Multi-Wavelength Synergies *with* Radio Surveys

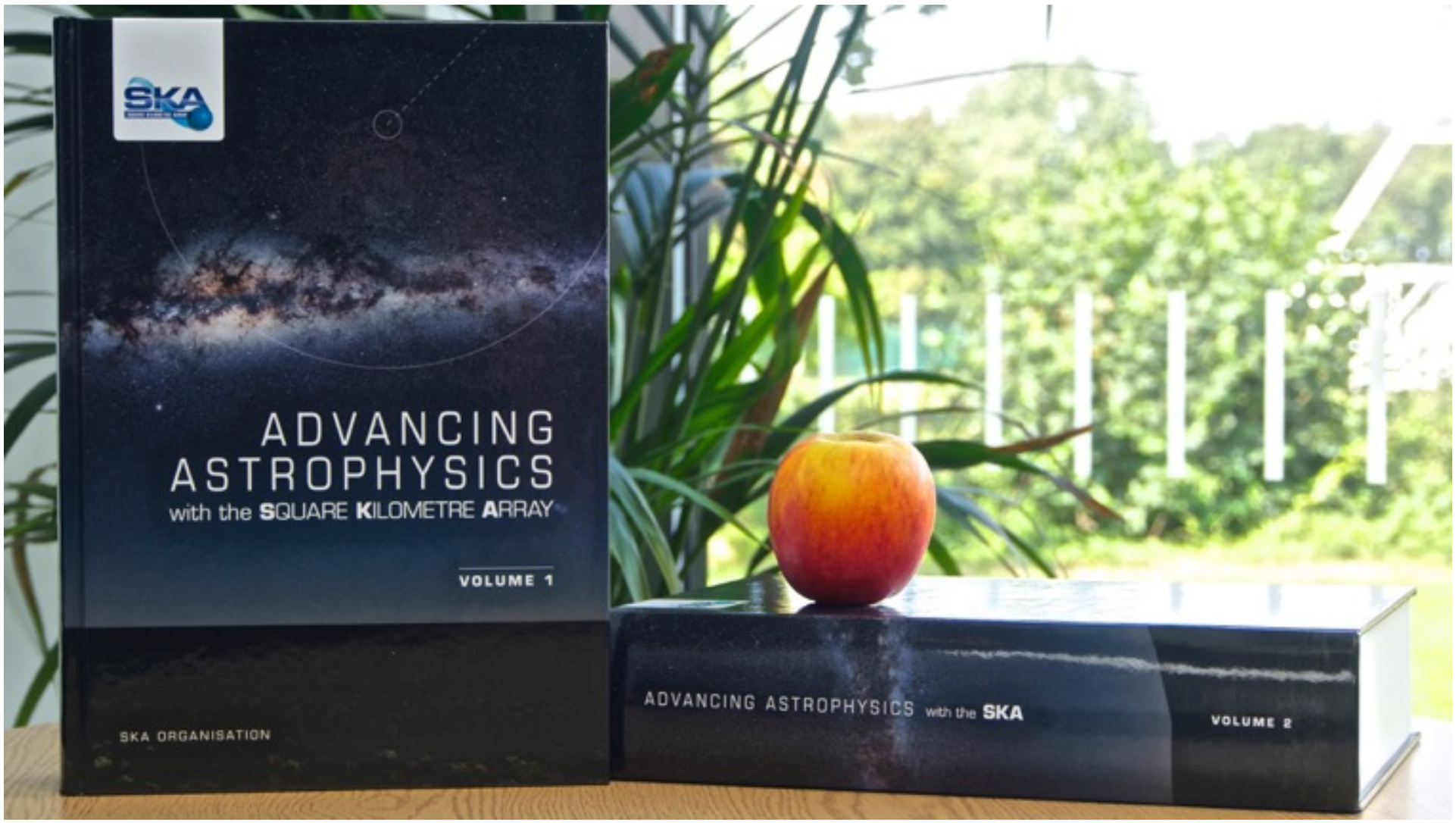
Stefano Camera

The University of Manchester

Jodrell Bank Centre for Astrophysics, The University of Manchester, UK

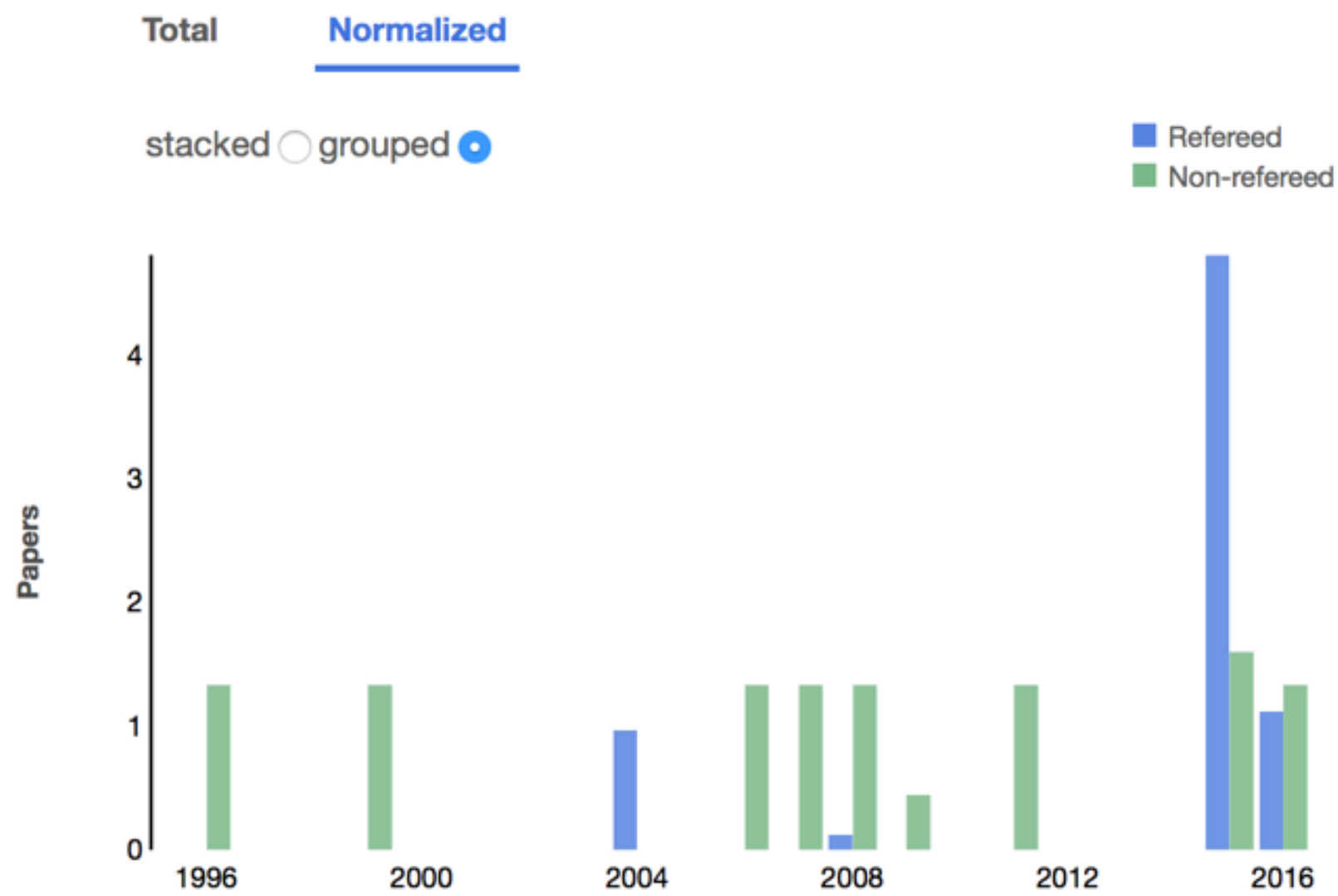
SKA *for* Cosmology

- Two years after AASKA @ Giardini Naxos, Sicily



SKA *for* COSMOLOGY

- Search for 'Square Kilometre Array cosmology' on ADS



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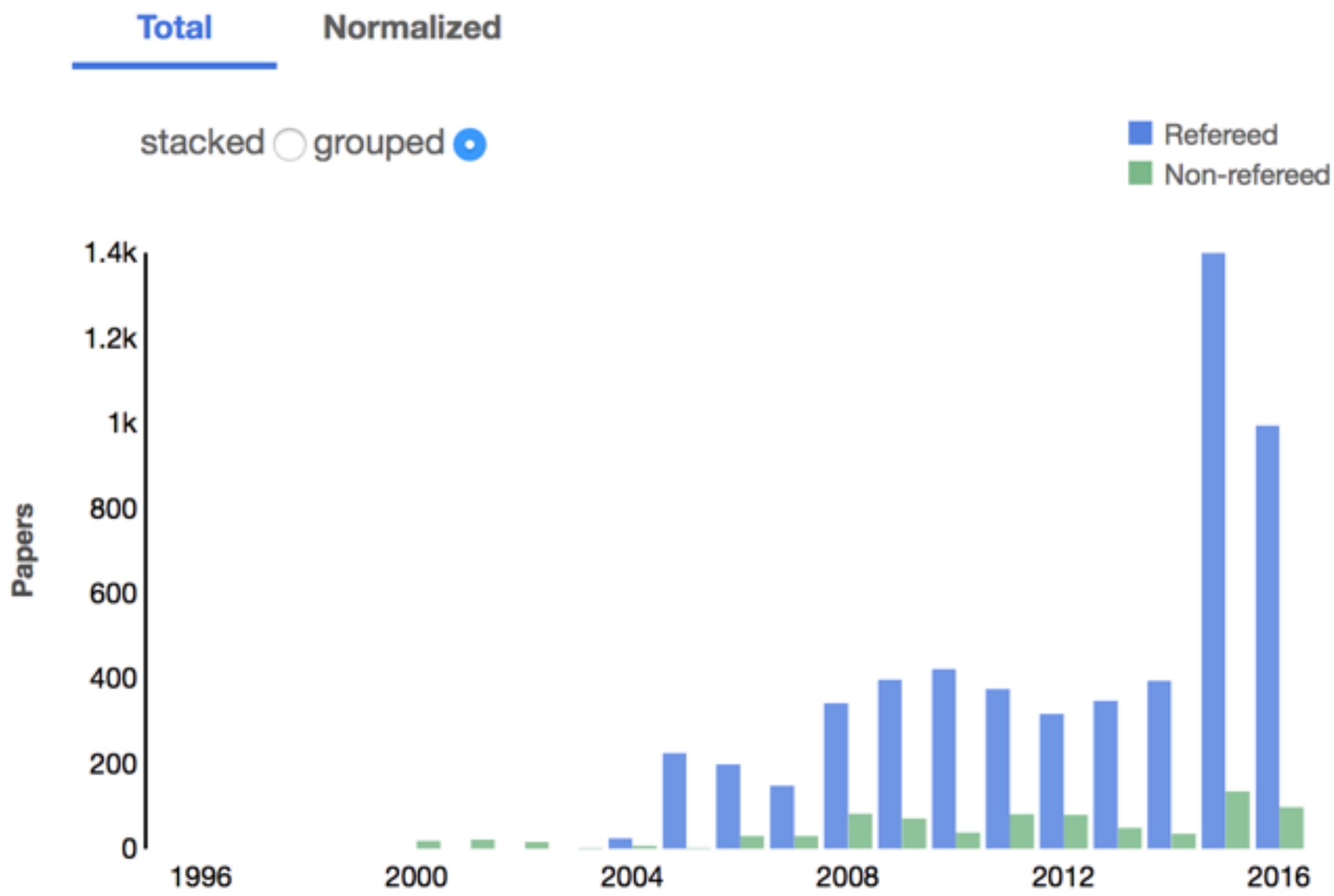

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SKA *for* Cosmology

- Angular power spectra of cosmological observables

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  - Density perturbations

$$\delta(t, \mathbf{x})$$

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$$\langle \hat{\delta}_{\mathbf{k}}(z) \hat{\delta}^{\star}_{\mathbf{k}'}(z) \rangle = \delta_D(\mathbf{k} - \mathbf{k}') P^{\delta}(k, z)$$

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- Angular power spectrum of observable *X*

$$C_\ell^X = \int \mathrm{d}\chi \left[\frac{W^X(\chi)}{\chi^2} \right]^2 P^\delta \left[\frac{\ell}{\chi}, z(\chi) \right]$$

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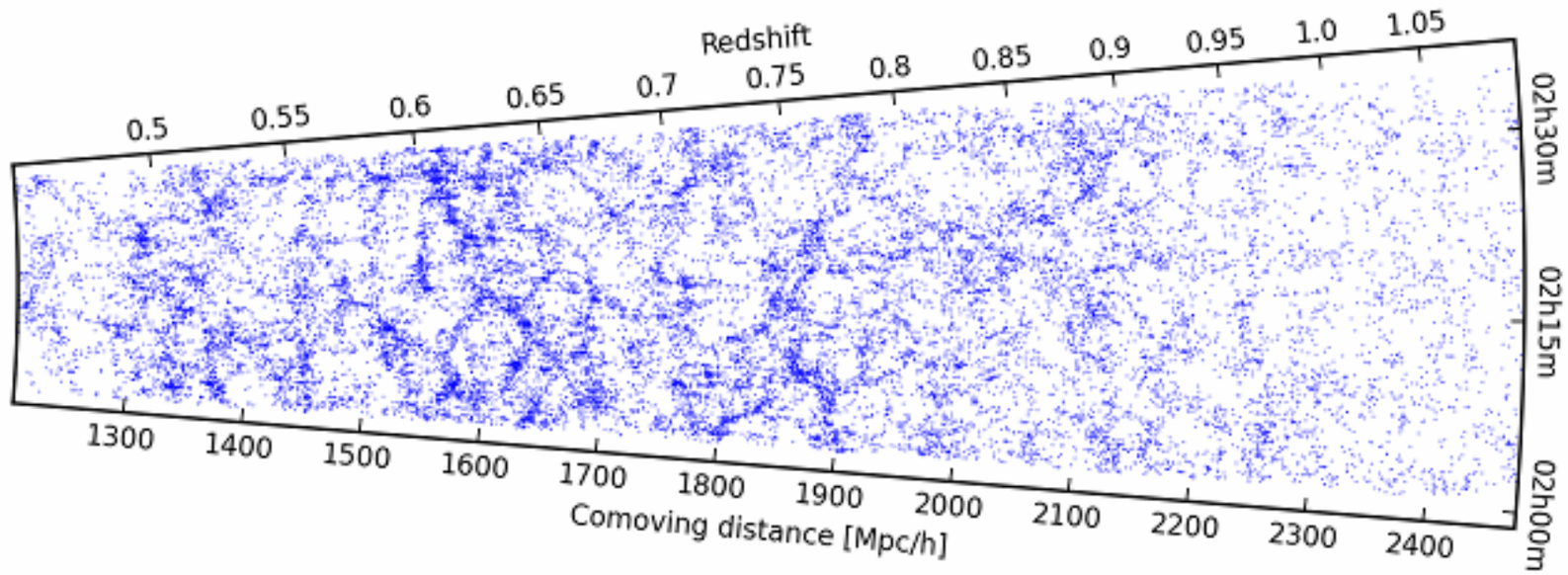
Galaxy Number Counts



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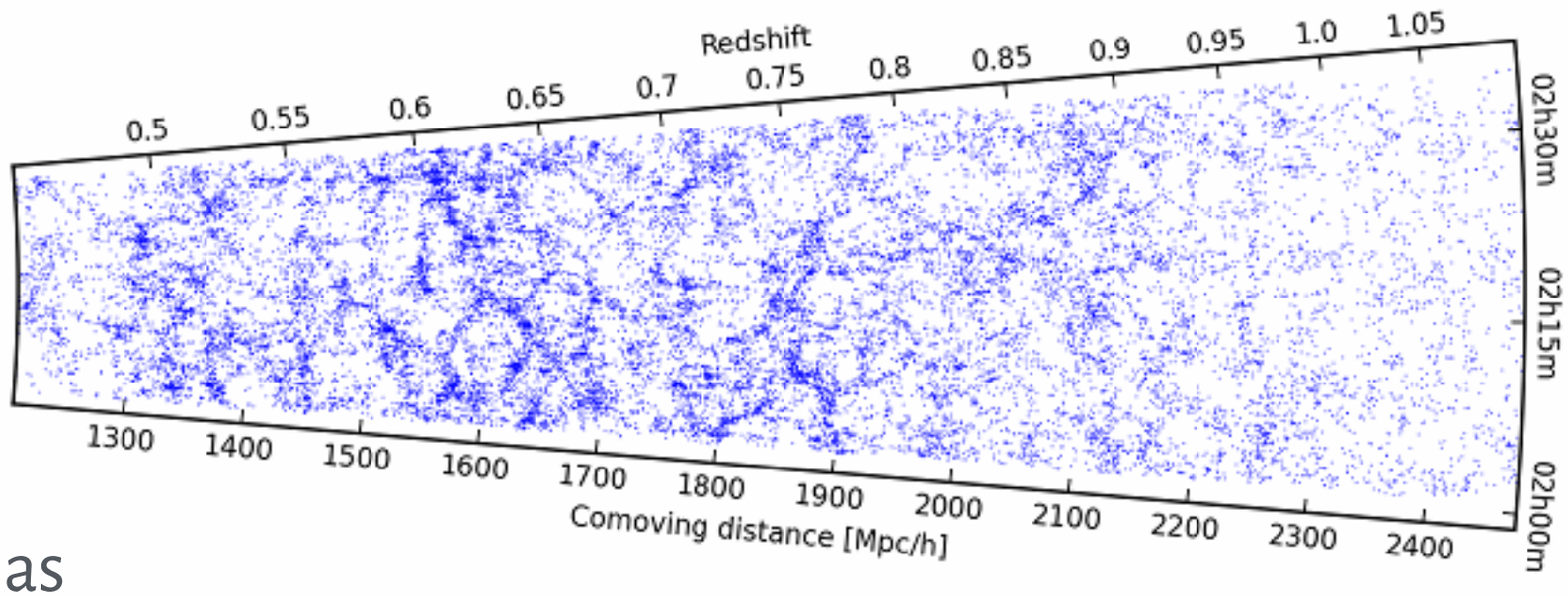

- Galaxy bias
- Redshift-space distortions

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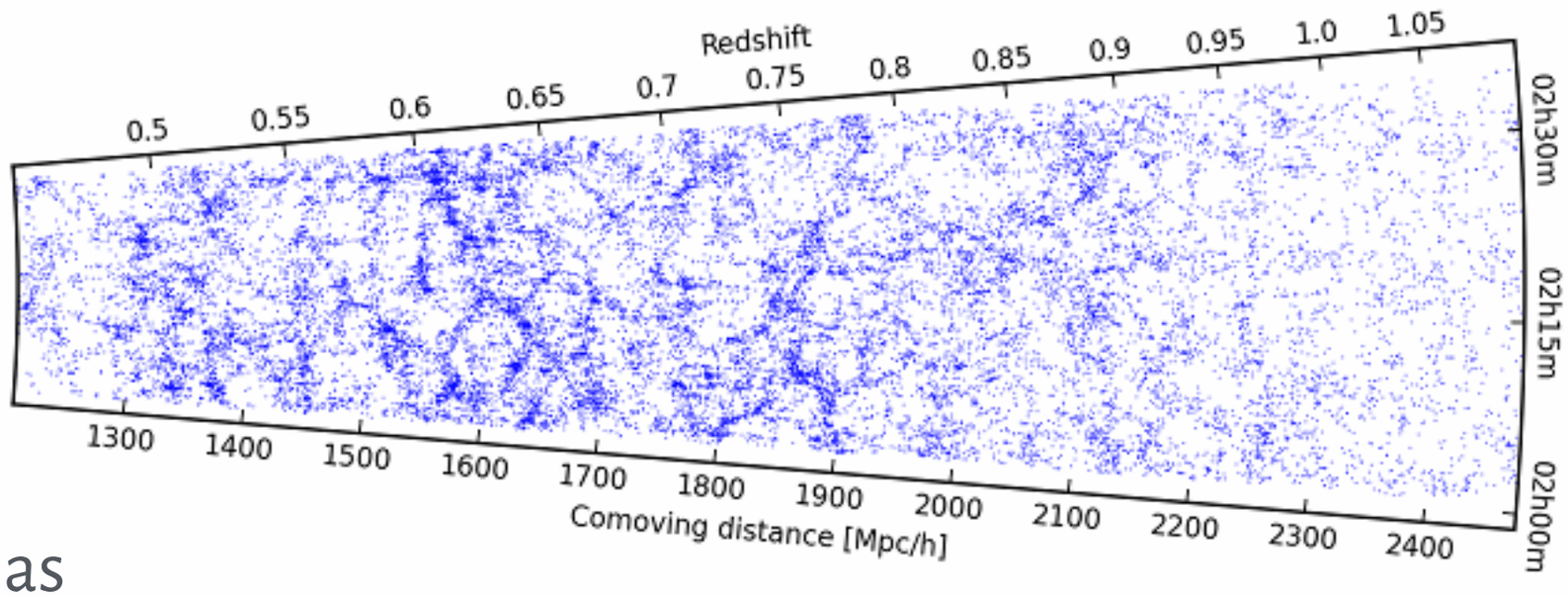

- Galaxy bias
- Redshift-space distortions
- Lensing

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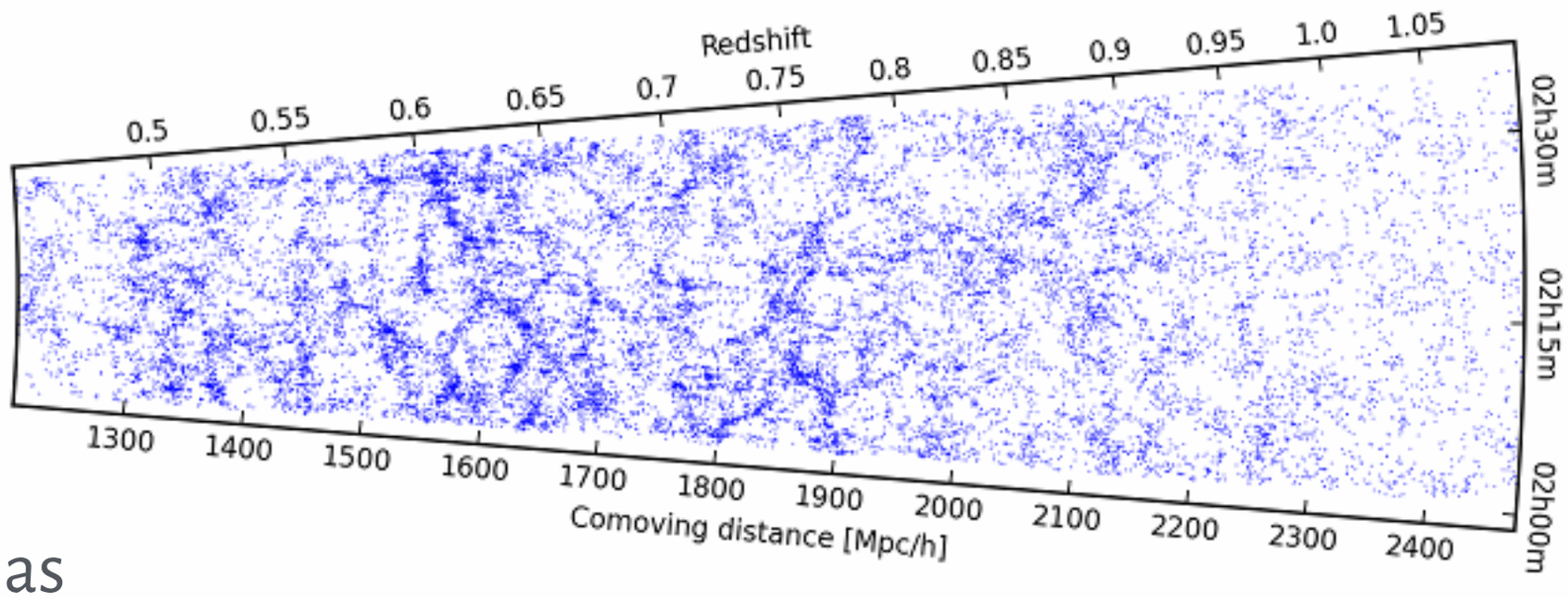
Galaxy Number Counts



- Galaxy bias
- Redshift-space distortions
- Lensing + relativist effects (e.g. gravitational redshift, SW/ISW, time delay)

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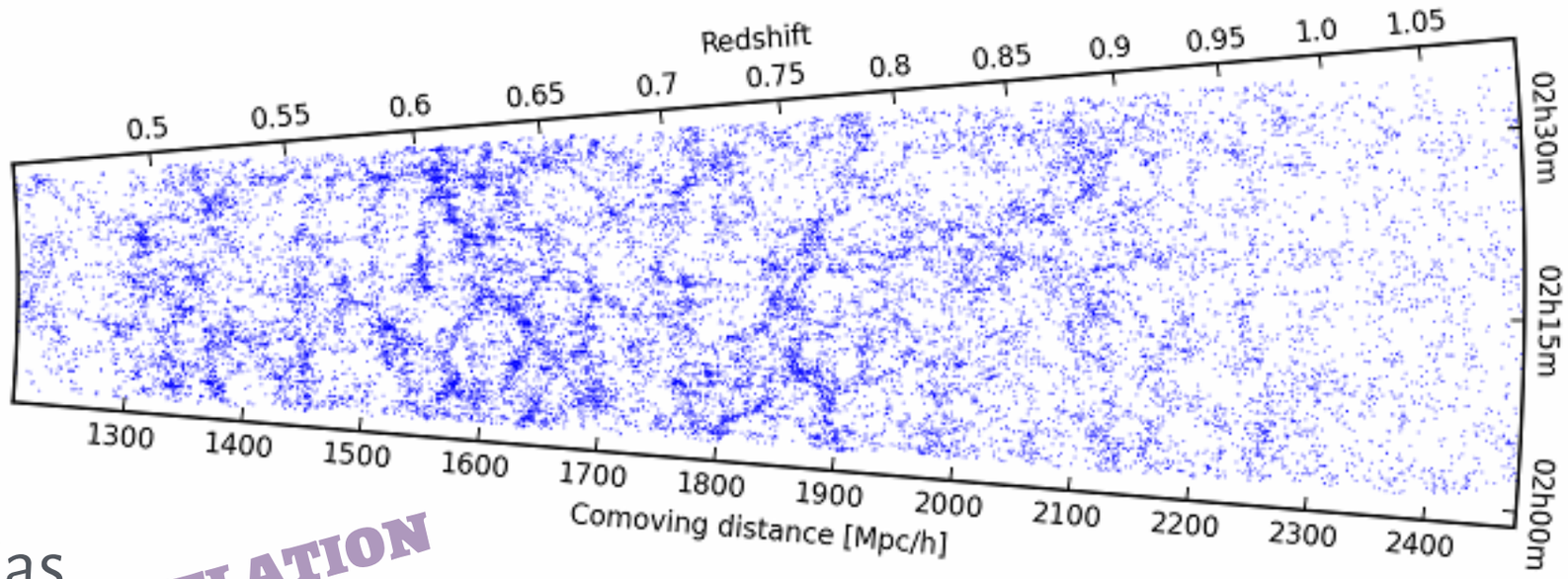

- Galaxy bias — INFLATION
- Redshift-space distortions — DARK ENERGY
- Lensing + relativist effects (e.g. gravitational redshift, SW/ISW, time delay) — GRAVITY

$$C_\ell^g = \int \mathrm{d}\chi \left[\frac{W^g(\chi)}{\chi}\right]^2 P^\delta\left[\frac{\ell}{\chi}, z(\chi)\right]$$

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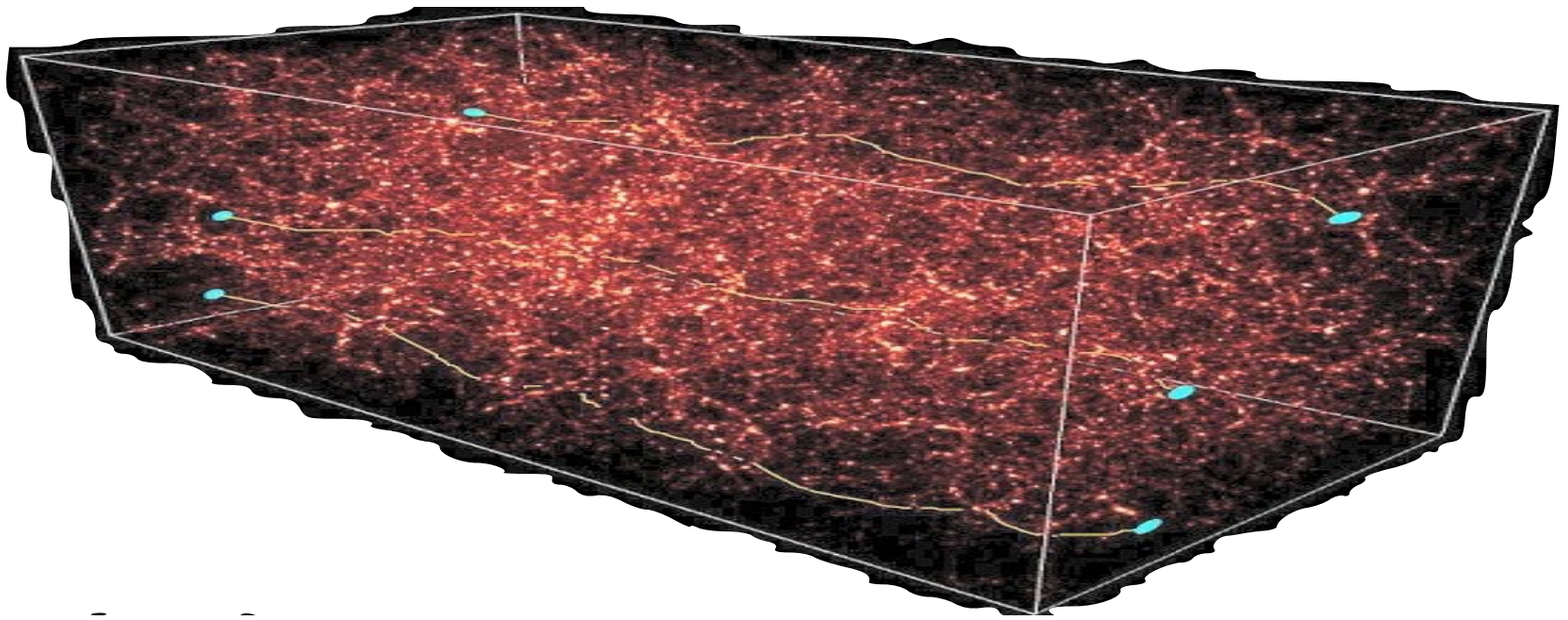
Cosmic Shear



$$C_\ell^\gamma = \int \mathrm{d}\chi \left[\frac{W^\gamma(\chi)}{\chi}\right]^2 P^\delta\left[\frac{\ell}{\chi}, z(\chi)\right]$$

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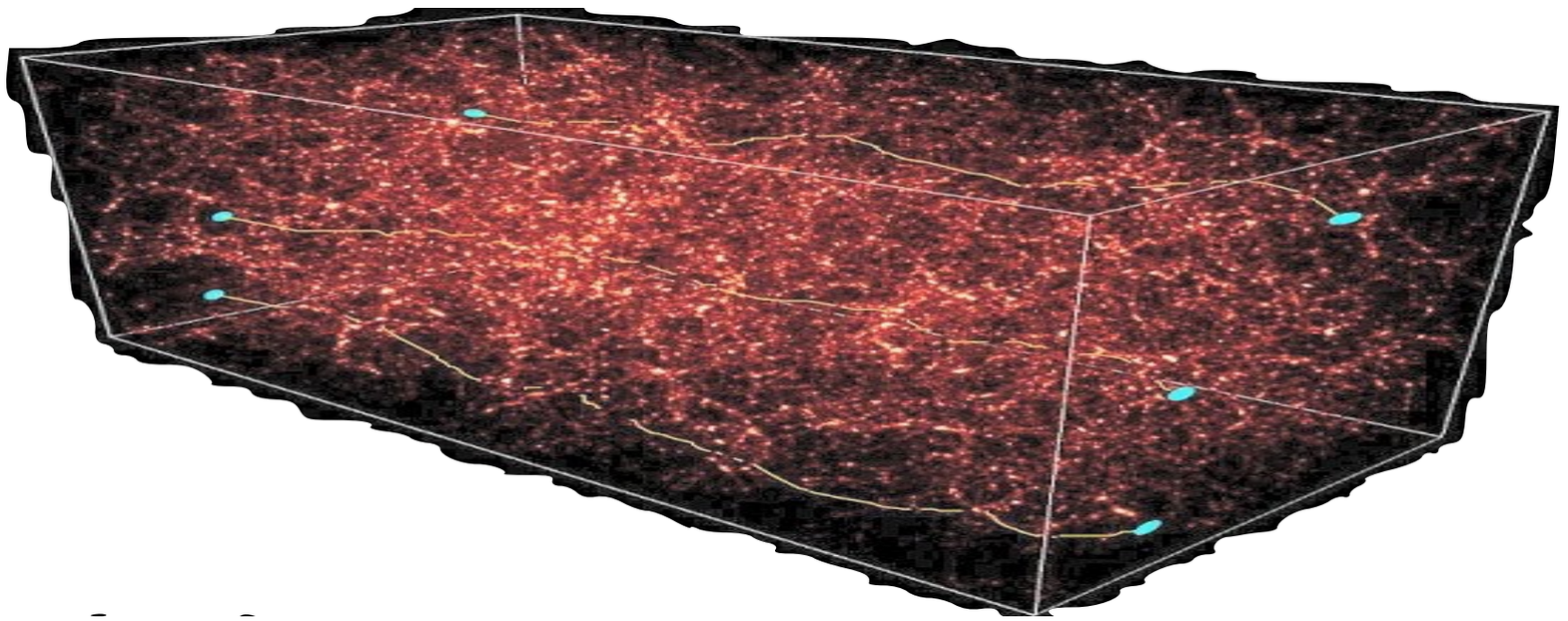

- Geometry of the Universe

- Poisson's equation

$$C_\ell^\gamma = \int \mathrm{d}\chi \left[\frac{W^\gamma(\chi)}{\chi}\right]^2 P^\delta\left[\frac{\ell}{\chi}, z(\chi)\right]$$

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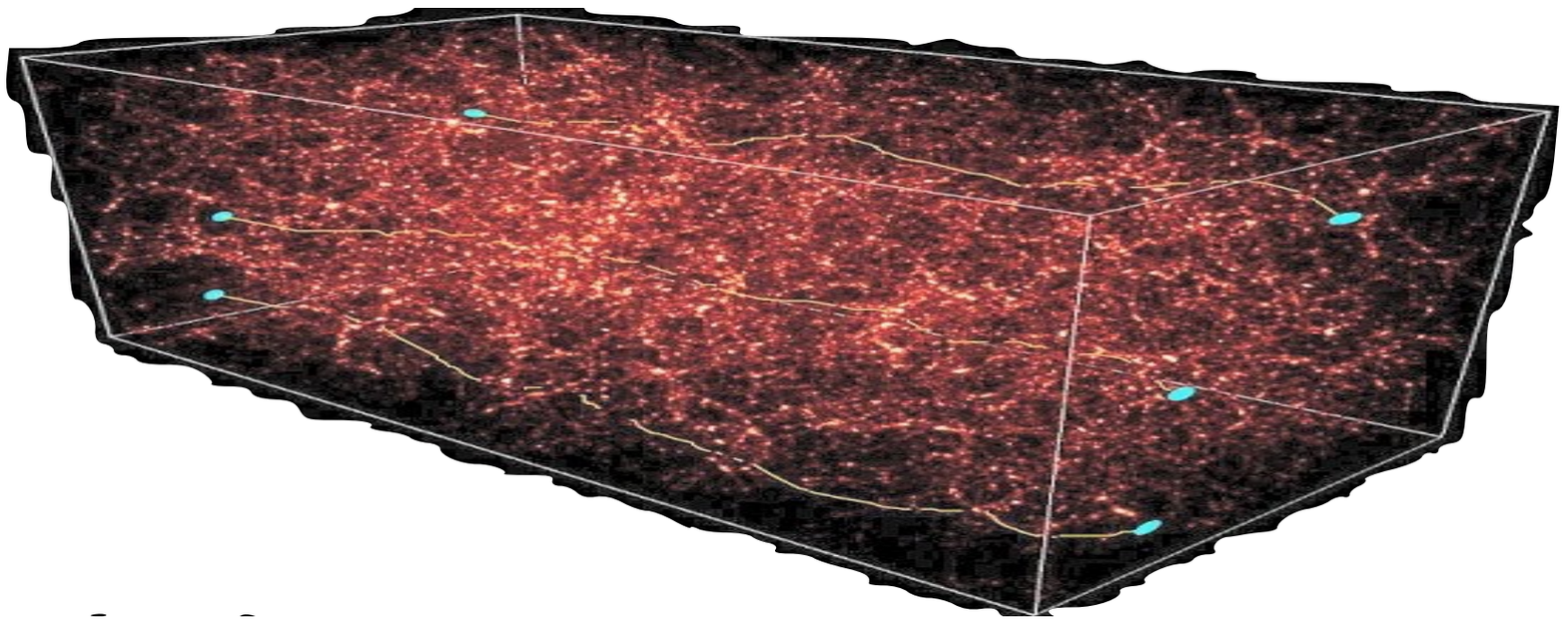
Cosmic Shear



- Geometry of the Universe **Dark energy**
- Poisson's equation **Modified gravity**

$$C_\ell^\gamma = \int \mathrm{d}\chi \left[\frac{W^\gamma(\chi)}{\chi}\right]^2 P^\delta\left[\frac{\ell}{\chi}, z(\chi)\right]$$

Synergies

- Cross-correlation angular power spectra

$$C_\ell^{XY} = \int \mathrm{d}\chi \frac{W^X(\chi) W^Y(\chi)}{\chi^2} P^\delta\left[\frac{\ell}{\chi}, z(\chi)\right]$$

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WHY?

Synergies

- Cross-correlation angular power spectra

$$C_\ell^{XY} = \int \mathrm{d}\chi \frac{W^X(\chi) W^Y(\chi)}{\chi^2} P^\delta\left[\frac{\ell}{\chi}, z(\chi)\right]$$

  - Measurement

$$\Delta C_\ell^X = \sqrt{\frac{2}{(2\ell+1) f_\mathrm{sky}}} \left(C_\ell^X + C_\ell^{X,\mathrm{sys}} + \mathcal{N}_\ell^X\right)$$

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Synergies

Definition of *synergy* in English:

synergy

Pronunciation: /ˈsɪnədʒi/

(also **synergism** /ˈsɪnədʒɪz(ə)m/)

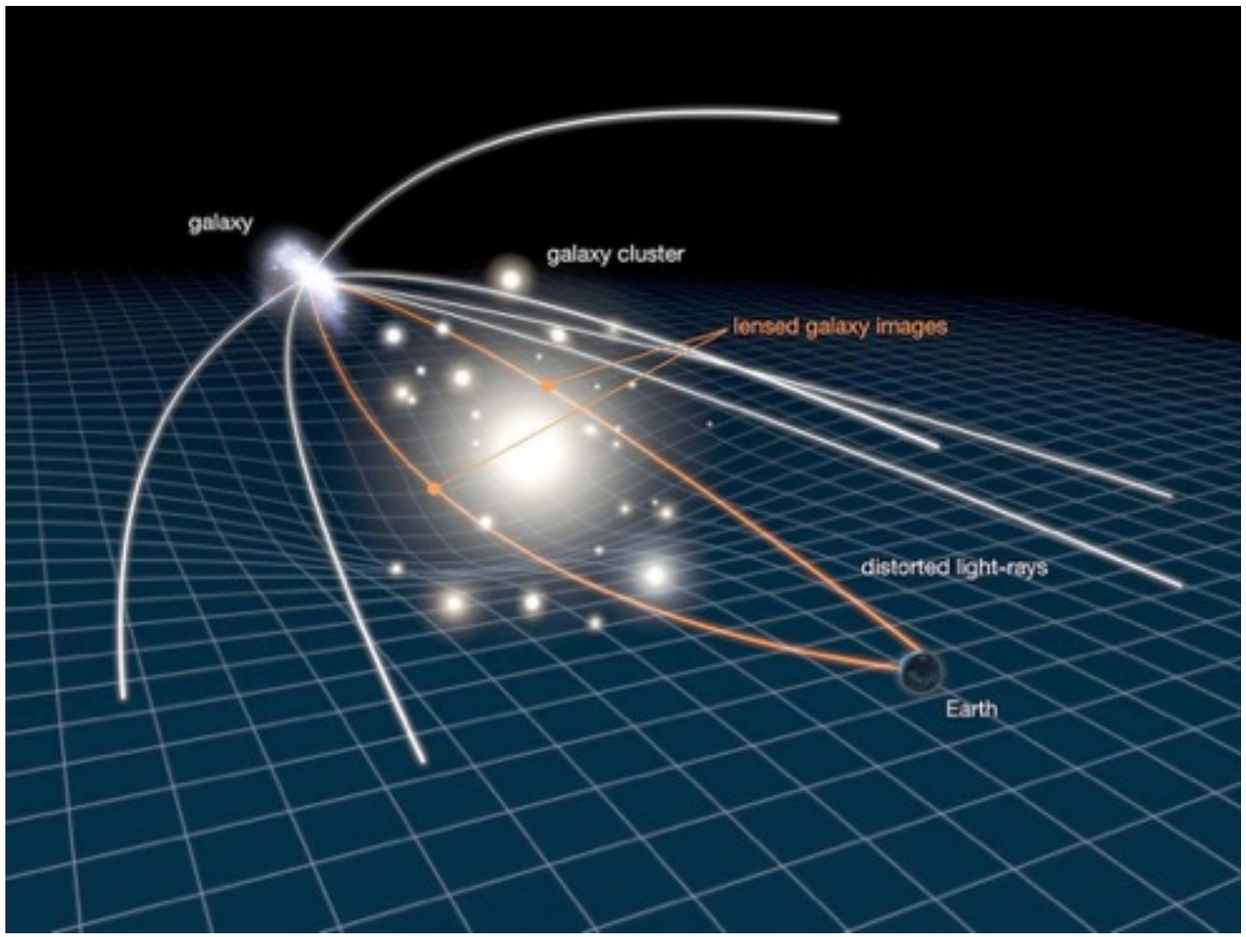
NOUN

[MASS NOUN]

The interaction or cooperation of two or more organizations, substances, or other agents to produce a combined effect greater than the sum of their separate effects:

Synergies *vs* Systematics

- Systematics in cosmic shear



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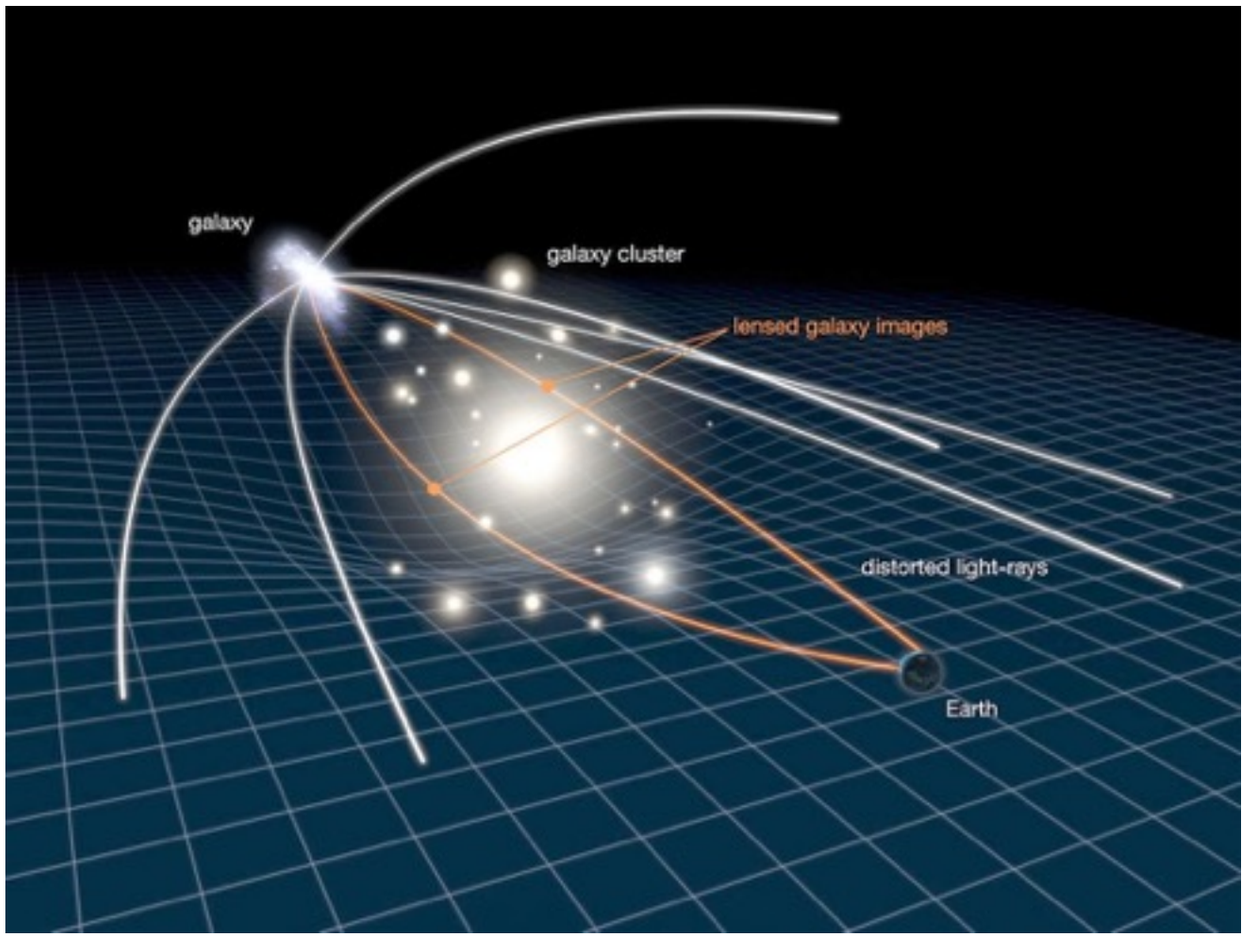

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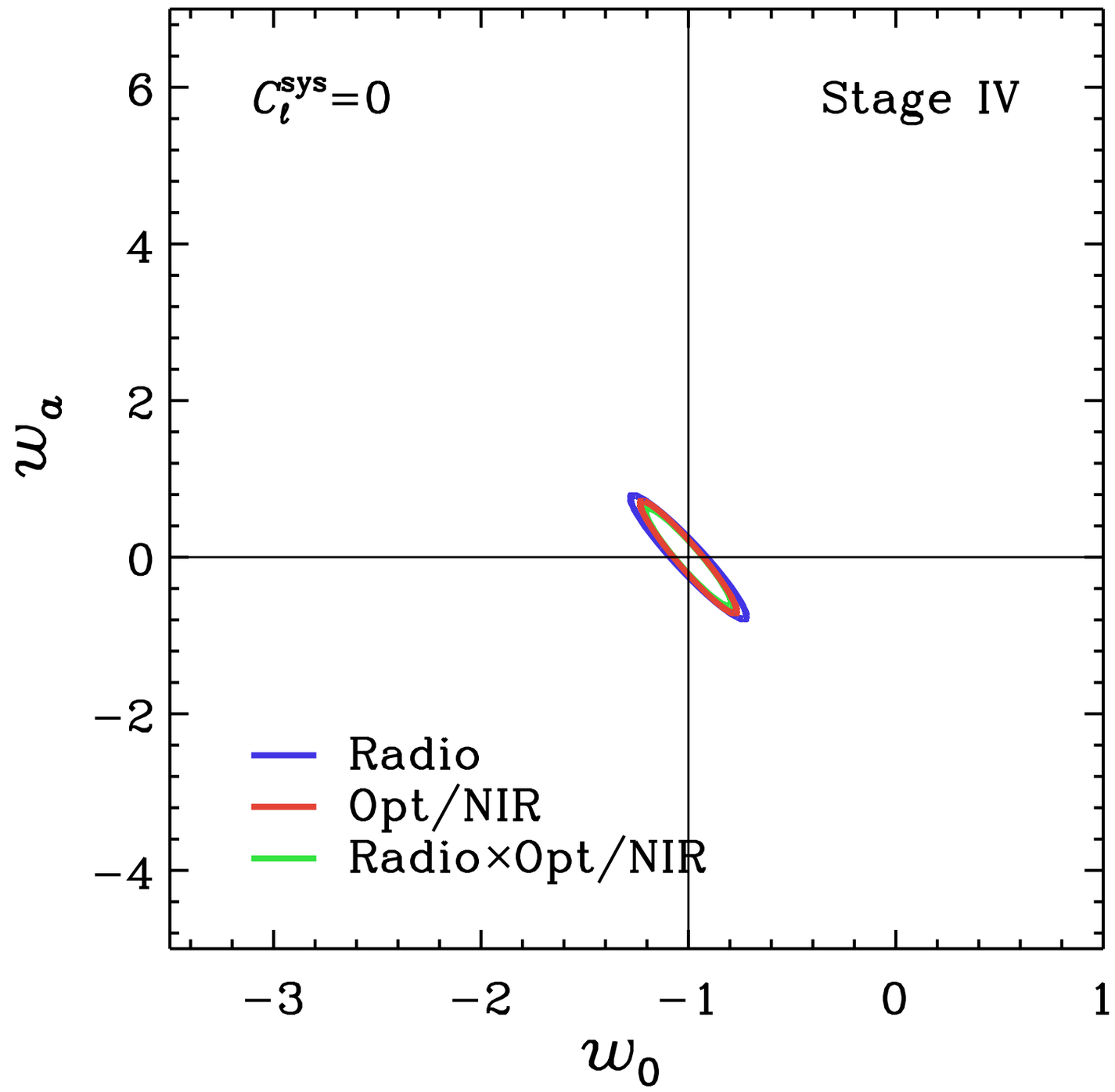
Synergies *vs* Systematics

[Harrison, SC, Bonaldi & Brown, 2016]



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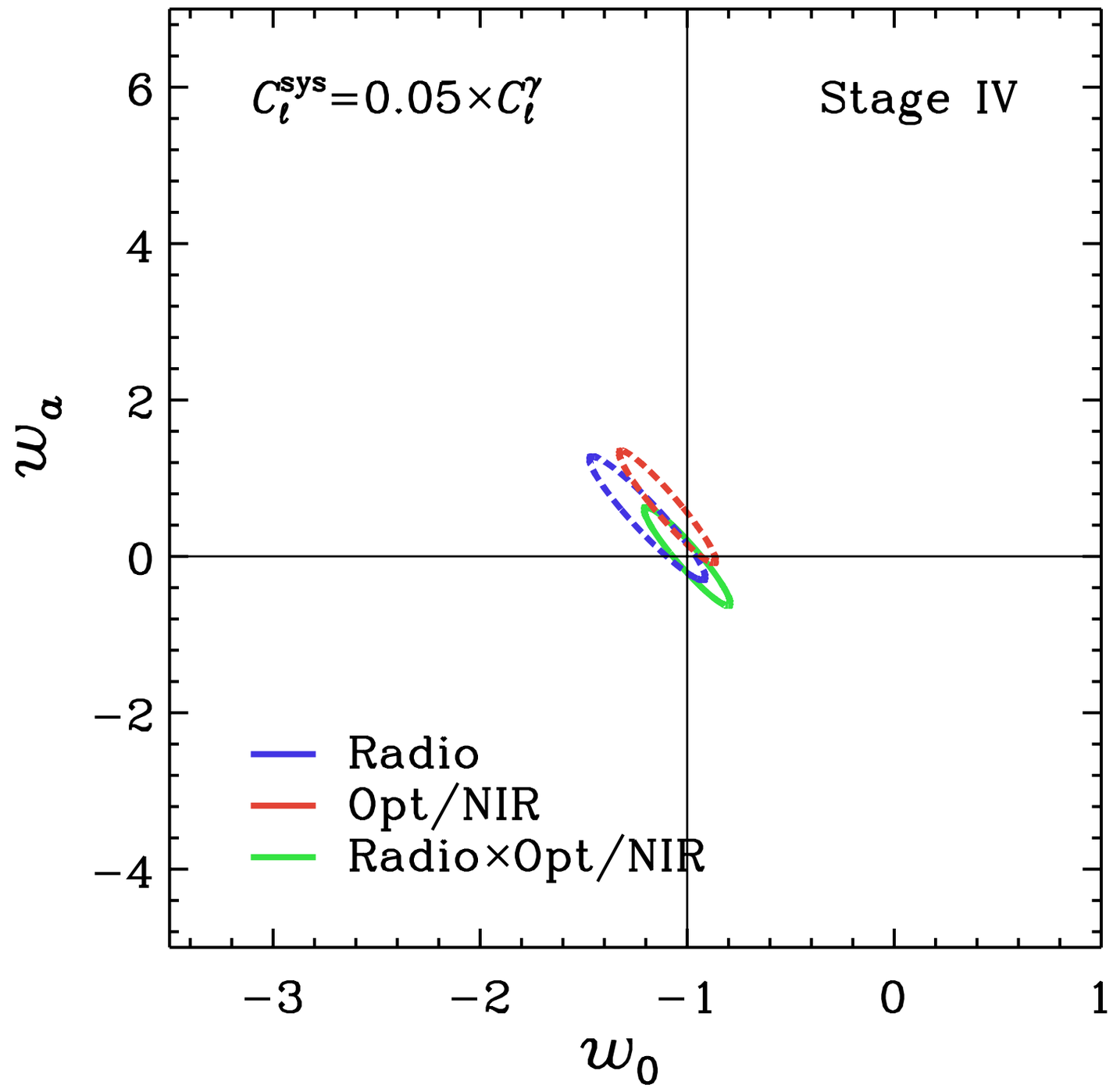

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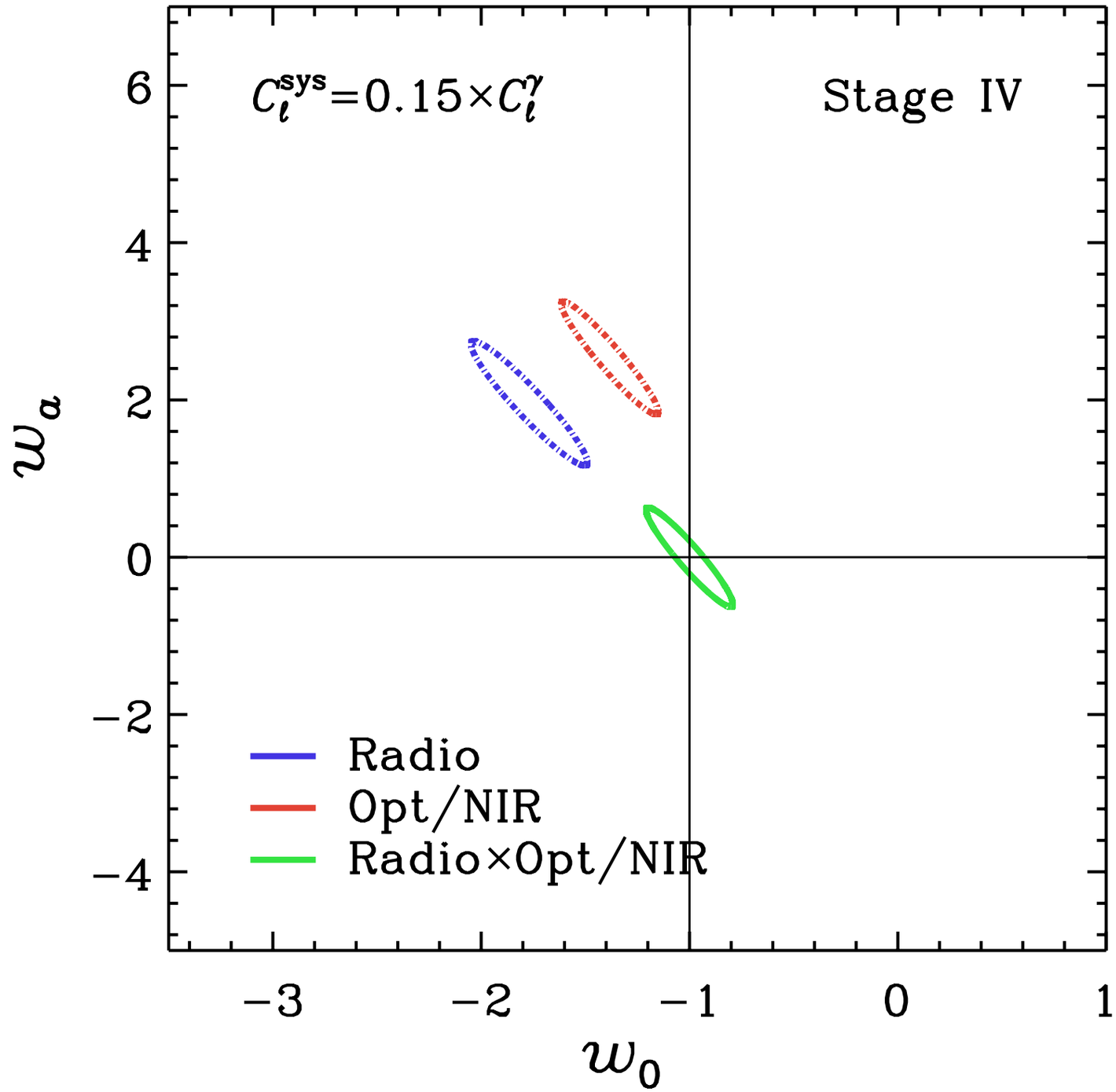

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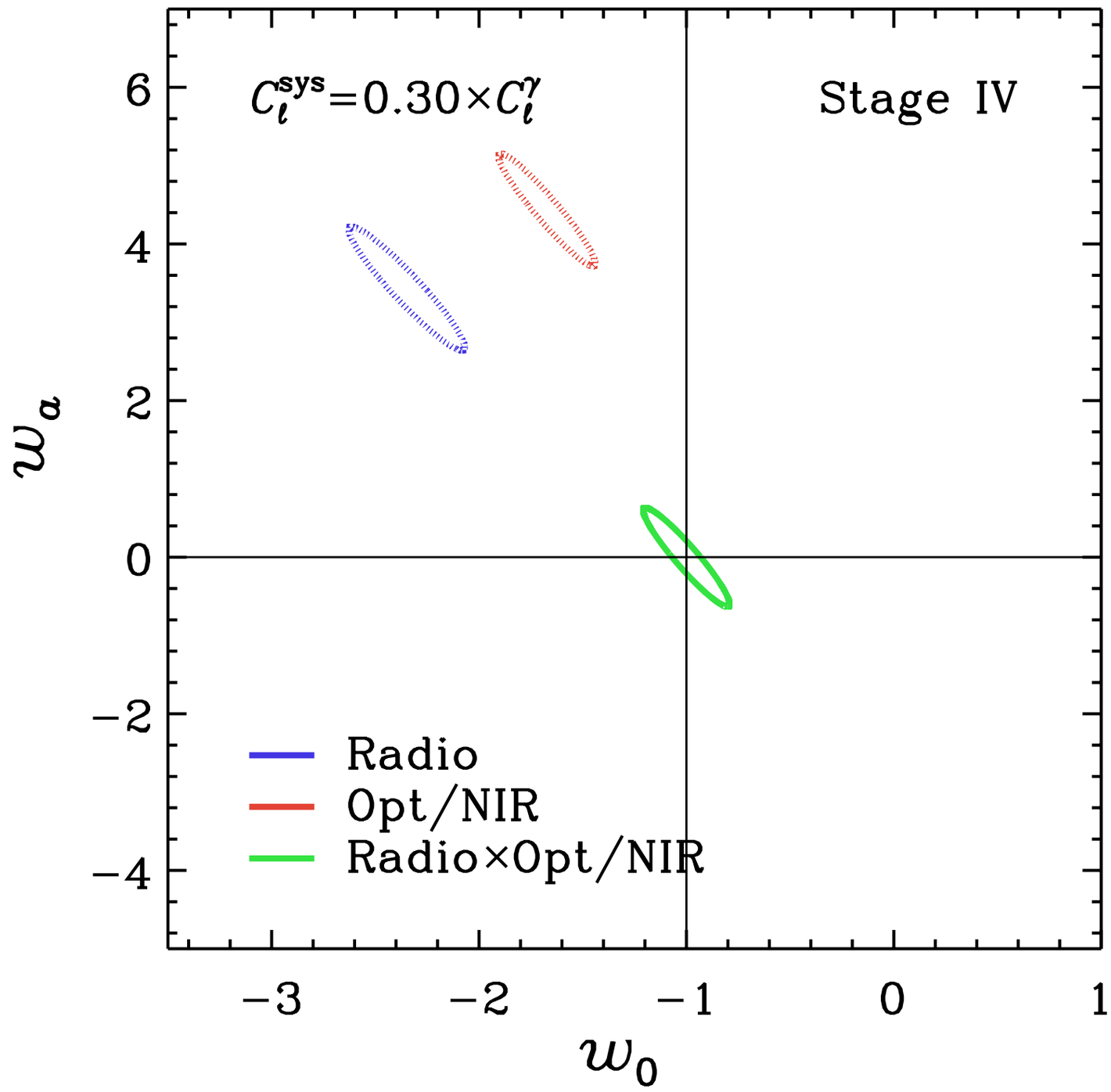

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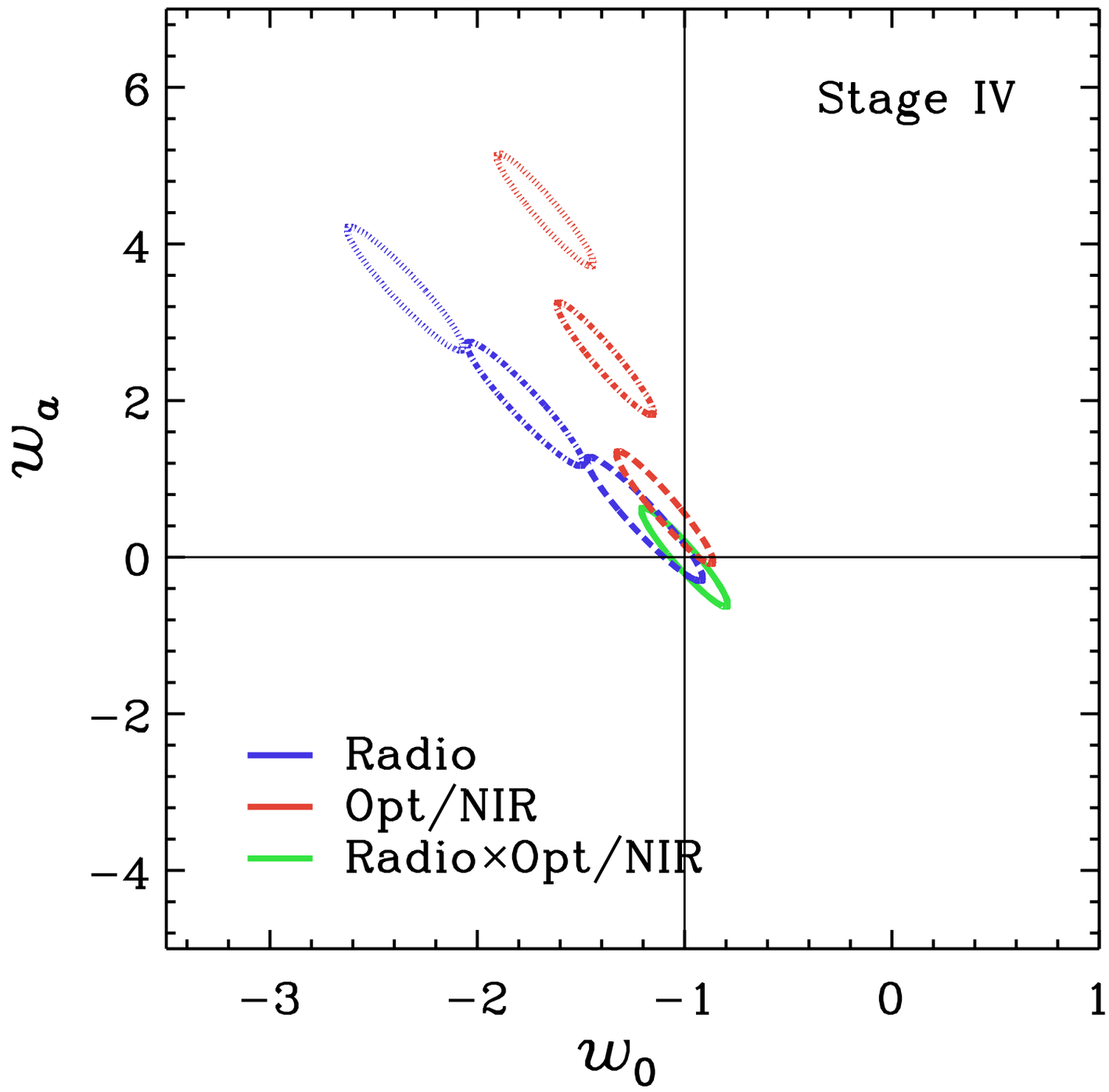

Synergies *vs* Cosmic Variance

- Cosmic variance hides relativistic effects and non-Gaussian signatures

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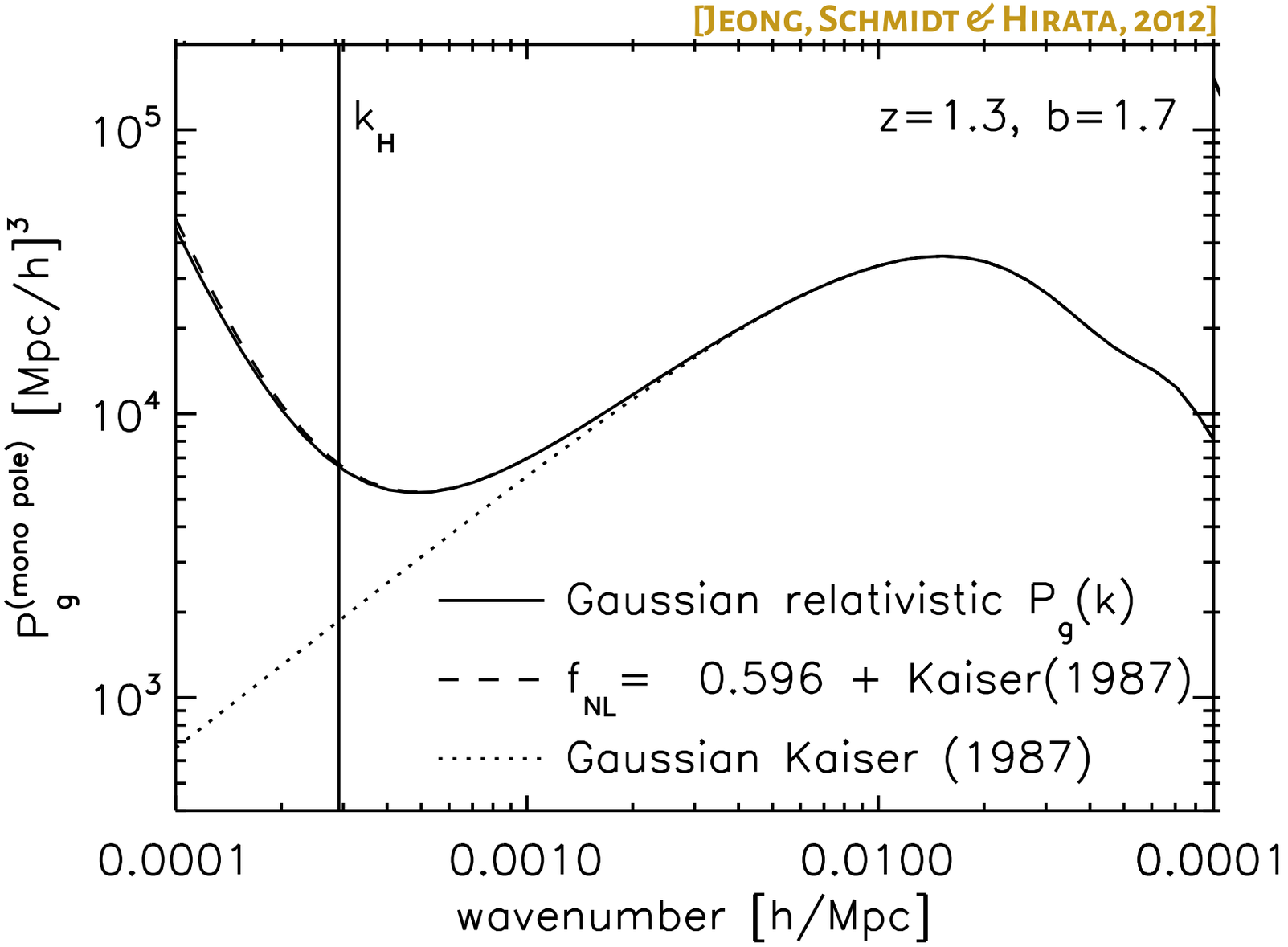
[JEONG, SCHMIDT & HIRATA, 2012]



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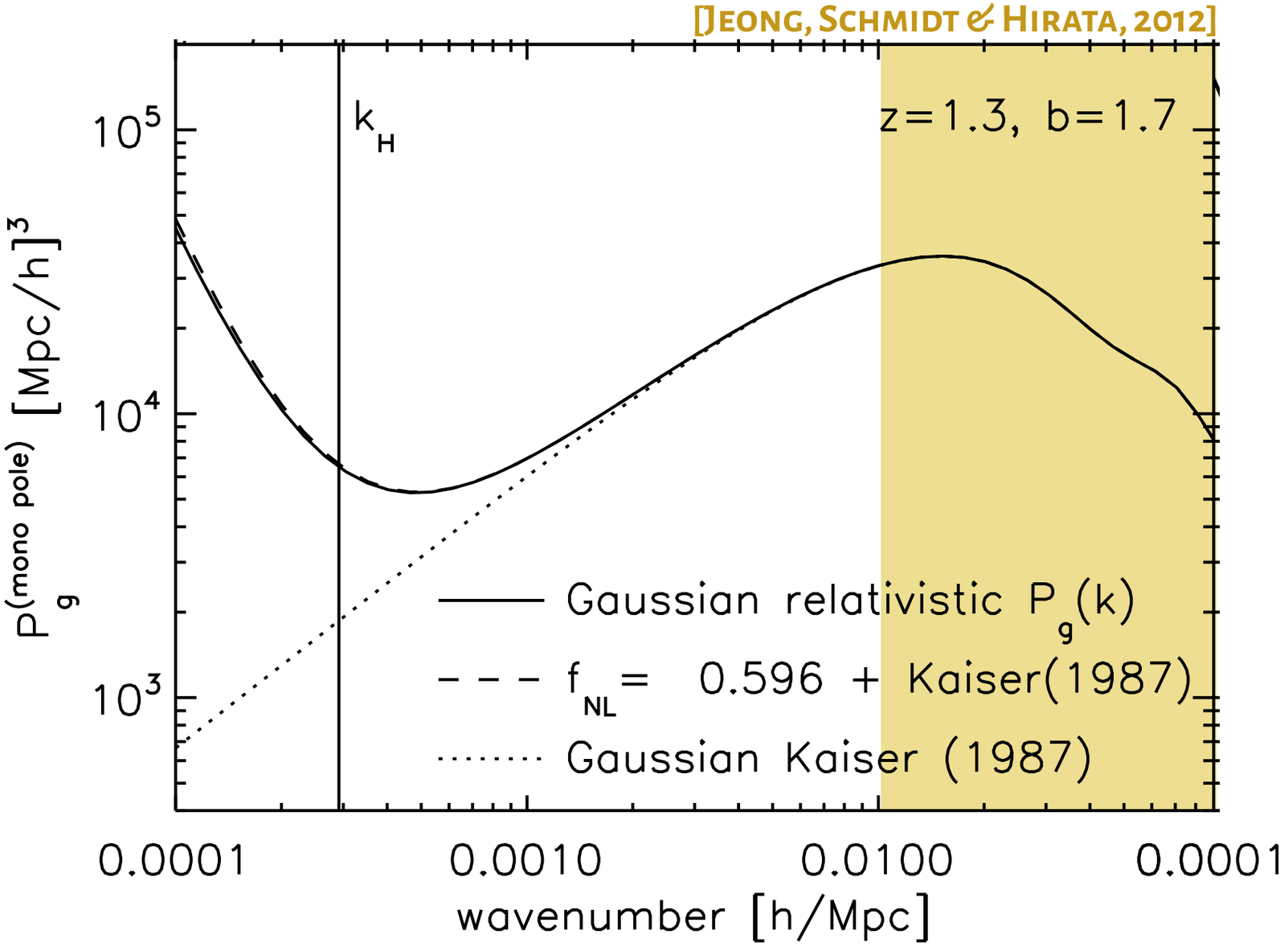

Synergies *vs* Cosmic Variance

- Multi-tracer cross-correlation to overcome cosmic variance

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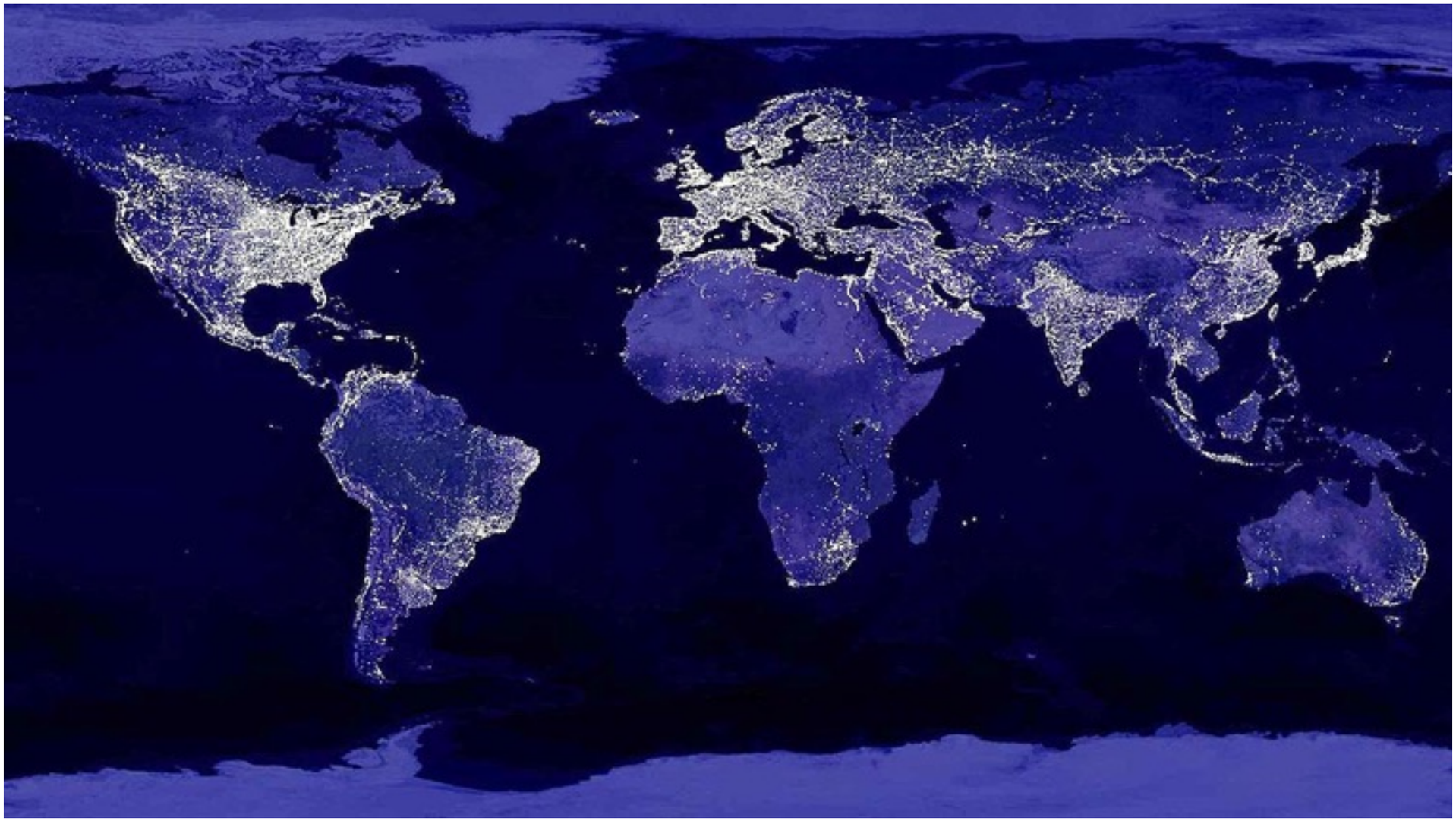

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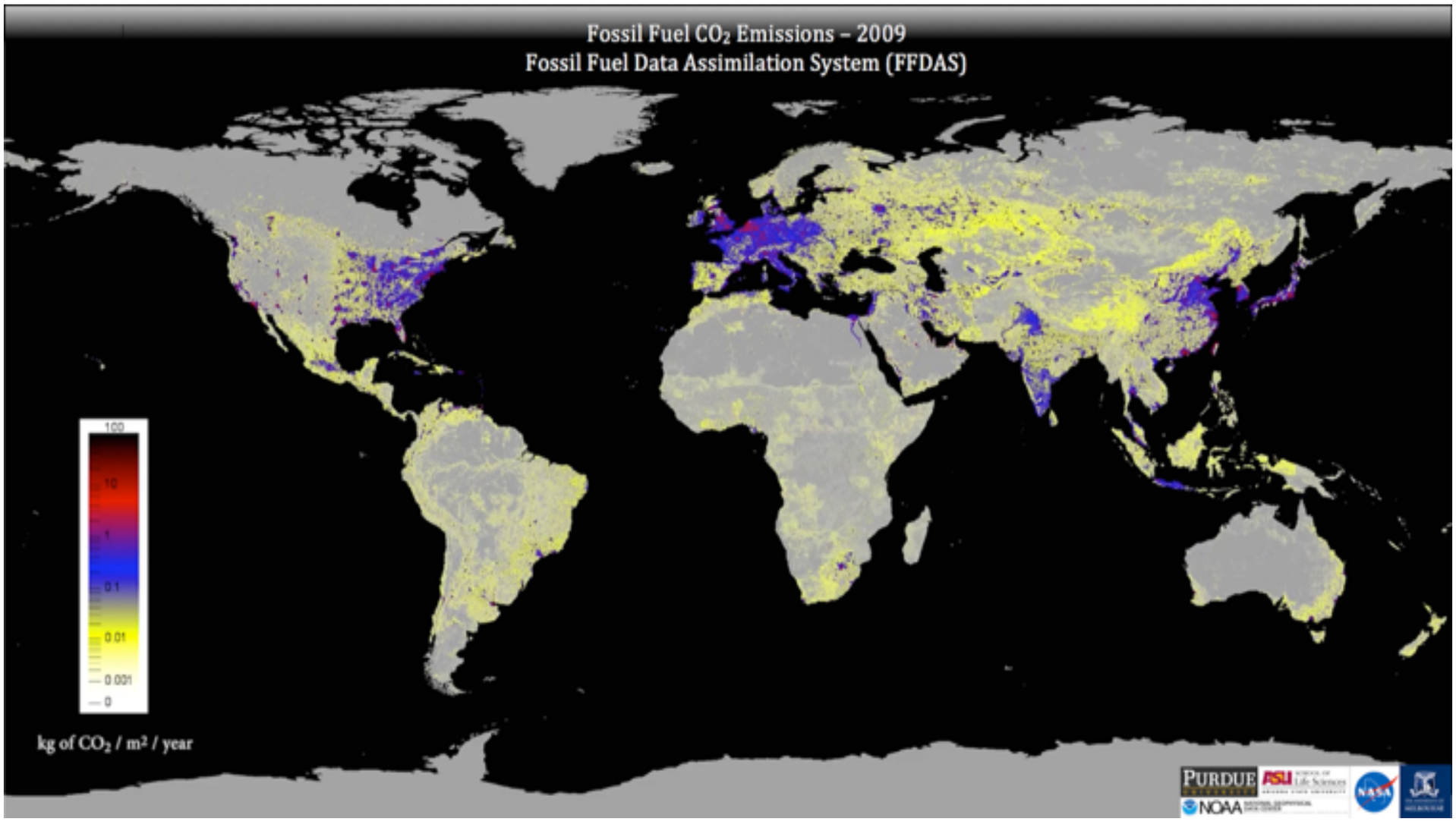

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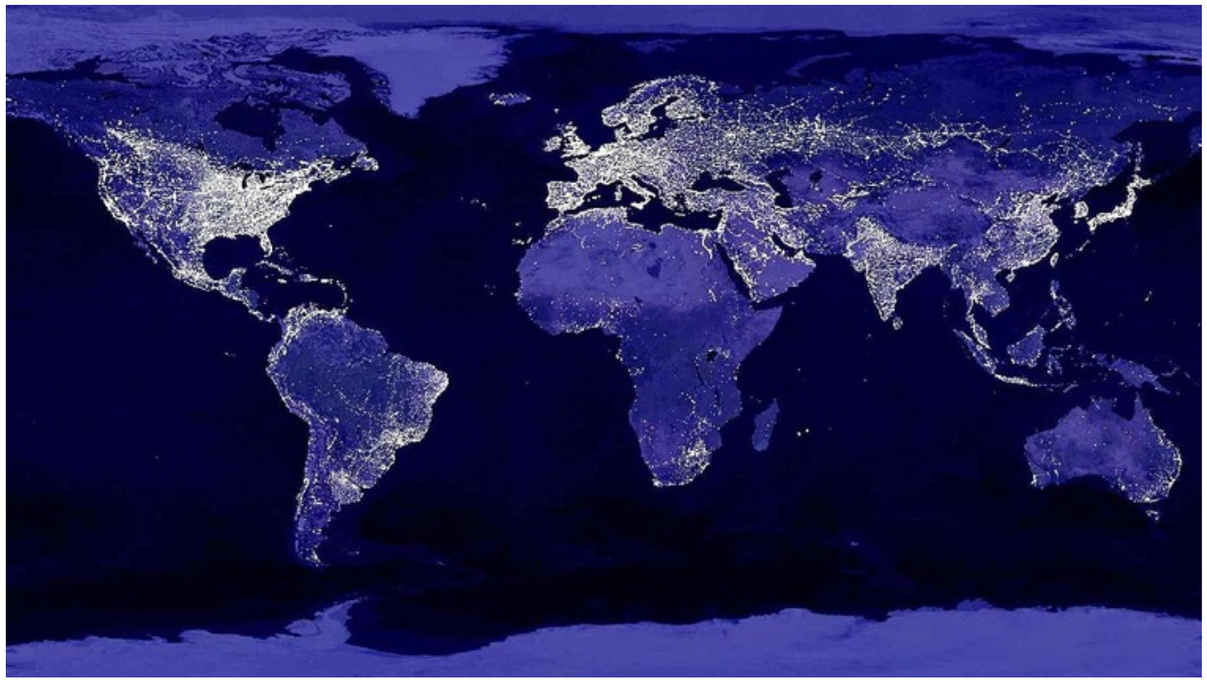

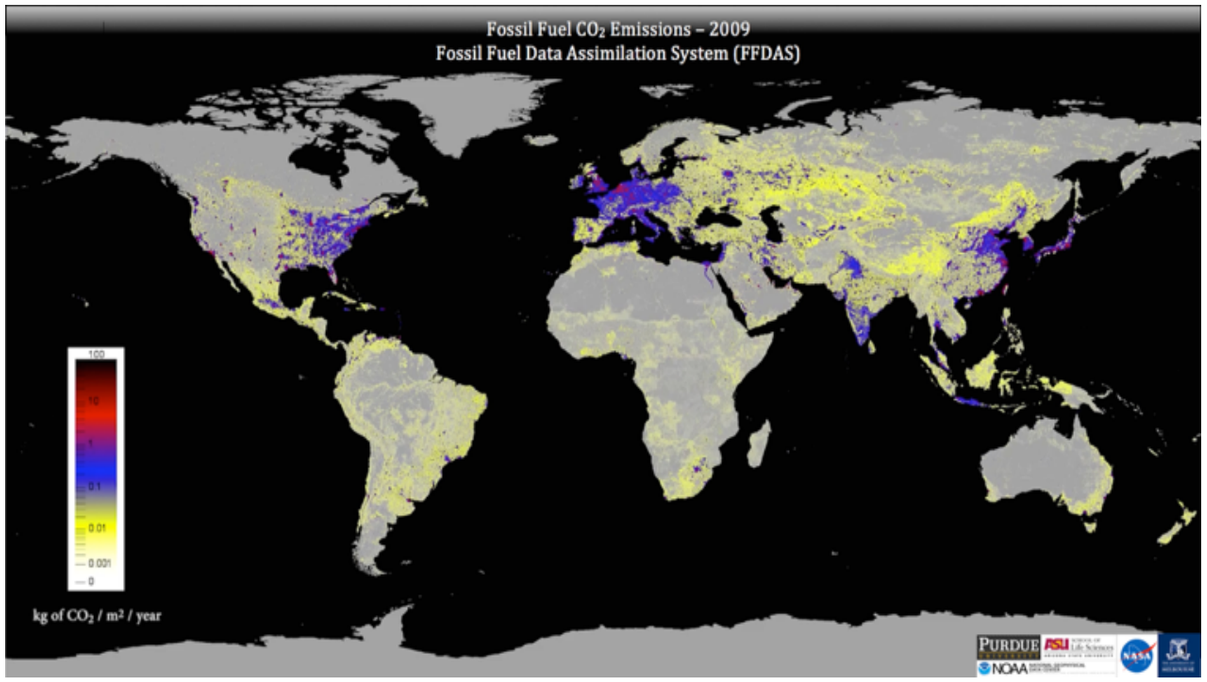

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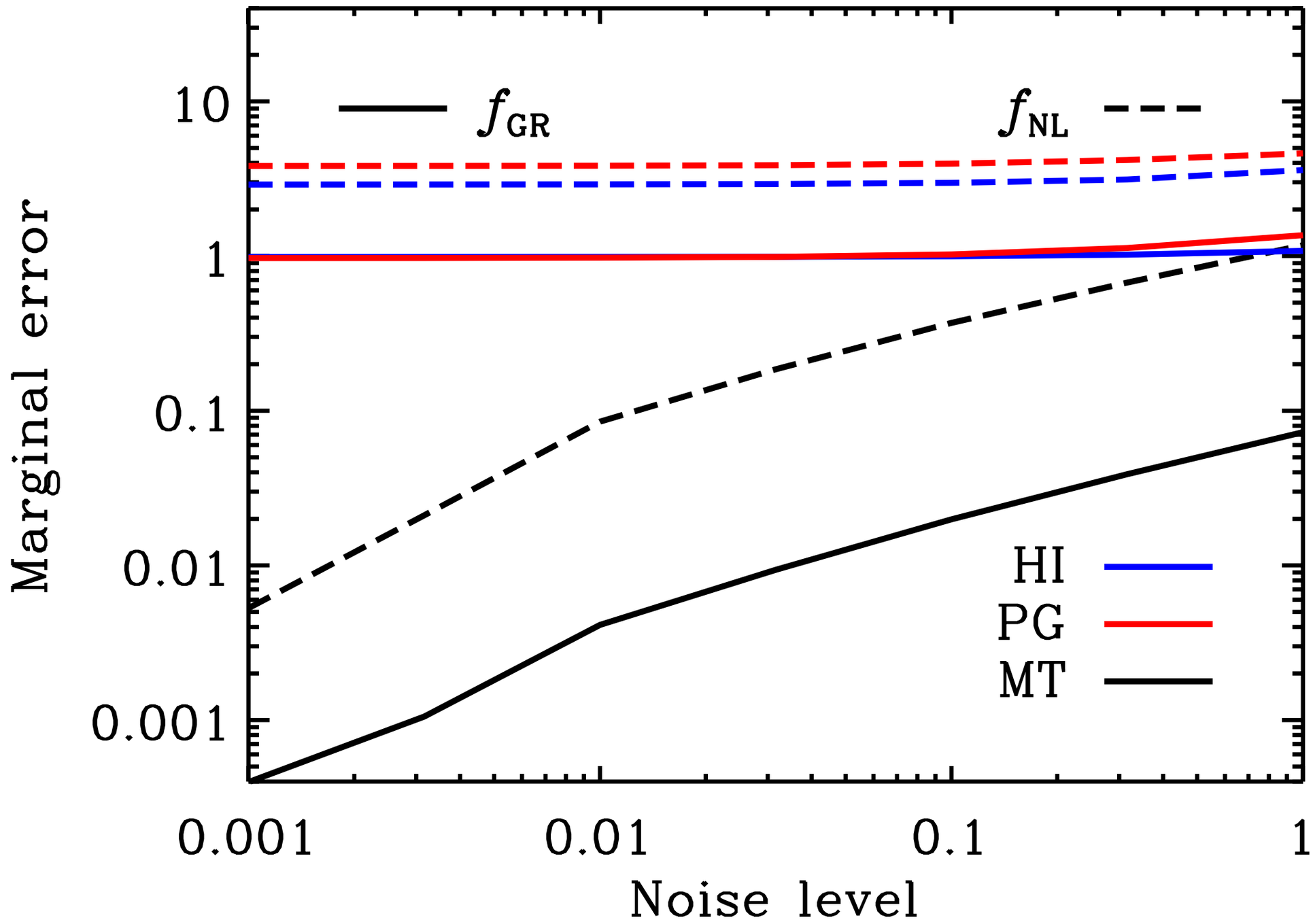
[Fonseca, SC, Santos & Maartens, ApJL 2015]



Take-Home Message

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Take-Home Message

- The SKA will be a powerful 'cosmology' machine

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- It will allow us to exploit for the first time multi-wavelength synergies for late Universe observables

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Take-Home Message

- The SKA will be a powerful 'cosmology' machine
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- Cross-check of cosmological results

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- Cross-check of cosmological results

- Added value to extend the reach of constraining power on our cosmological model

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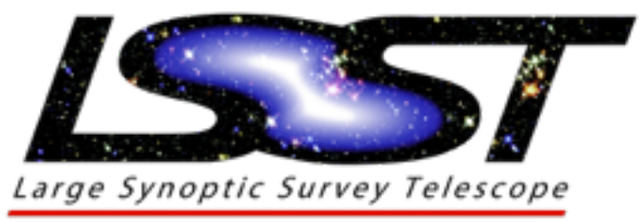
  - Added value to extend the reach of constraining power on our cosmological model
- Perfect timing w.r.t. other major optical/near-IR cosmological experiments



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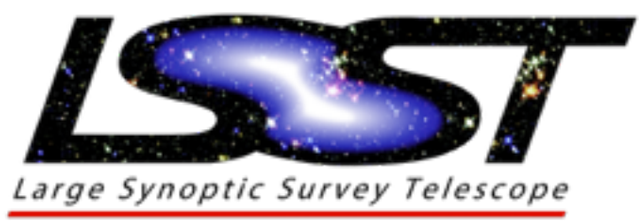

THANK YOU!