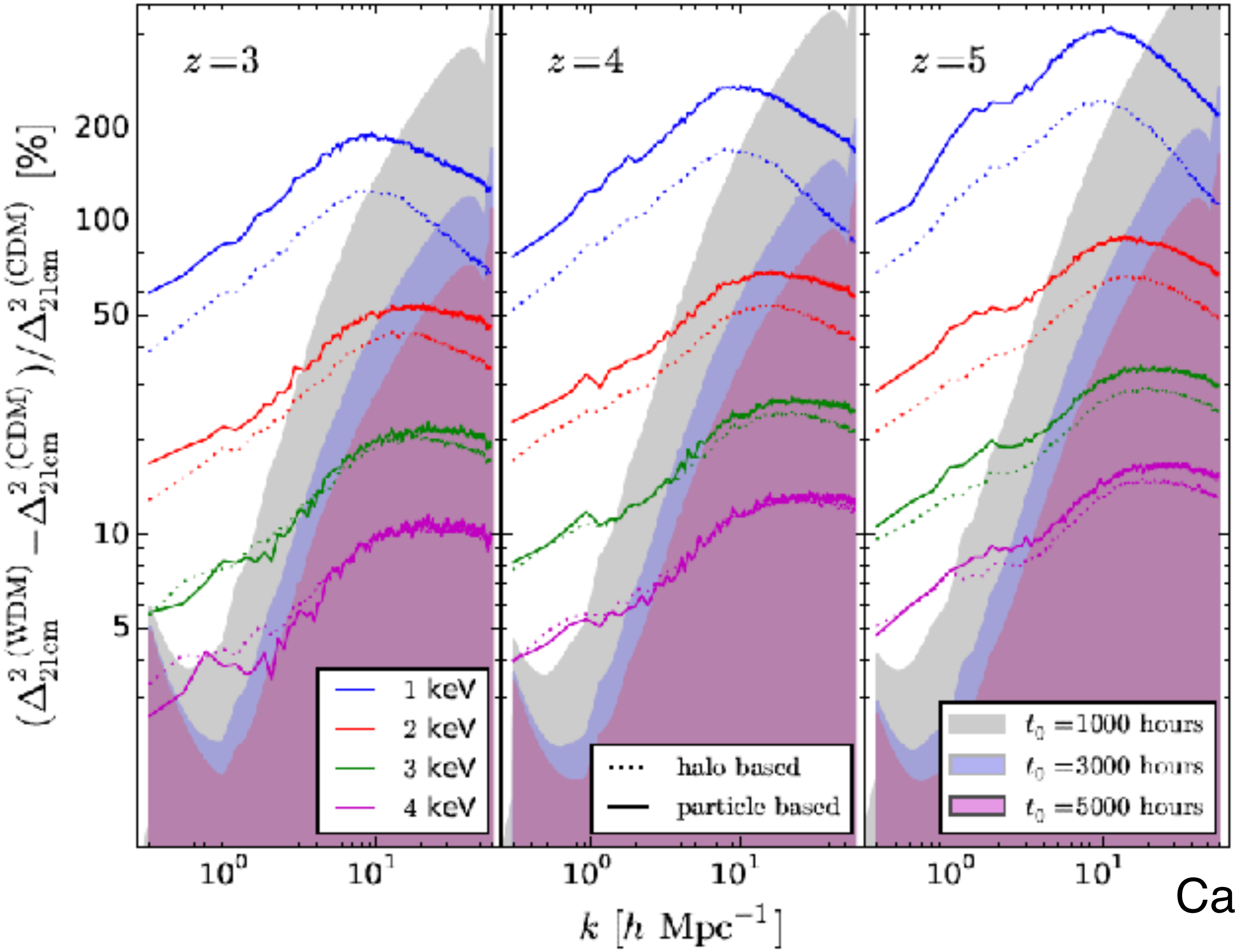
$$P^{\rm SN}_{\rm H\,I}(z) = \lim_{k\to 0} P_{\rm 1h,H\,I}(k,\, z) = \frac{1}{[\rho_{\rm c}^{0}\Omega_{\rm H\,I}(z)]^2} \times \int_0^\infty n(M,\, z) M^2_{\rm H\,I}(M,\, z)\, dM = \frac{\int_0^\infty n(M,\, z) M^2_{\rm H\,I}(M,\, z)\, dM}{\left[\int_0^\infty n(M,\, z) M_{\rm H\,I}(M,\, z)\, dM\right]^2}.$$

Villaescusa-Navarro+18

- Shot noise level in HI quite different from the standard case of galaxies and haloes good amount of HI substructure within each DM halo

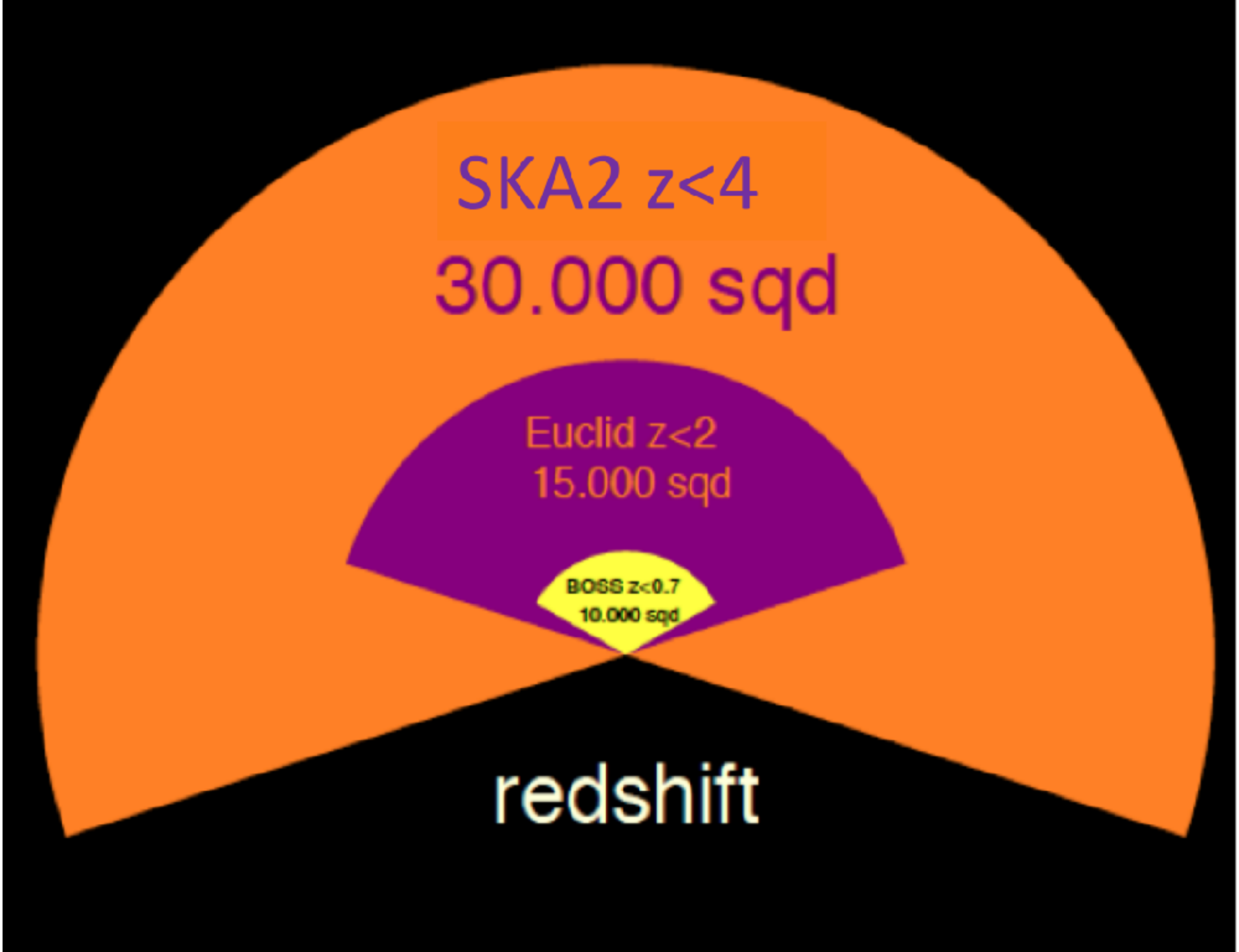
- Note further that *numerical convergence of all quantities not fully achieved*.

Simulating intensity mapping signal: WDM



Carucci, Villaescusa, MV, Lapi 15

Probably able **to rule out a 4 keV WDM model** with 5000 hours of observations at z > 3, while a smaller mass of 3 keV, comparable to present day constraints, can be ruled out at more than 2 confidence level with 1000 hours of observations at z > 5 - Note that *density inside haloes poorly modelled.*


SKA2 z<4
30.000 sqd
Euclid z<2
15.000 sqd
BOSS z<0.7
10.000 sqd
redshift

Measuring the ISW effect

Measuring ISW with next-generation radio surveys

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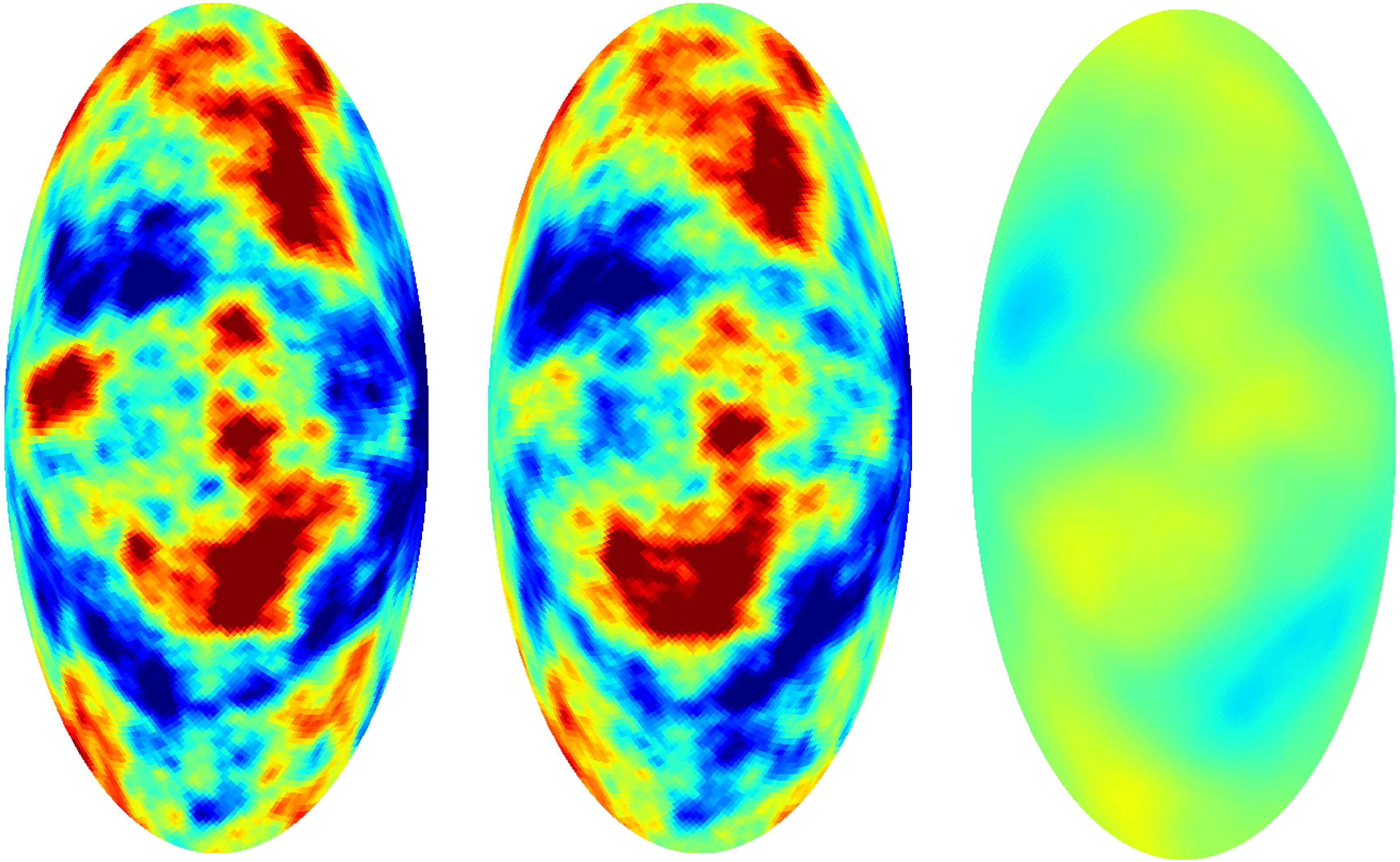
[3]Institute of Cosmology & Gravitation, University of Portsmouth, Portsmouth PO1 3FX, UK



Example of the reconstruction procedure applied to simulations data. The left panel shows the input ISW map, the central panel shows the recovered ISW estimate using CMB temperature in combination with SKA1 continuum survey (S_{cut} = 22 μJy), and the right panel shows the recovered ISW estimate using CMB temperature alone.

Probing GR at the largest scales

LIGER: mock relativistic light-cones from Newtonian simulations

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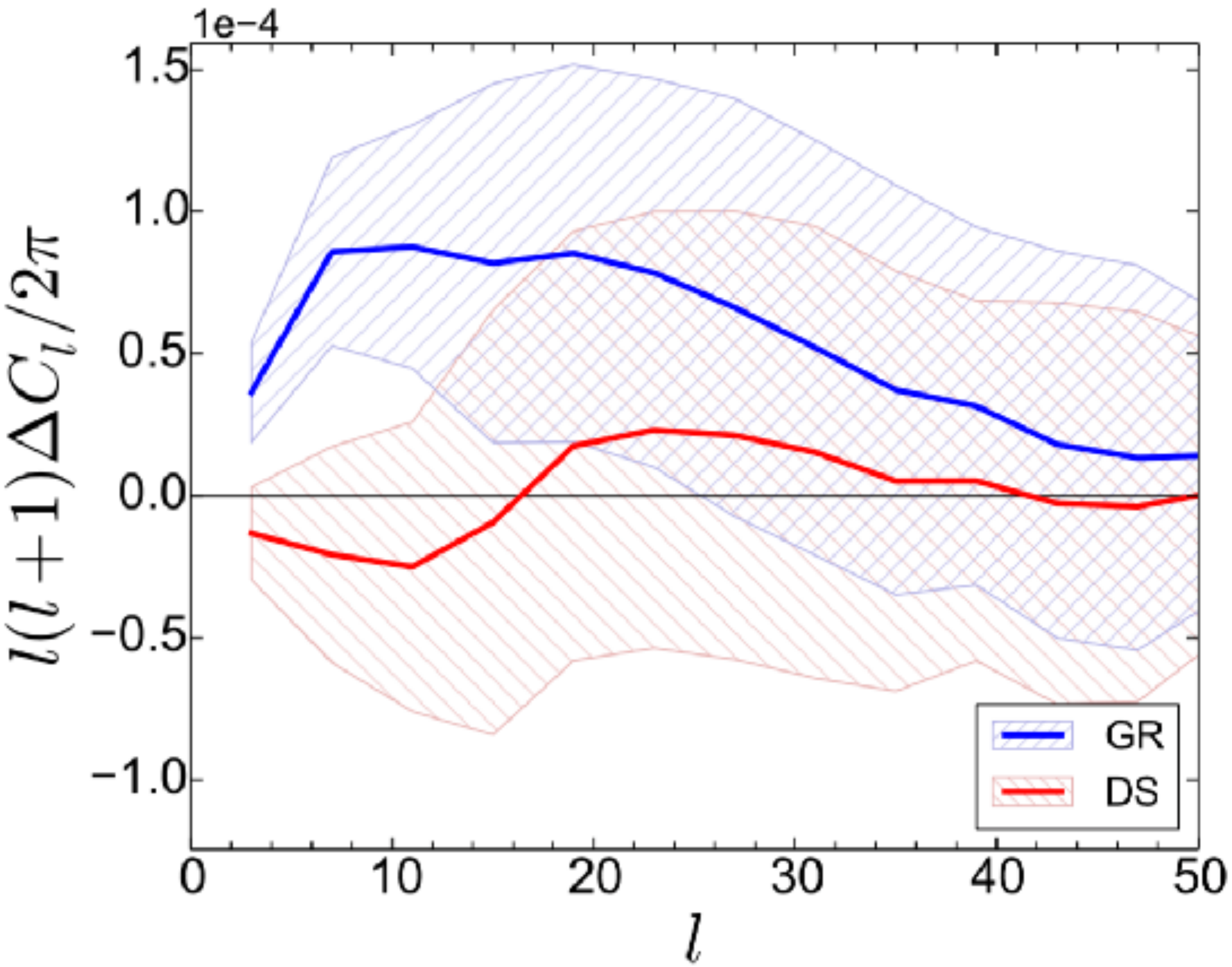
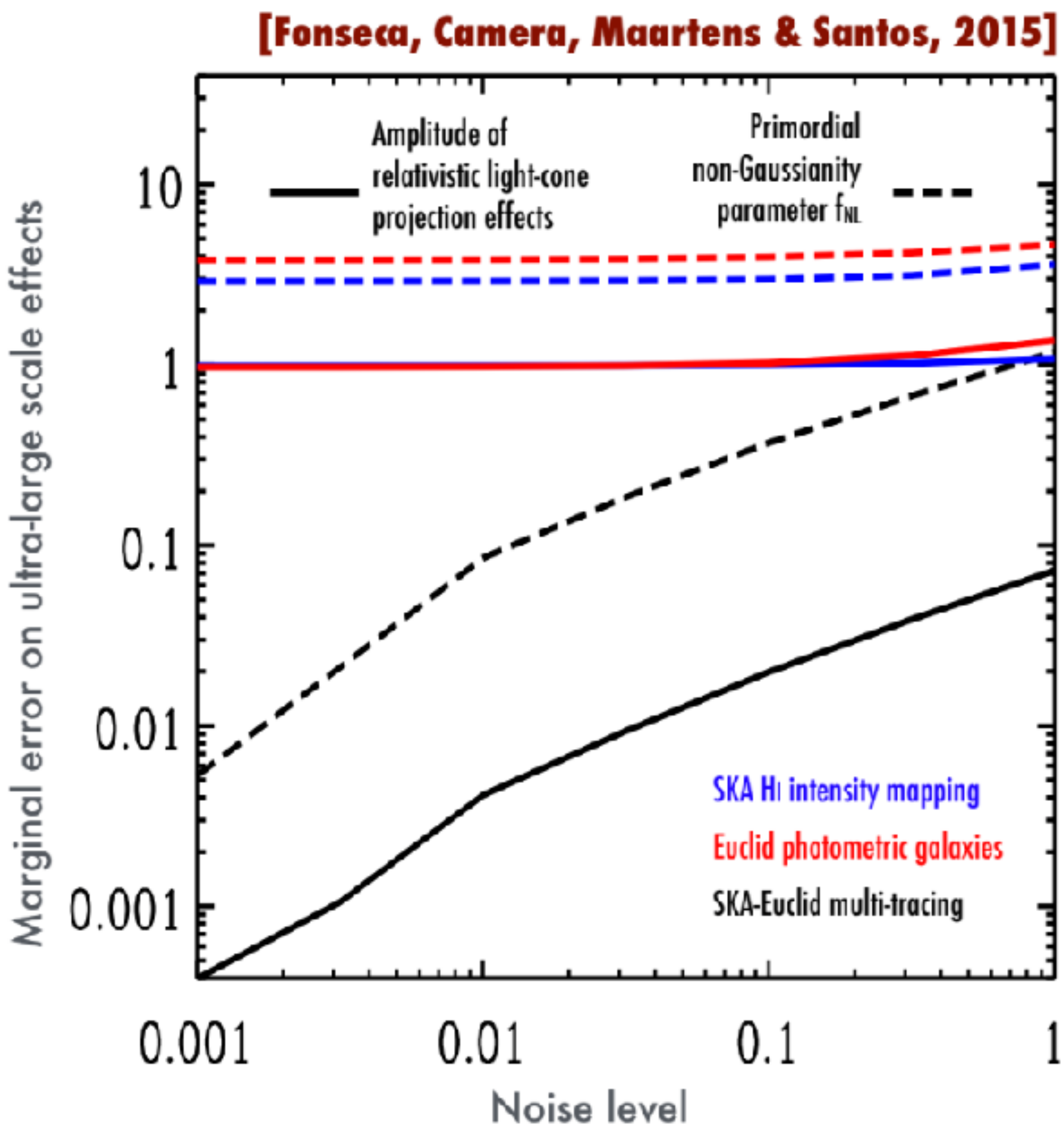
Argelander-Institut für Astronomie, Auf dem Hügel 71, D-53121 Bonn, Germany



SKA2 should be able to detect the non-standard Doppler contribution to galaxy clustering.

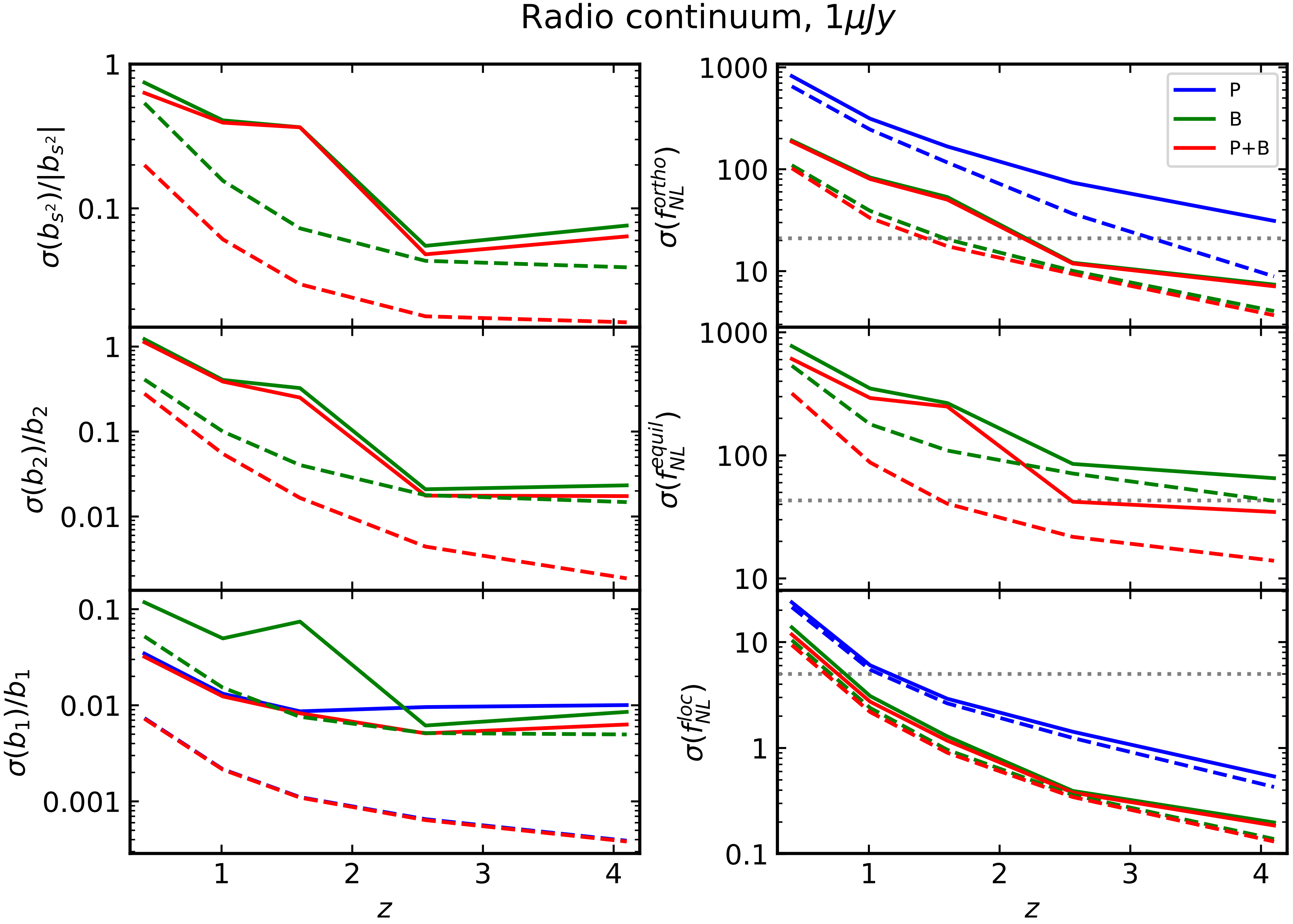
Multi-tracing techniques



Non-Gaussianity

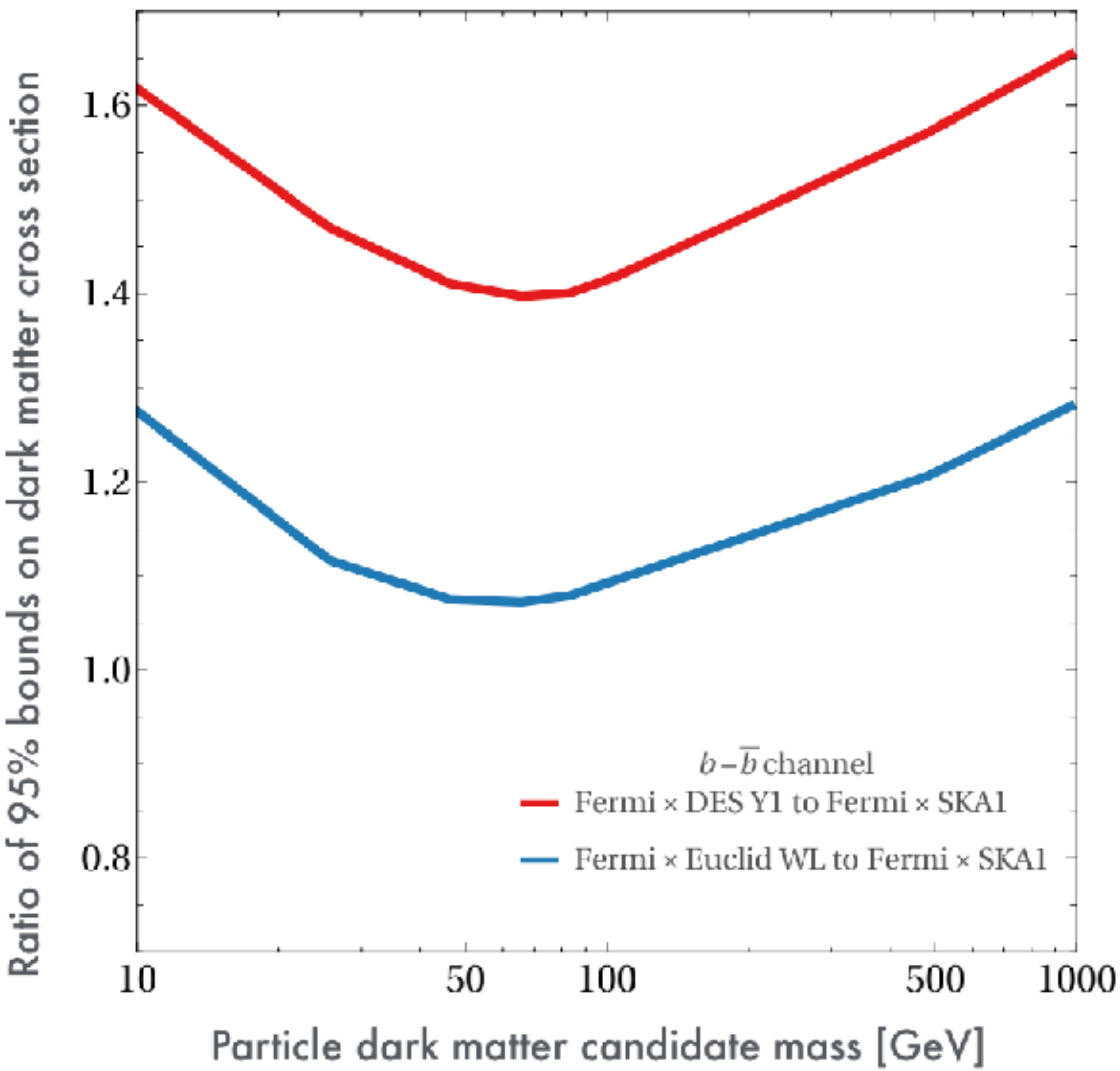
Constraining Primordial non-Gaussianity with Bispectrum and Power Spectrum from Upcoming Optical and Radio Surveys

Dionysios Karagiannis[1*], Andrei Lazanu[2], Michele Liguori[1,2,3], Alvise Raccanelli[4,5†], Nicola Bartolo[1,2,3], Licia Verde[4,6]



Particle DM searches

[SKA1 Red Book 2018 (Bacon, Camera et al.), 2018]



radio data is expected to correlate with the gamma-ray sky and can be exploited to filter out the information concerning the composition of the gamma-ray background contained in maps of the unresolved gamma-ray emission.

SKA HI galaxies are at low-z and with low shot-noise level, in a regime heavily dominated by astrophysics (spectroscopy is important to get a precise window/filter function).