Added value of optical/NIR data to shed new light on the dark Universe

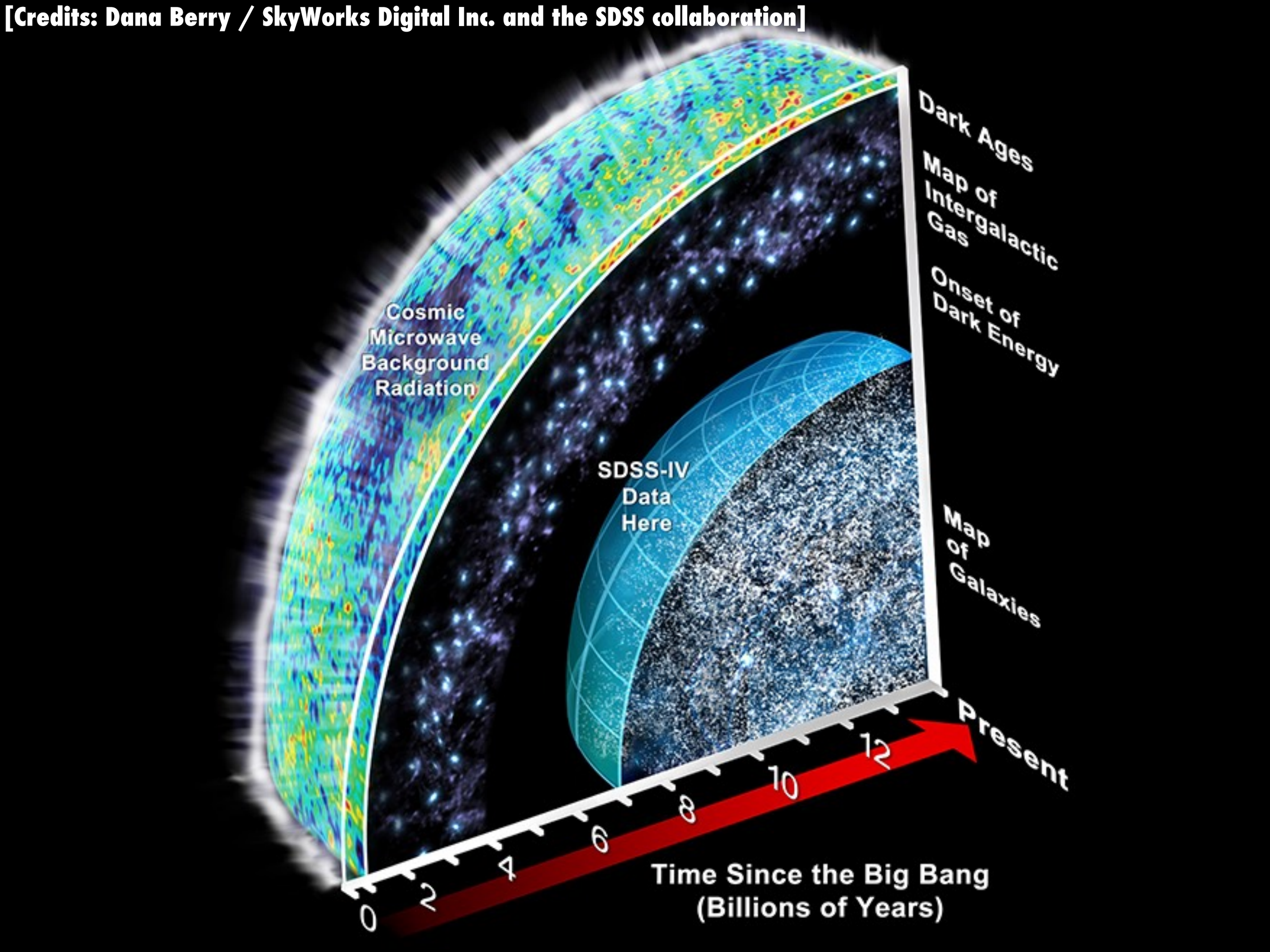
Stefano Camera

Department of Physics, Alma Felix University of Turin, Italy

Programma per Giovani Ricercatori
"Rita Levi Montalcini"

Physics Torino Department of Excellence

[Credits: Dana Berry / SkyWorks Digital Inc. and the SDSS collaboration]



ΛCDM cosmology

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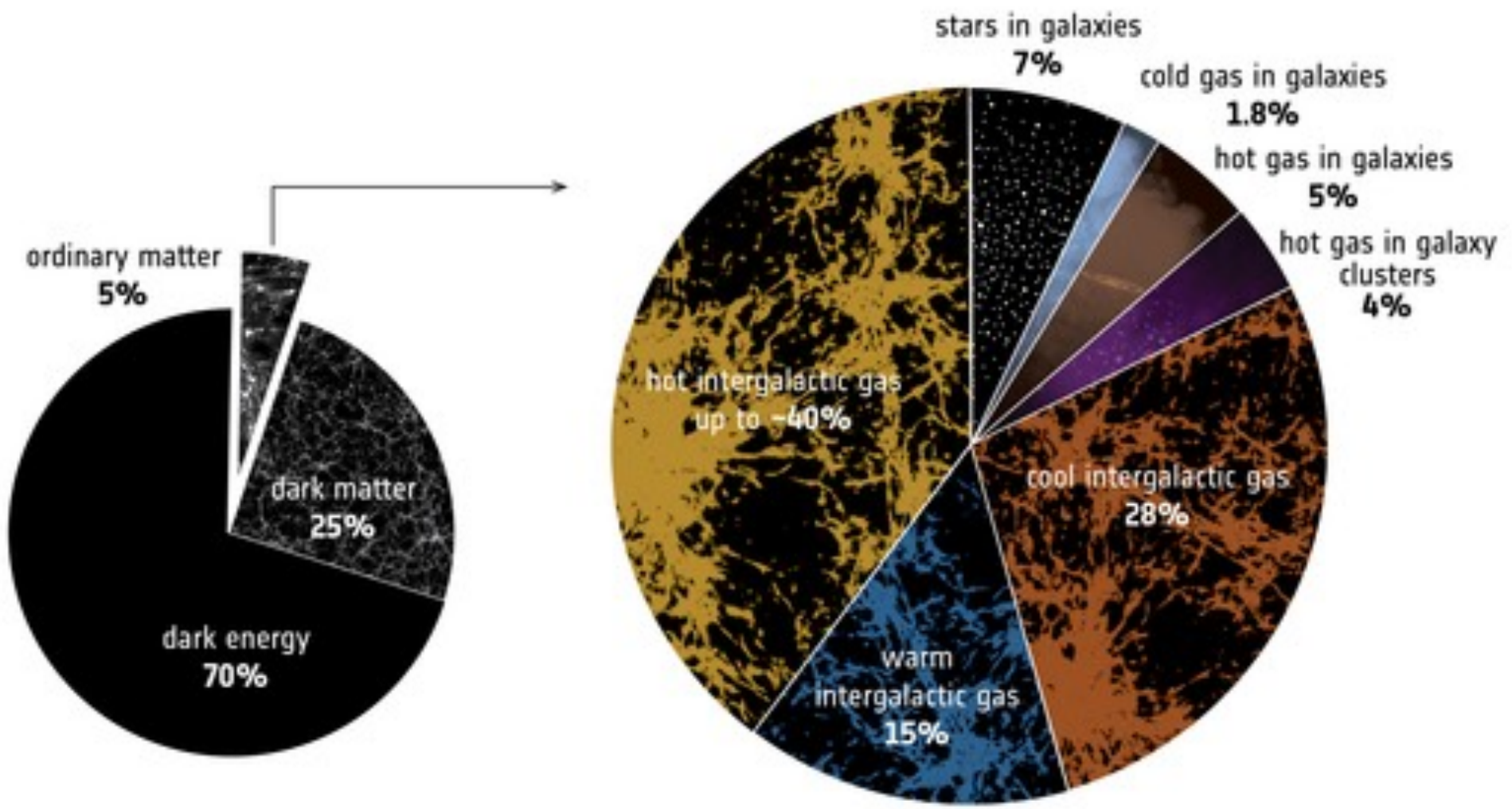
[Credits: ESA, 2018]



ΛCDM cosmology

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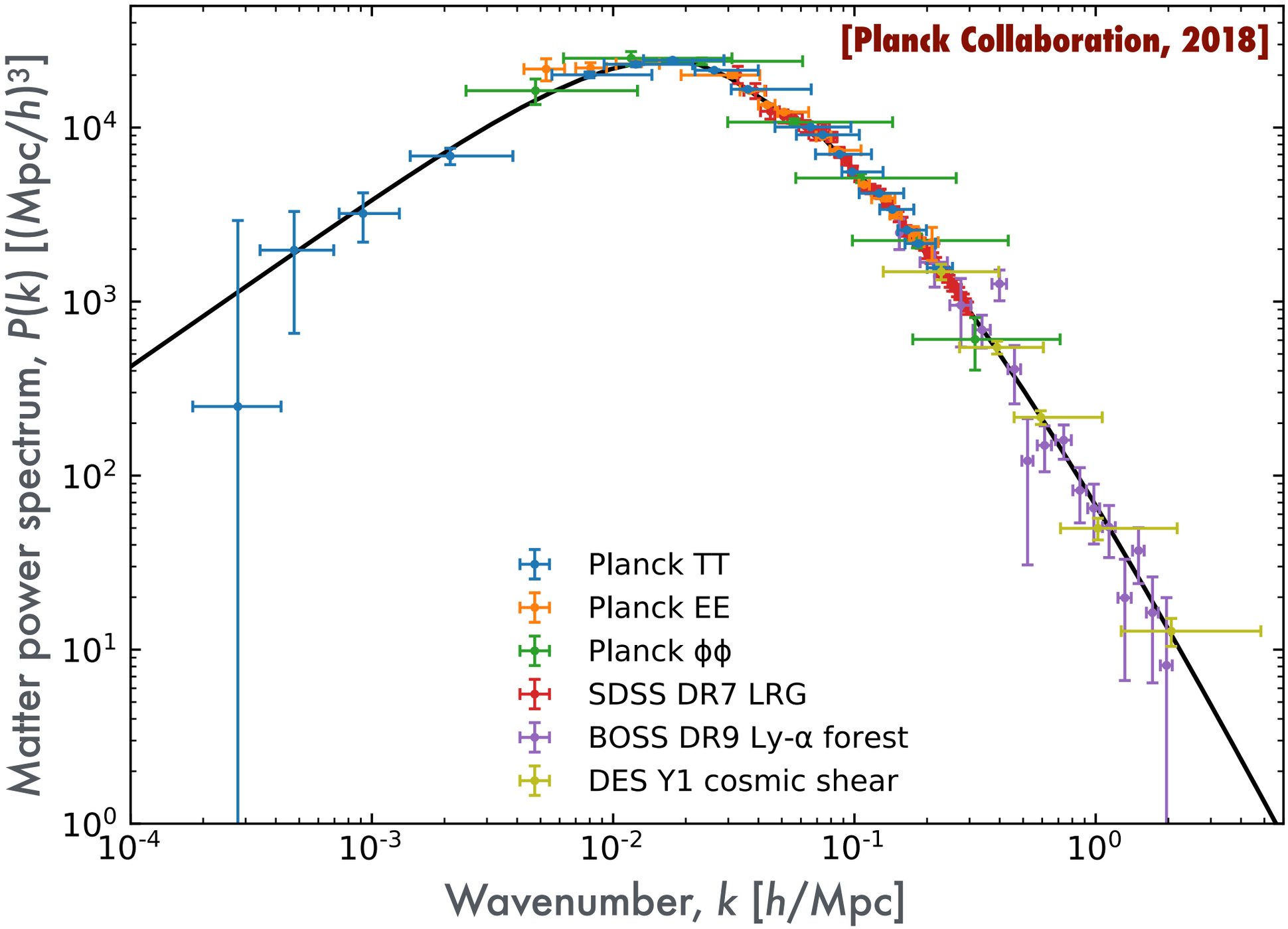

‘Within a forest dark’

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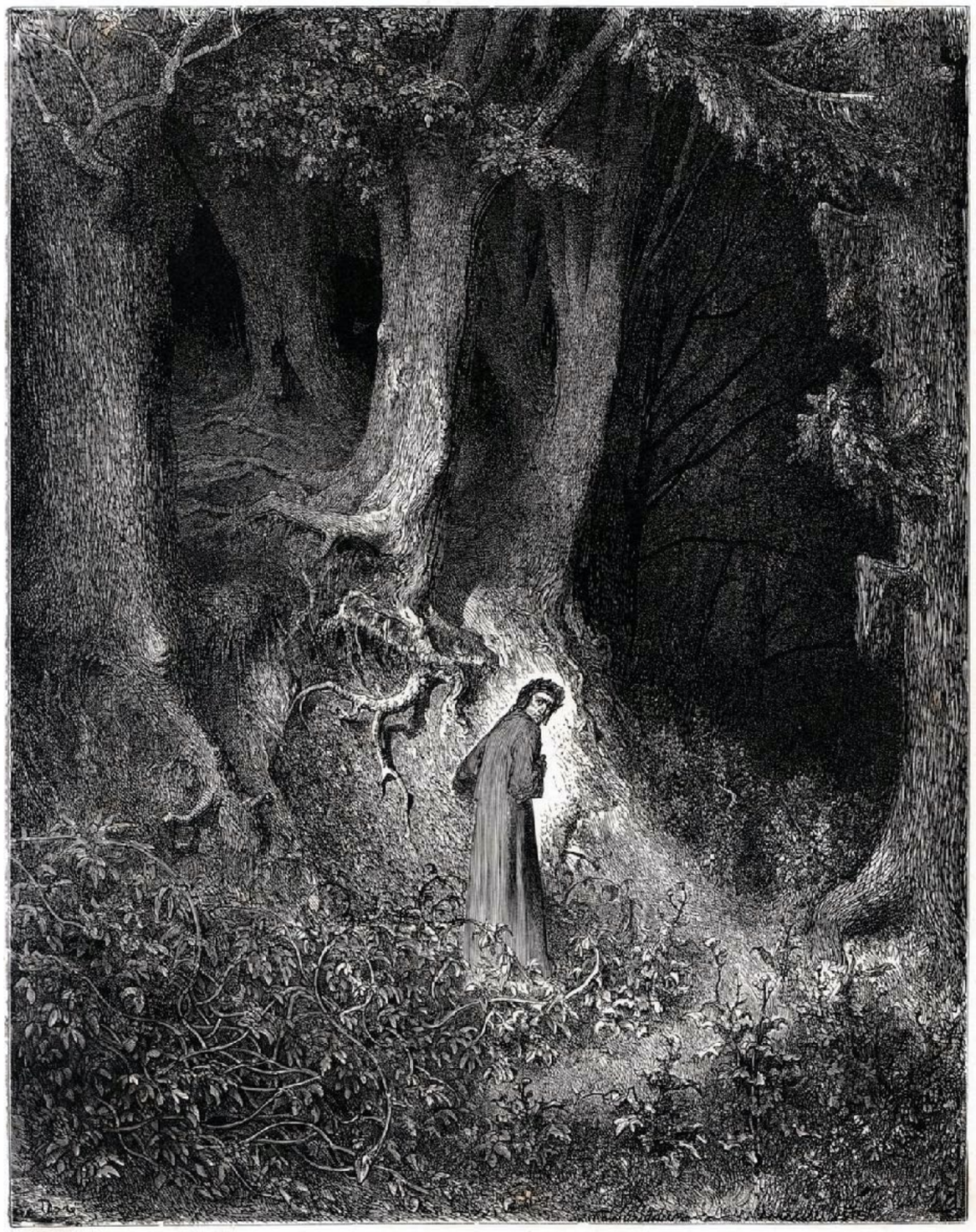

‘Within a forest dark’

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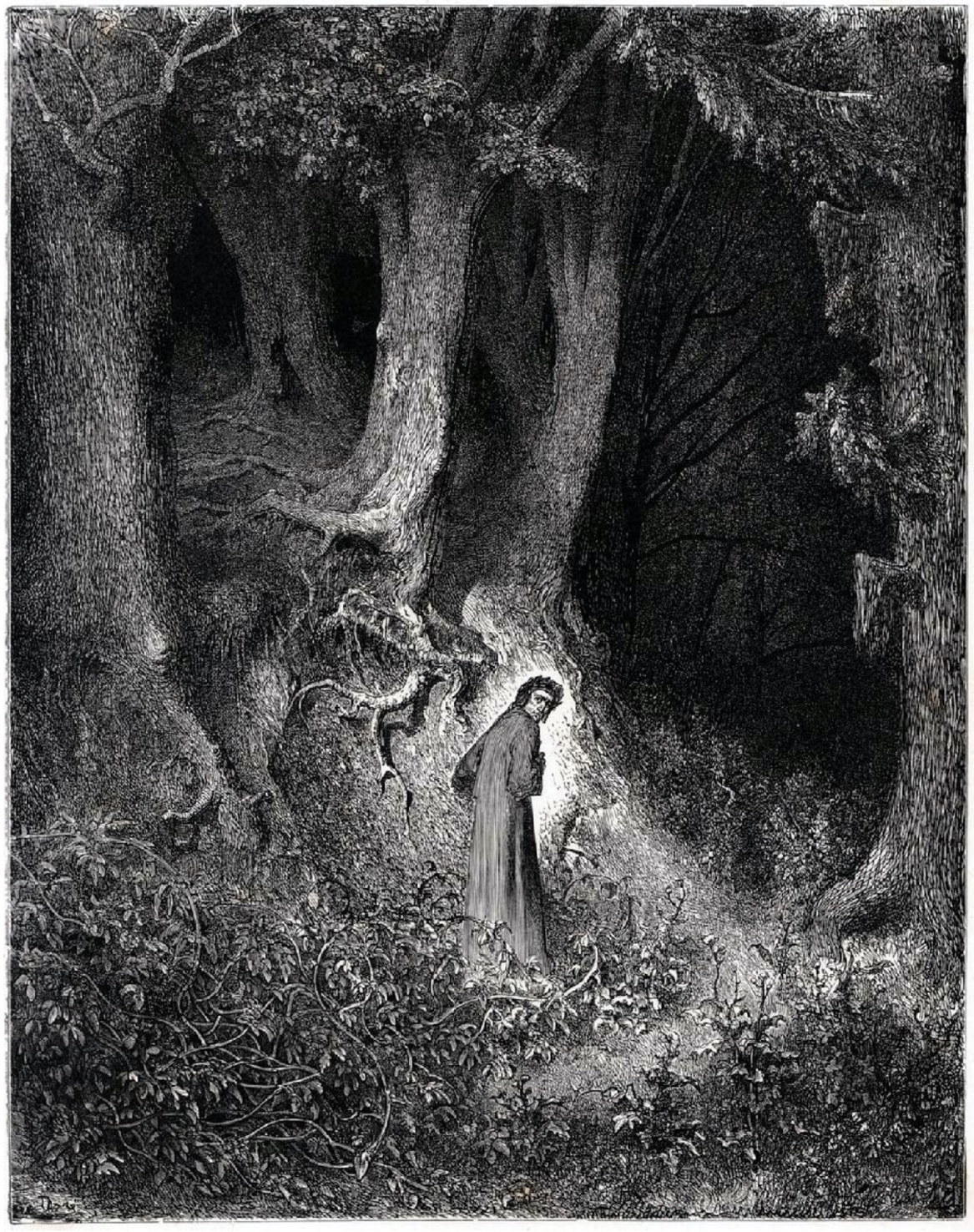

Lion

Panther

She-wolf

‘Within a forest dark’

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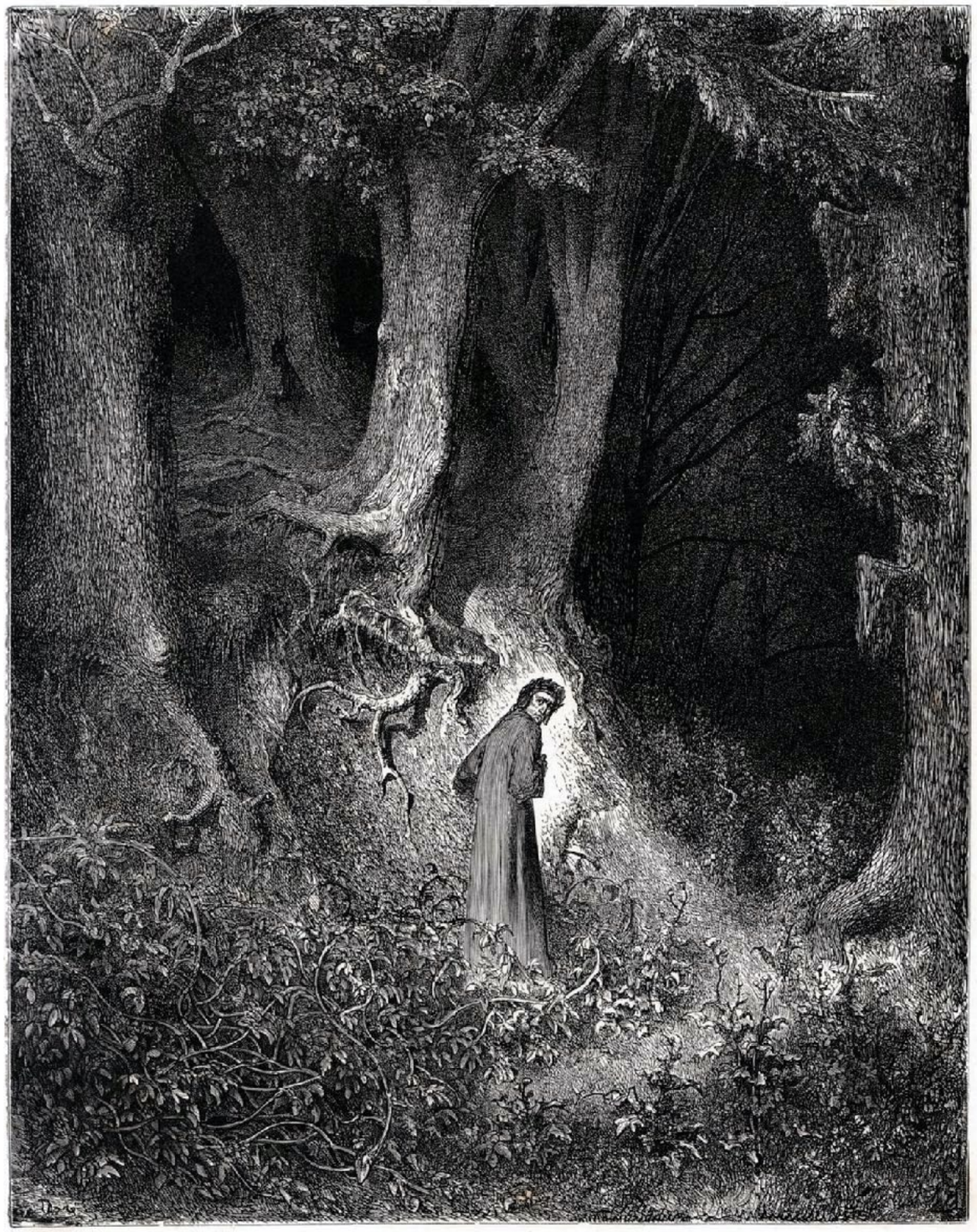

Dark matter

Dark energy

Inflation

Present and future data

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Outline

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- Exploiting synergies between optical/NIR data and observations of the cosmos at other wavelengths:
- Optical/NIR-radio synergies for dark energy
- Optical/NIR-gamma ray synergies for dark matter

Optical/NIR-radio synergies for dark energy

Cosmic shear

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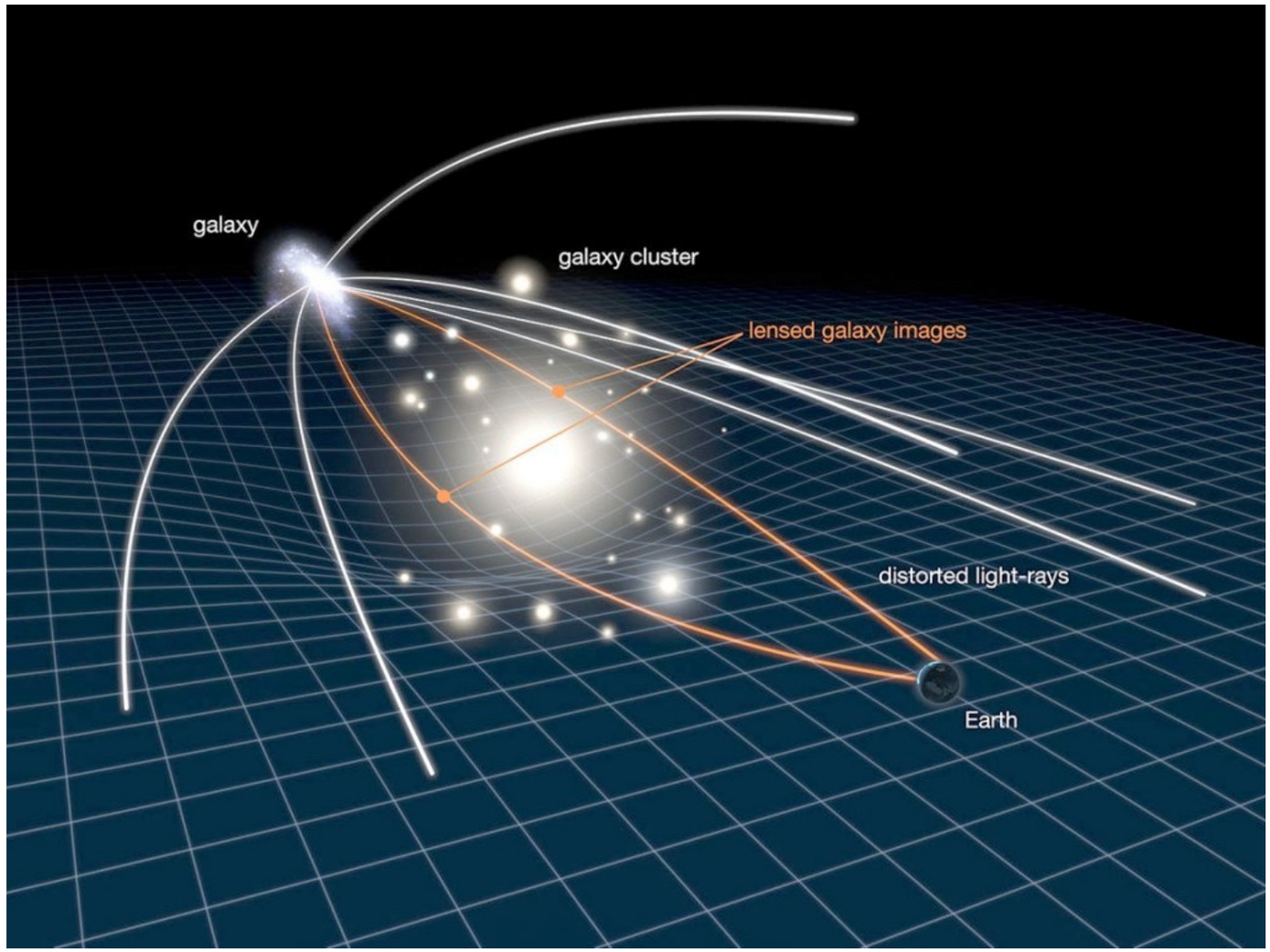

Cosmic shear

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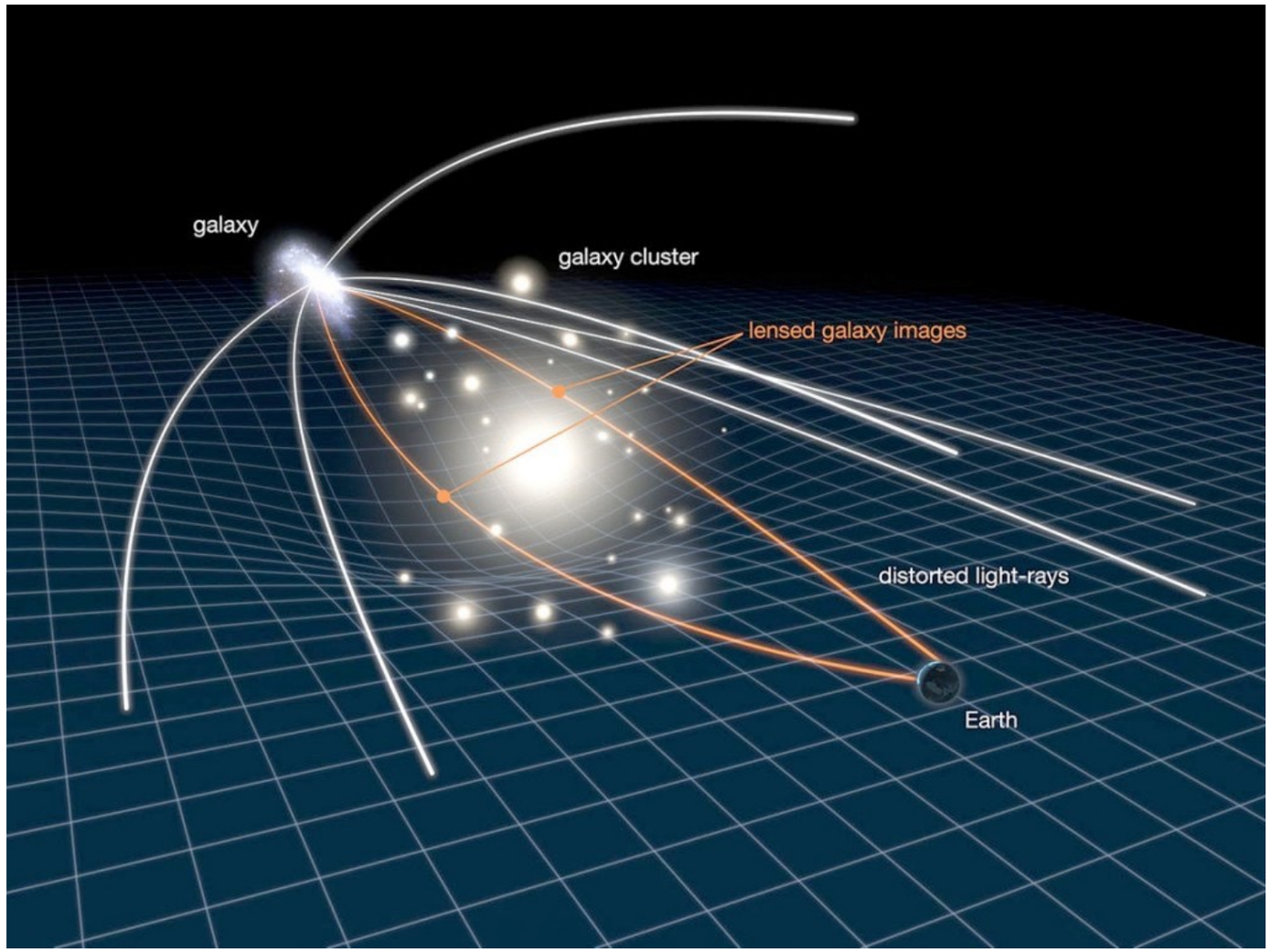

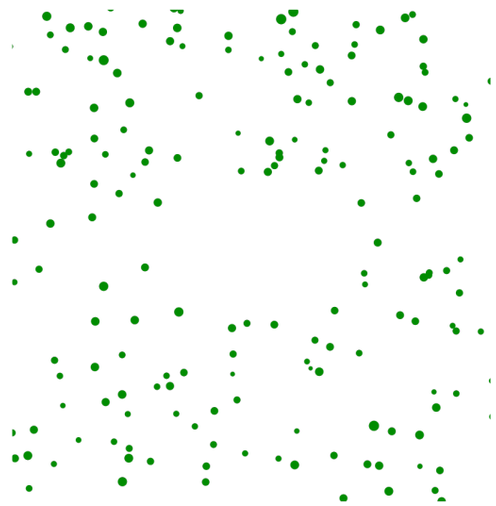

Cosmic shear

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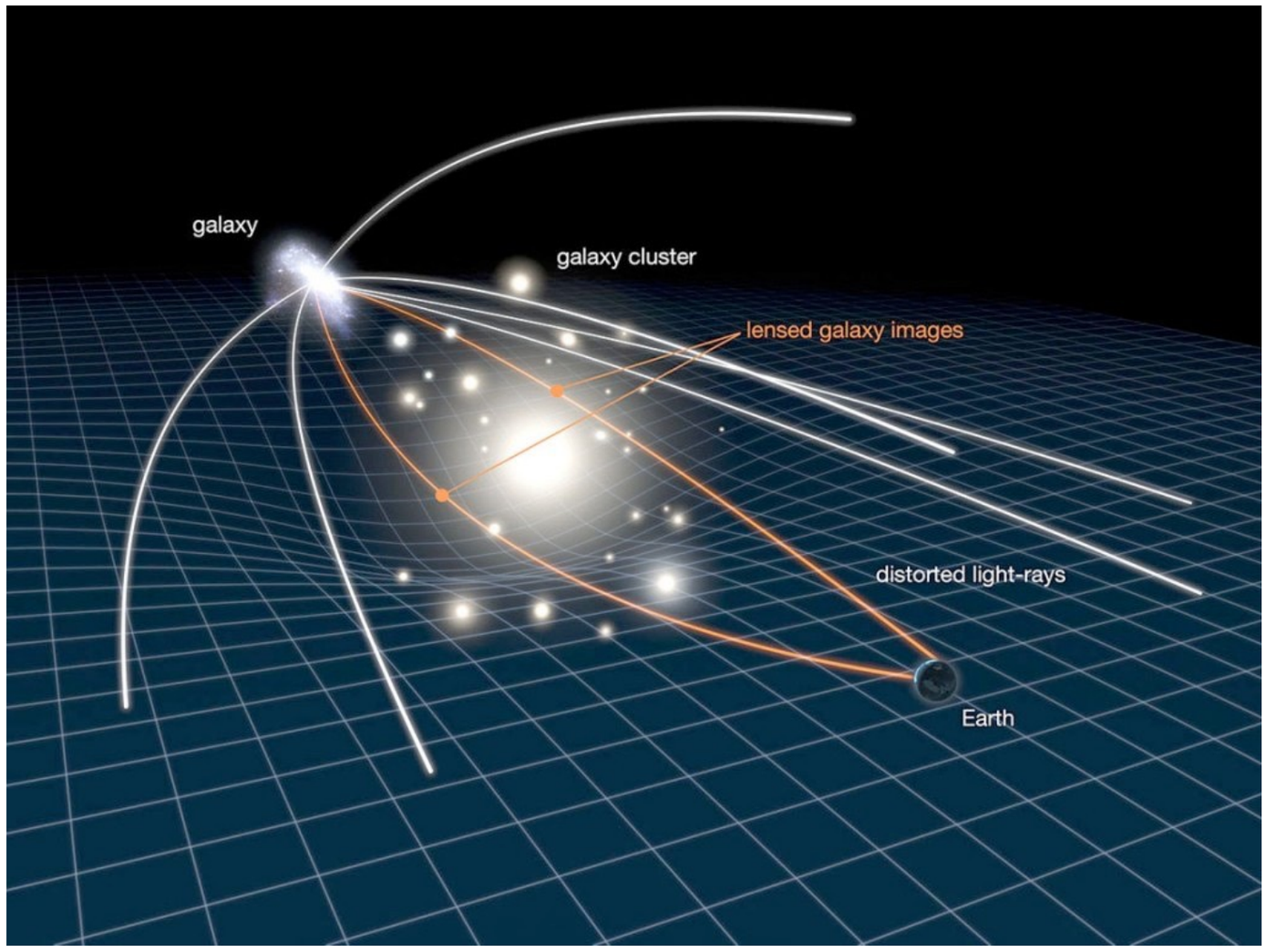

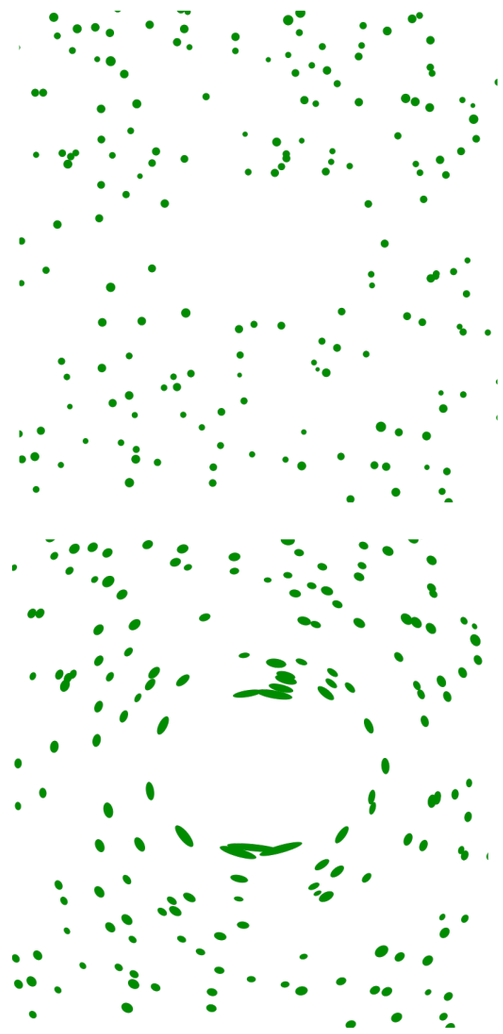

Cosmic shear

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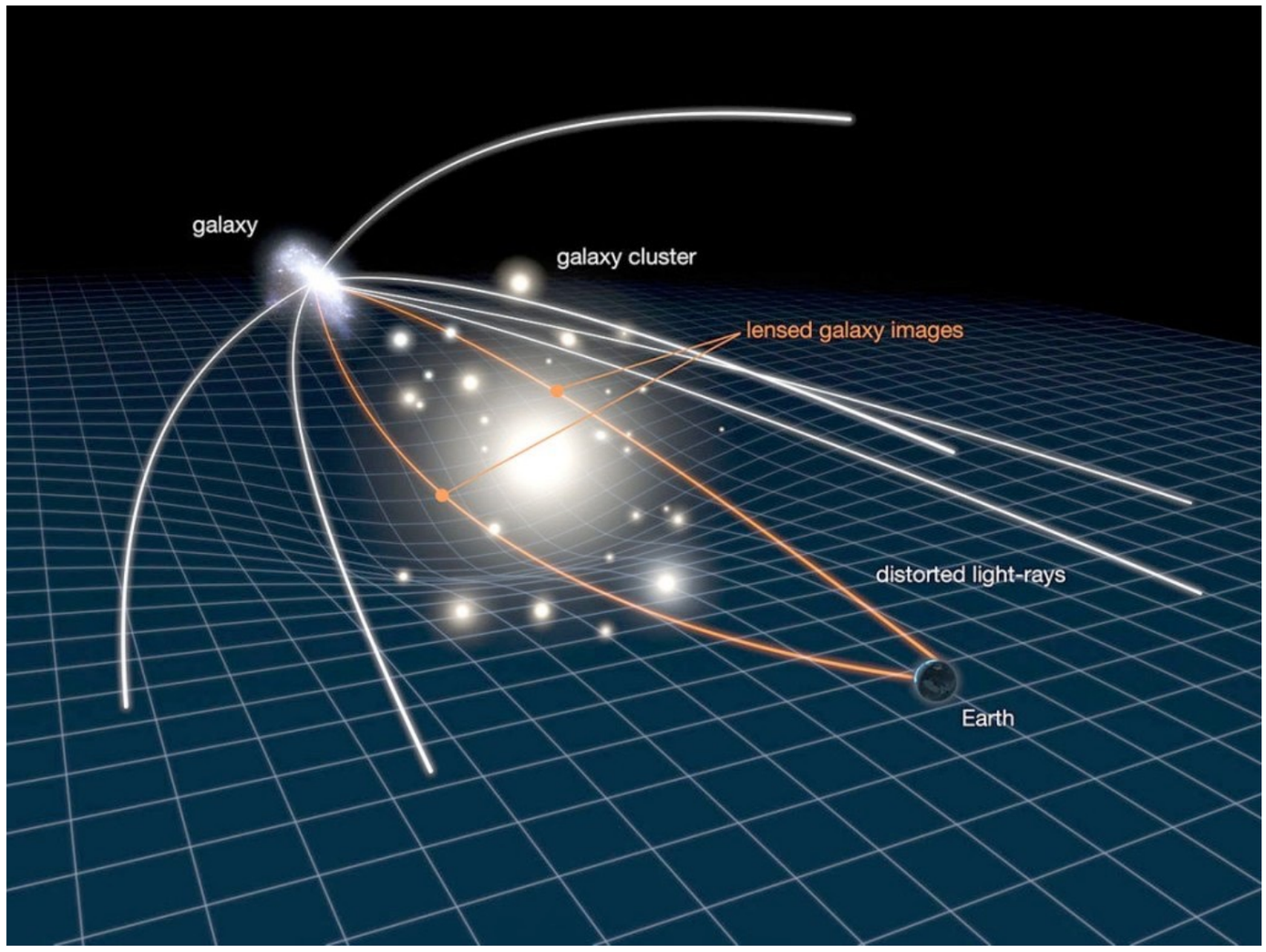
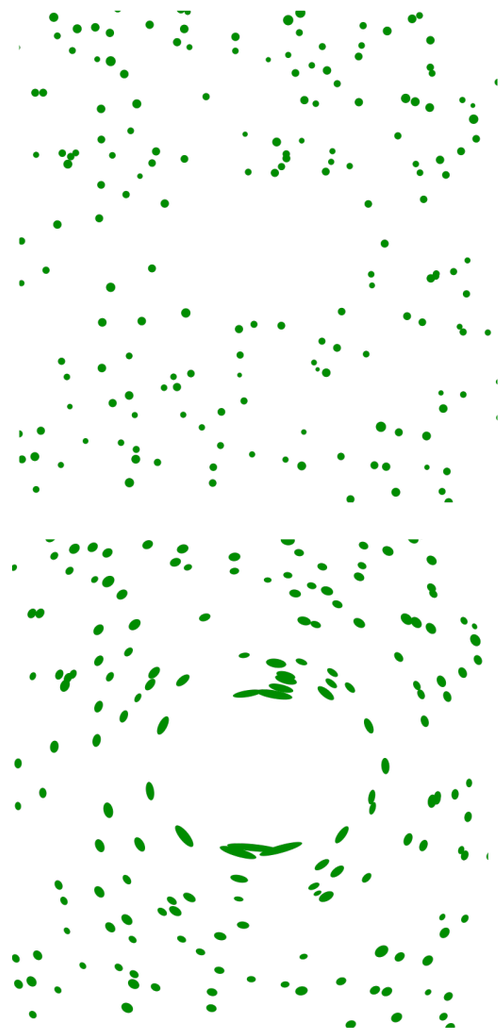
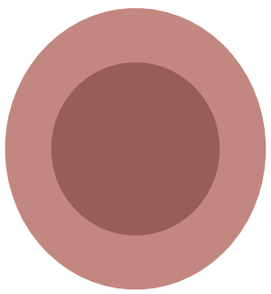
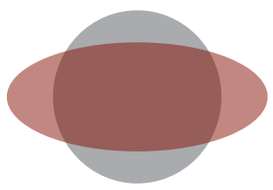




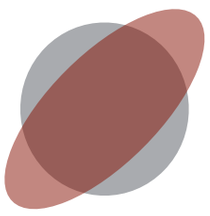
convergence



shear +



shear ×



Cosmic shear

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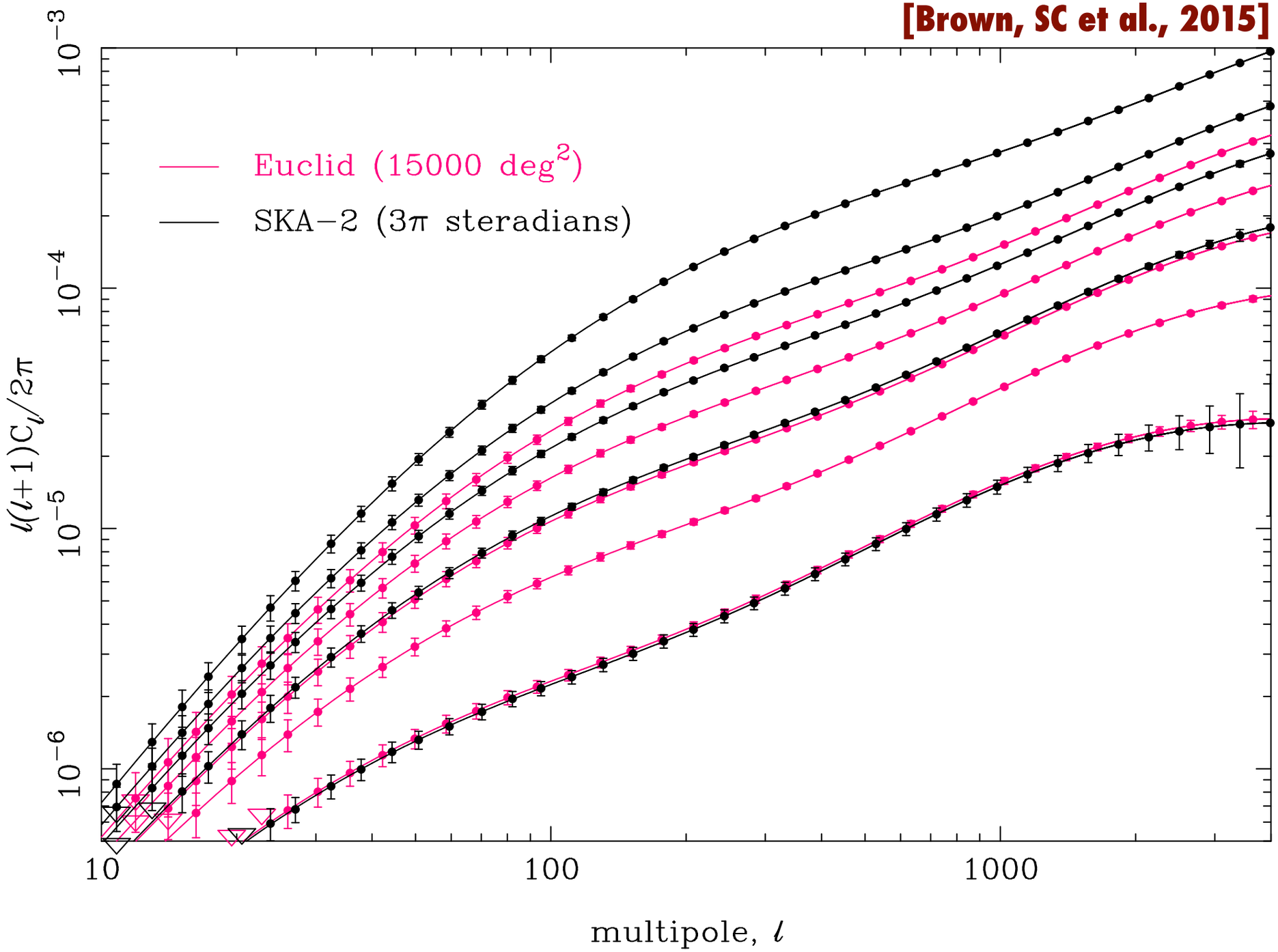
[Brown, SC et al., 2015]



Cosmic shear

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$$\gamma^{\rm obs}(z,\vec{\theta}) = \gamma(z,\vec{\theta}) + \gamma^{\rm sys}(z,\vec{\theta})$$

Cosmic shear

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$$\gamma^{\rm obs}(z,\vec{\theta}) = \gamma(z,\vec{\theta}) + \gamma^{\rm sys}(z,\vec{\theta})$$

$$\langle\gamma^{\rm obs}\gamma^{\rm obs}\rangle = \langle\gamma\gamma\rangle + 2\langle\gamma^{\rm sys}\gamma\rangle + \langle\gamma^{\rm sys}\gamma^{\rm sys}\rangle$$

Cosmic shear

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Cosmic shear

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$$\langle \gamma^{\rm obs}_{(o)}\gamma^{\rm obs}_{(r)}\rangle = \langle\gamma\gamma\rangle + \langle\gamma^{\rm sys}_{(o)}\gamma_{(r)}\rangle + \langle\gamma_{(o)}\gamma^{\rm sys}_{(r)}\rangle + \langle\gamma^{\rm sys}_{(o)}\gamma^{\rm sys}_{(r)}\rangle$$

Cosmic shear

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Cosmic shear

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Radio-optical cosmic shear

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SKA
SQUARE KILOMETRE ARRAY

$$\gamma^{\mathrm{obs},i}_{(b)} = \gamma^i + \mathfrak{a}^i_{(b)}$$

euclid

Radio-optical cosmic shear

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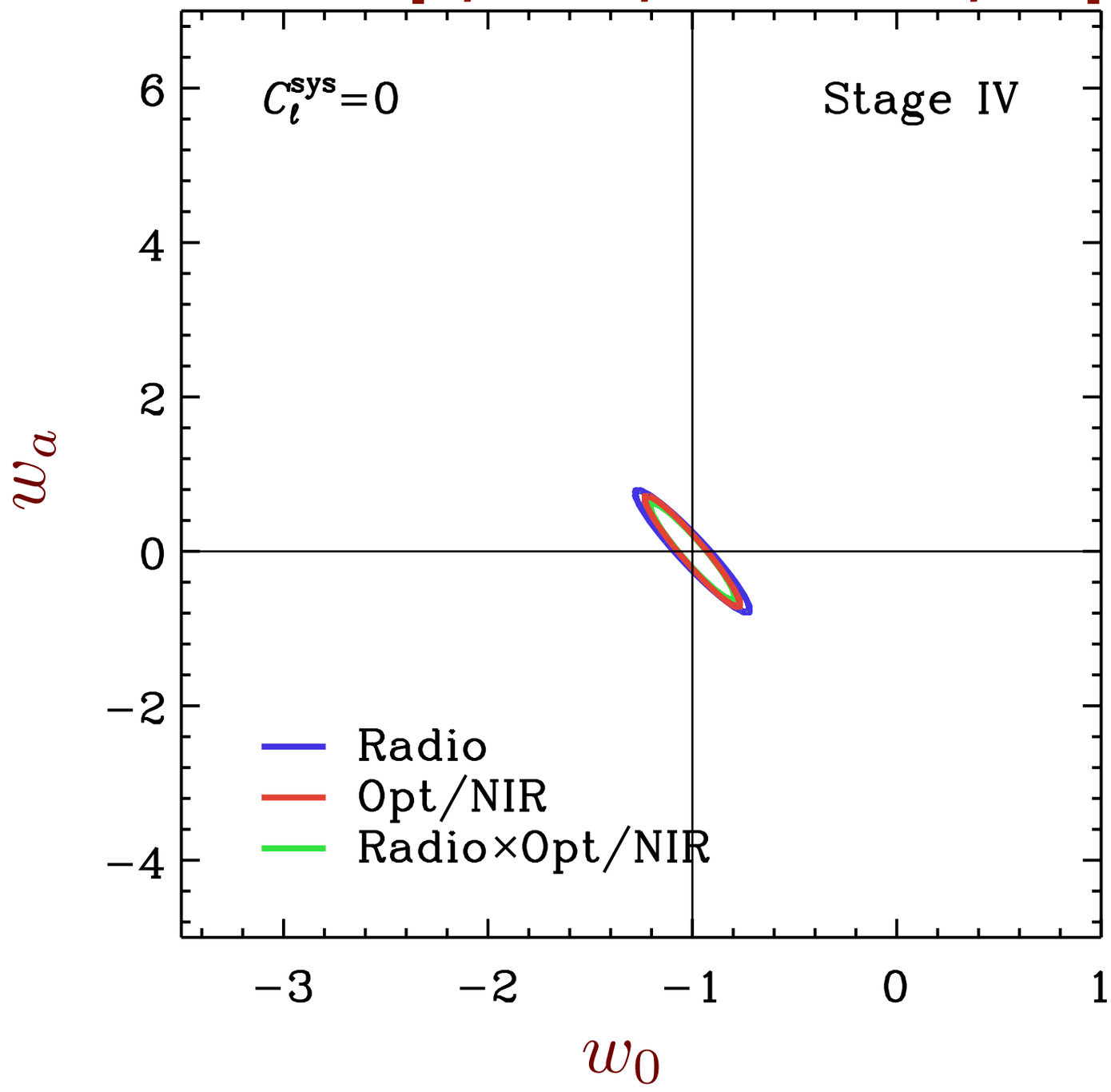
euclid

[SC, Harrison, Bonaldi & Brown, 2016]



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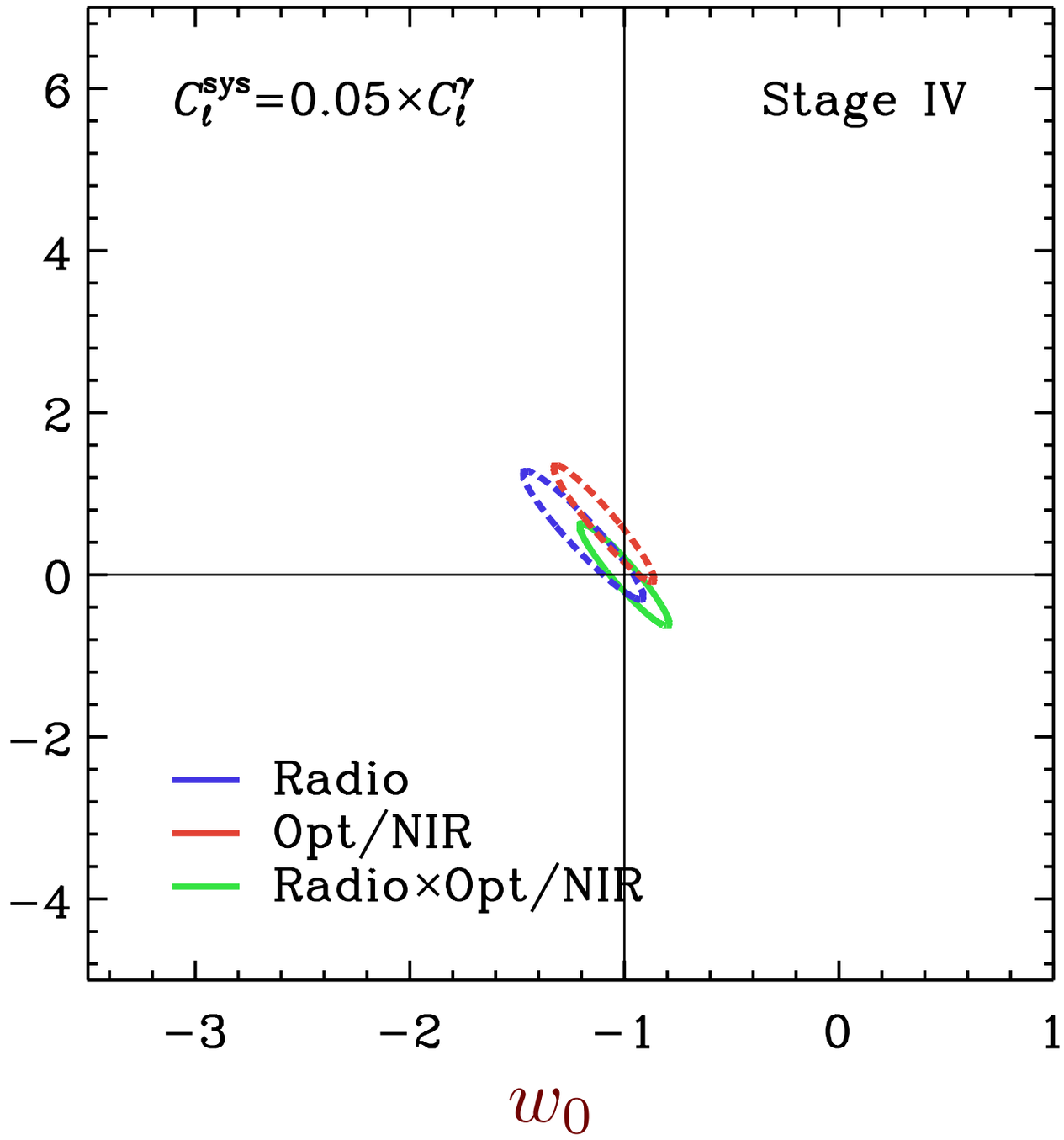

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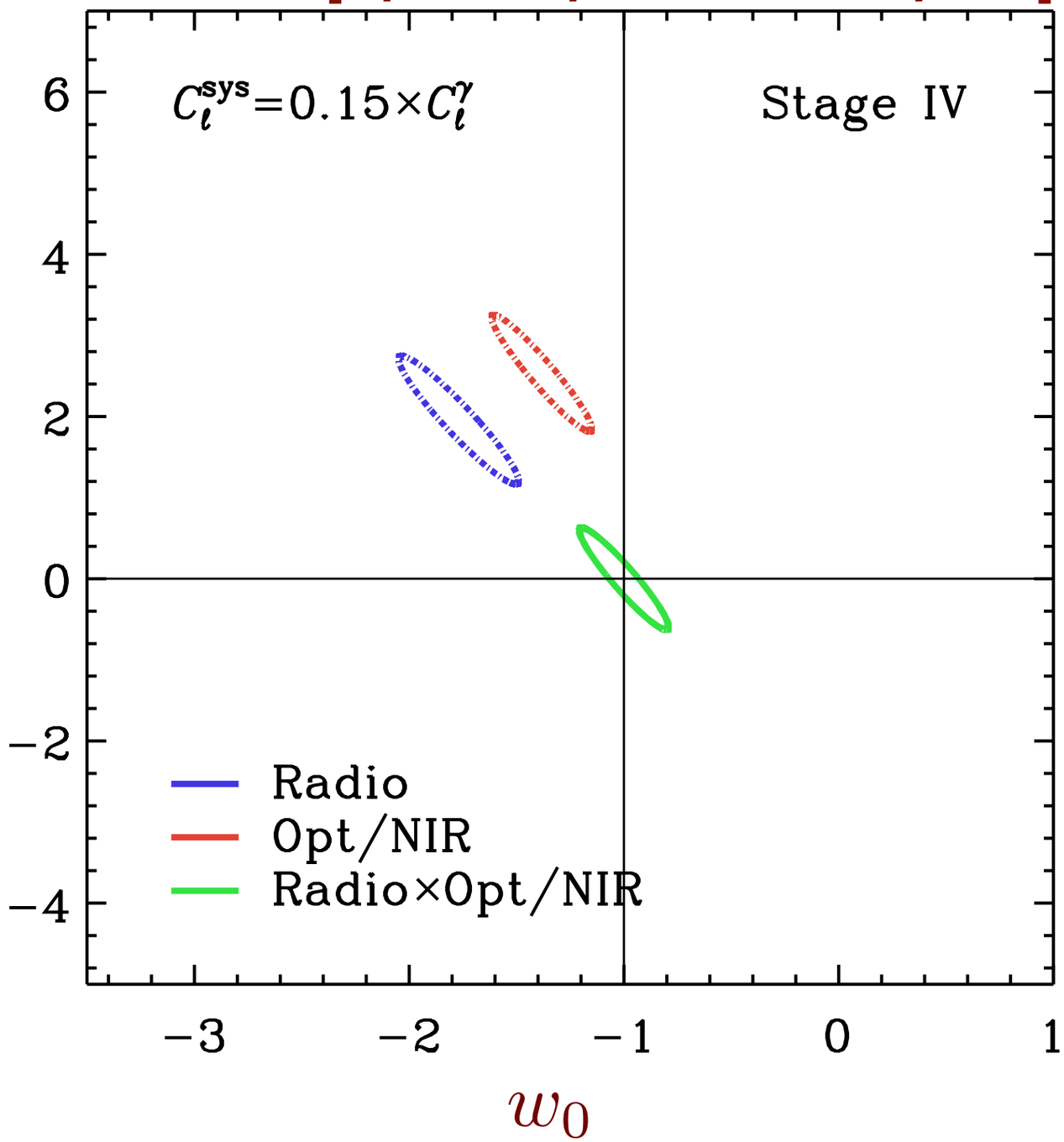

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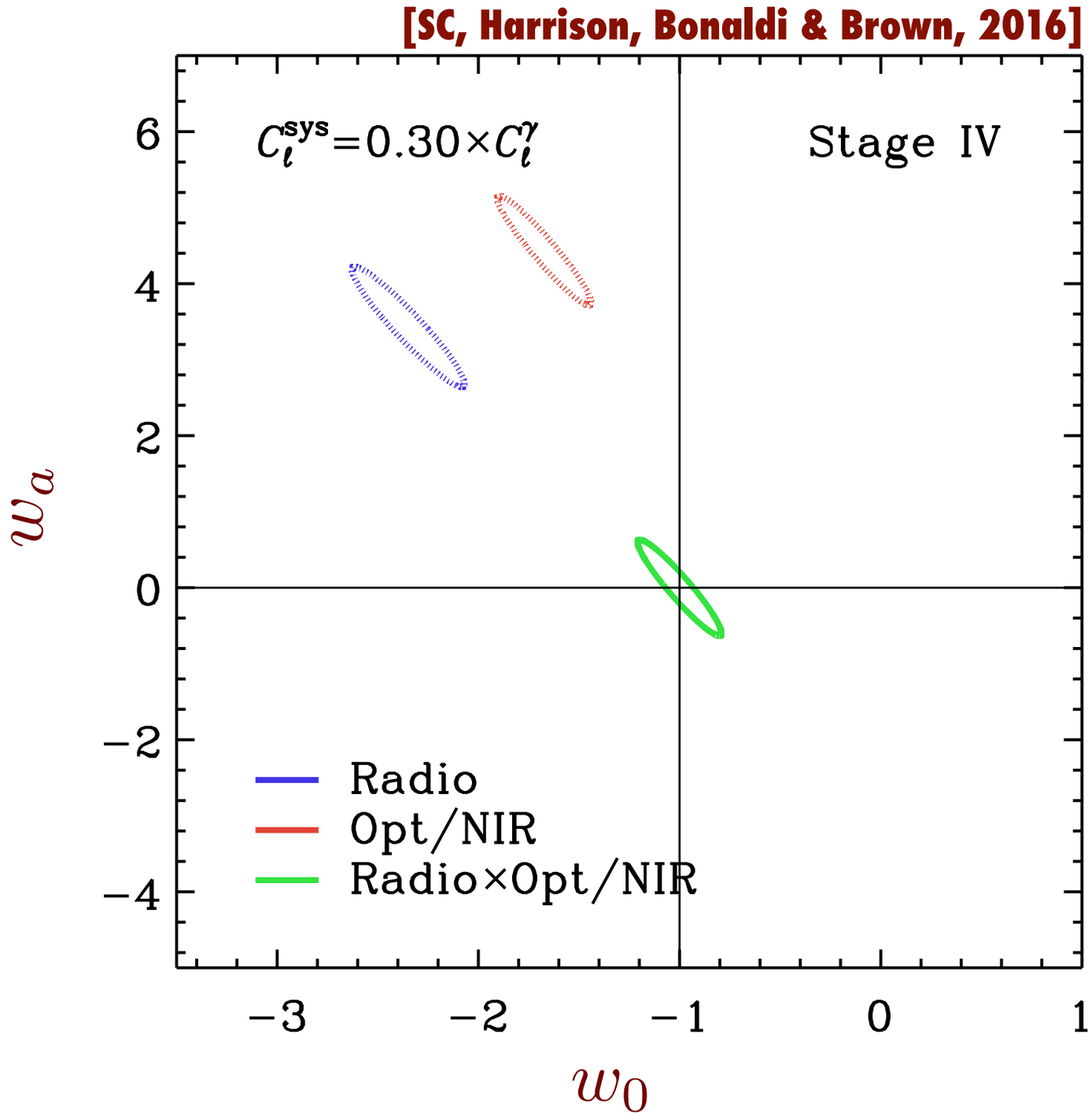

Radio-optical cosmic shear

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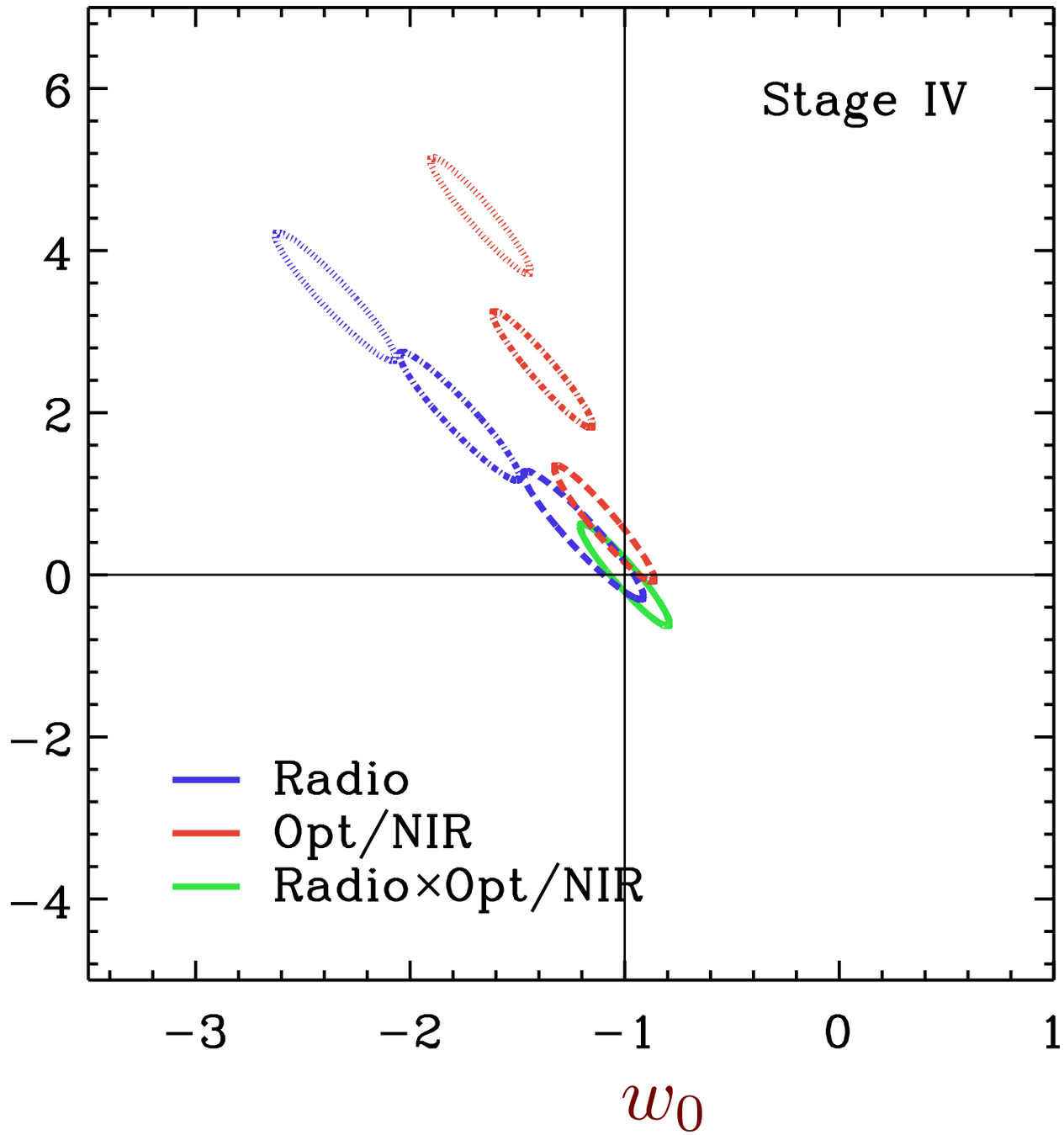

Radio-optical cosmic shear

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SKA SQUARE KILOMETRE ARRAY

$$\gamma_{(b)}^{\mathrm{obs},i} = \left[1 + \mathfrak{m}_{(b)}^{i}\right] \gamma^{i}$$

euclid

Radio-optical cosmic shear

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[Berardi, SC & Brown, in prep.]

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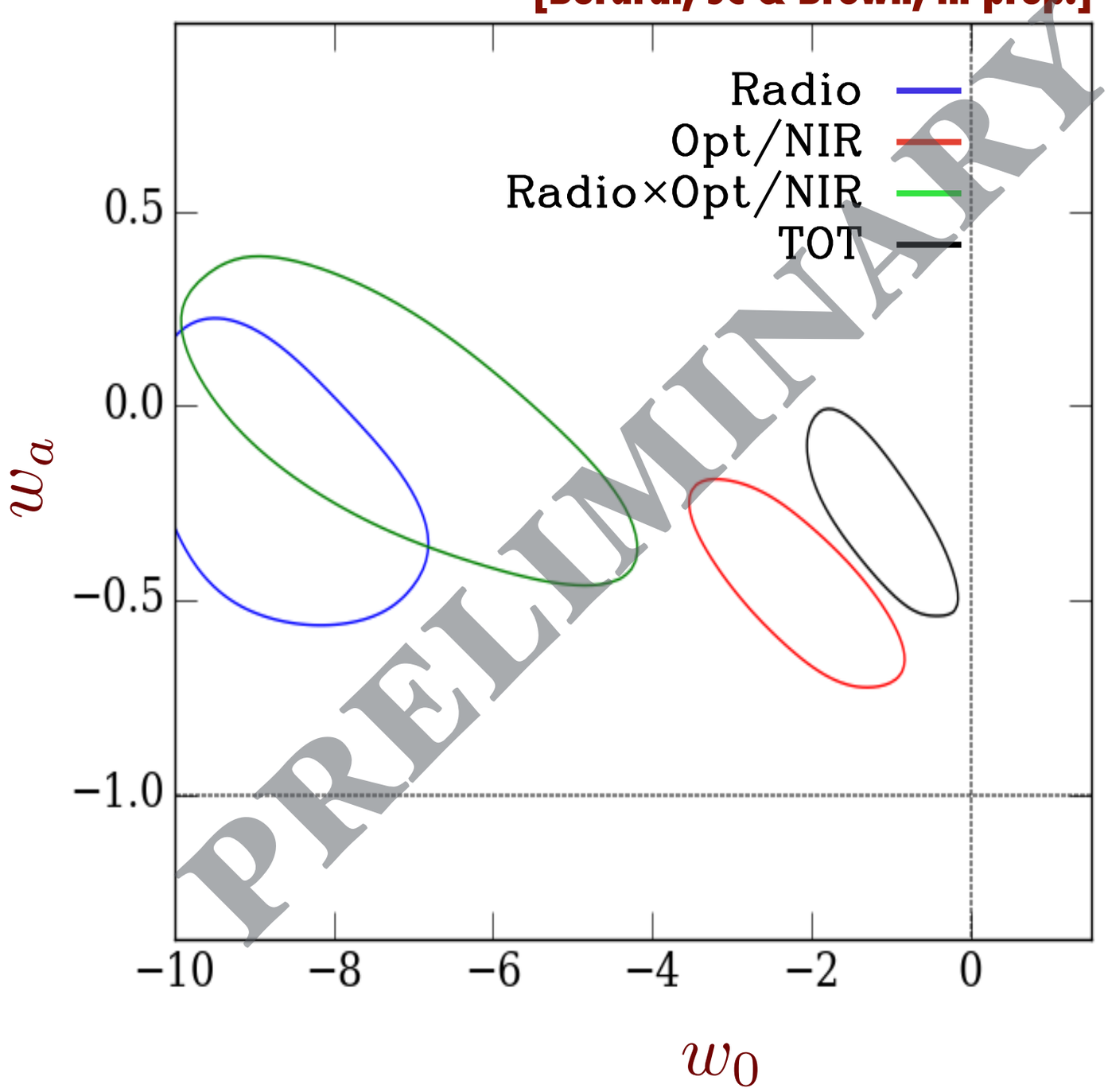

euclid

Radio-optical cosmic shear

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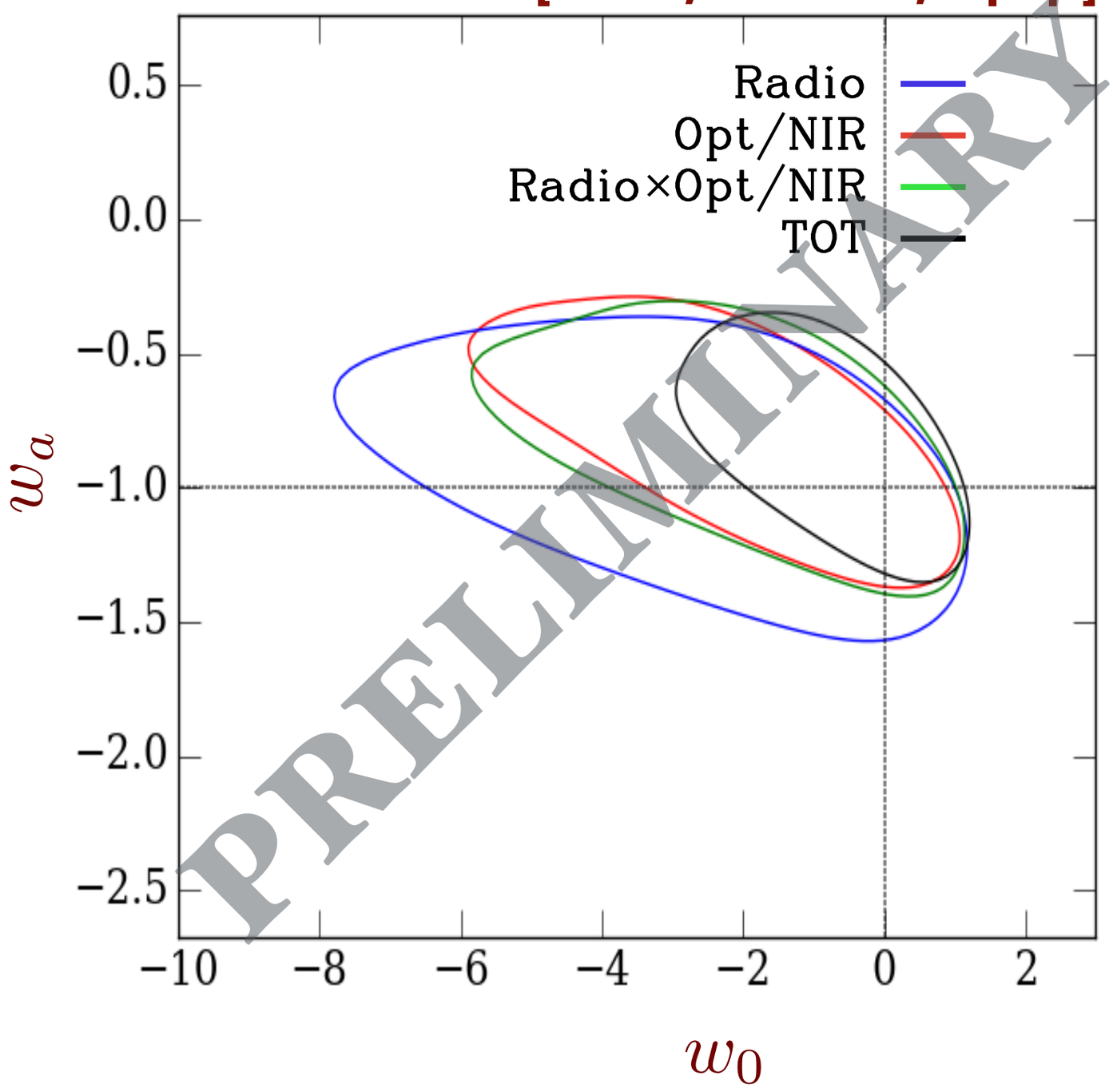

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Optical/NIR-gamma ray synergies for dark matter

Particle dark matter

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- Particle dark matter is an established ingredient of ΛCDM

Particle dark matter

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- Particle dark matter is an established ingredient of ΛCDM
- Weakly interacting massive particles (WIMPs)
- Indirect detection experiments: WIMP-sourced cosmic and γ rays

Particle dark matter

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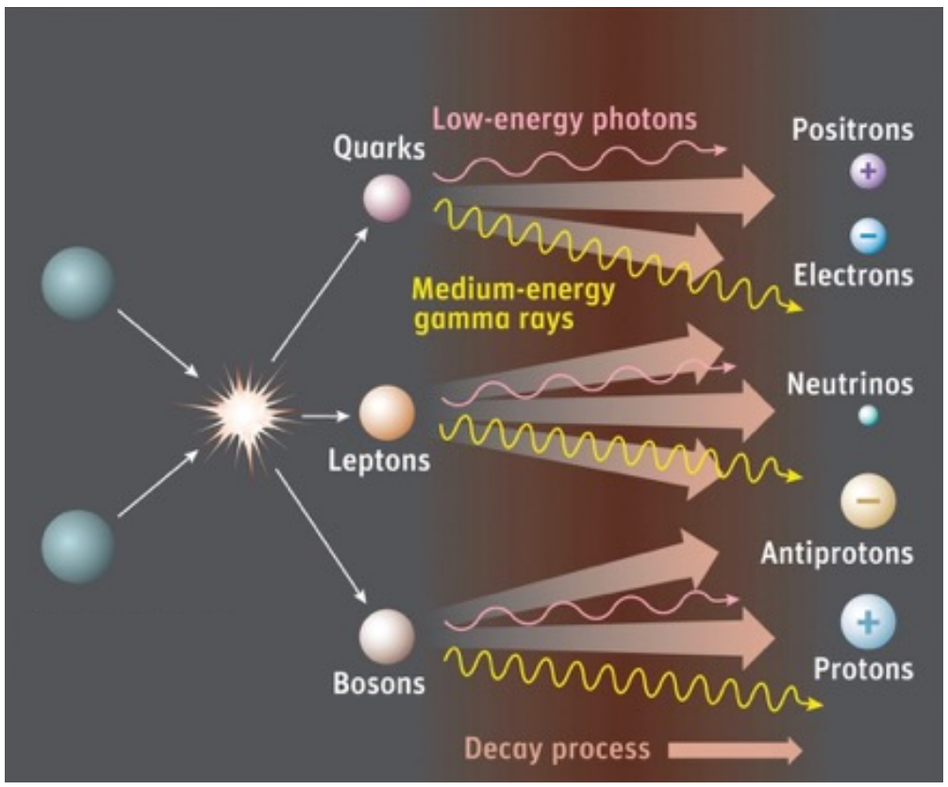

Particle dark matter

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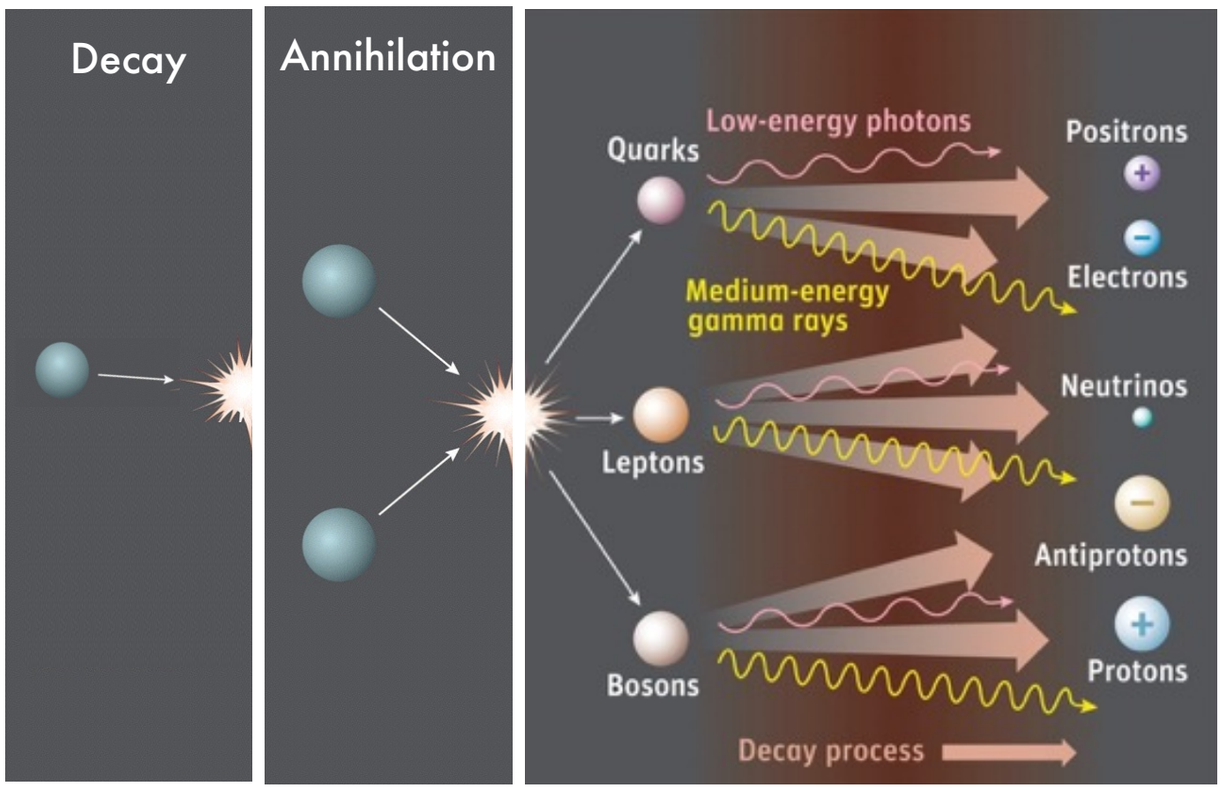

DM-sourced γ rays

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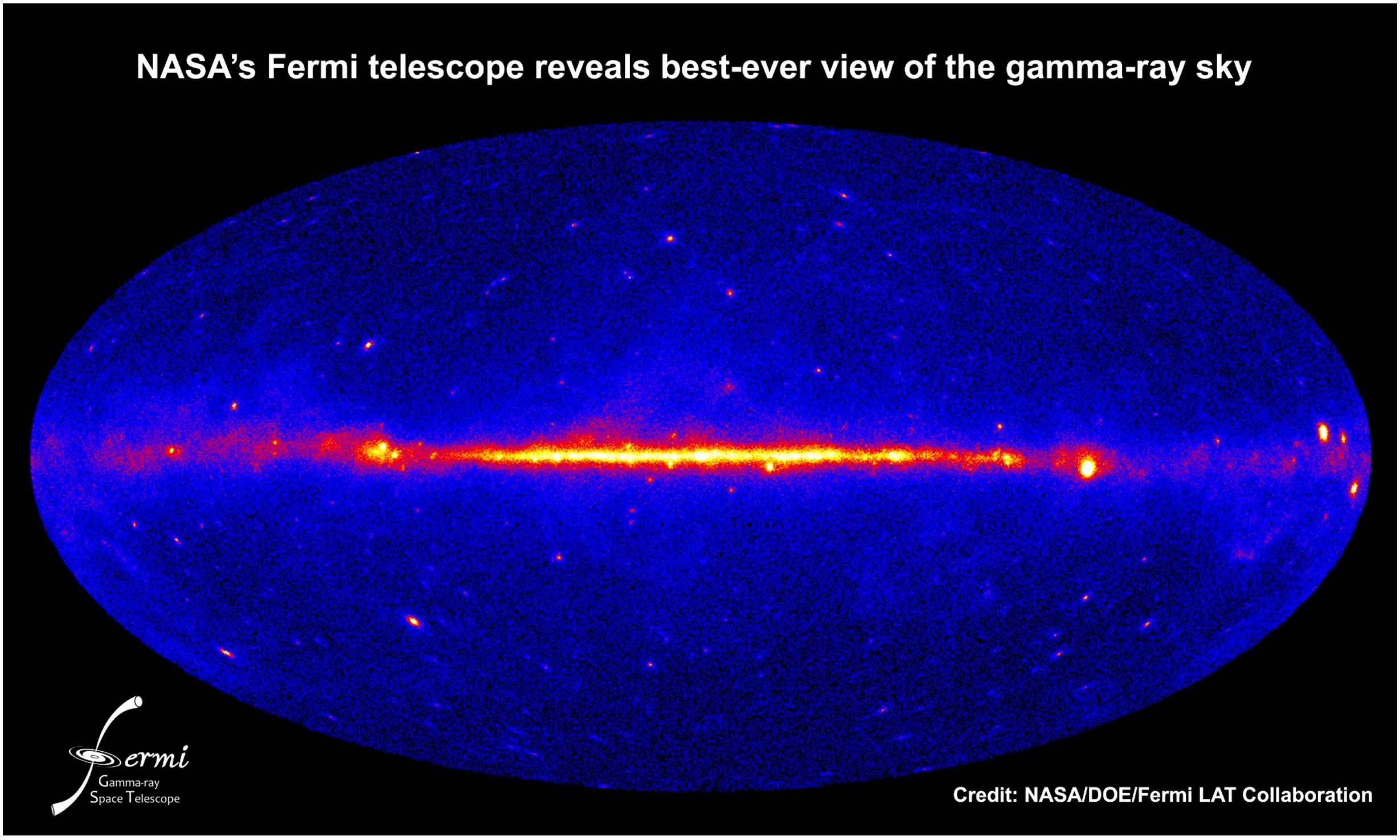

DM-sourced γ rays

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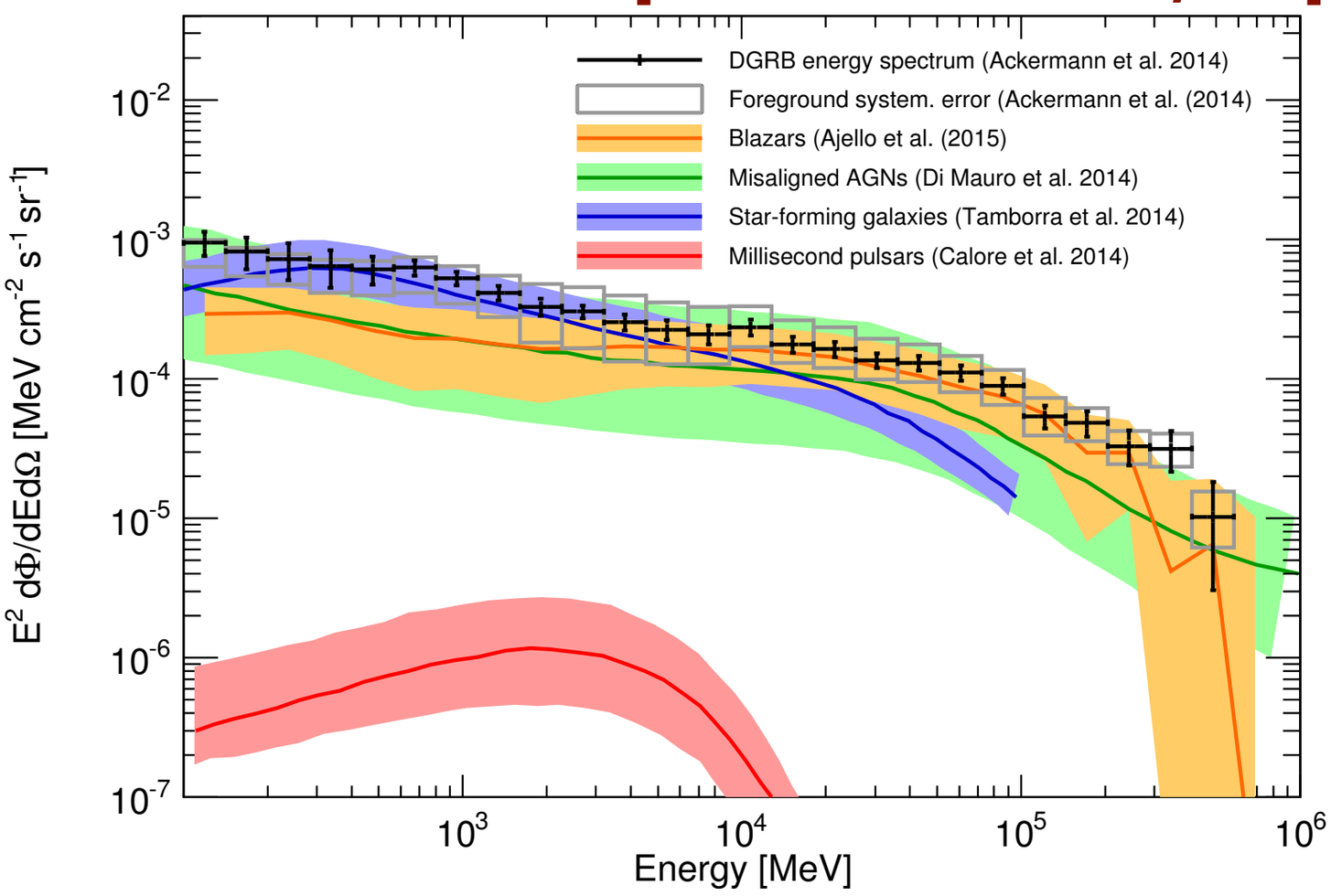
- Hunting down signals of WIMP annihilation/decay
  - γ-ray energy spectrum

[Fornasa & Sánchez-Conde, 2015]



DM-sourced γ rays

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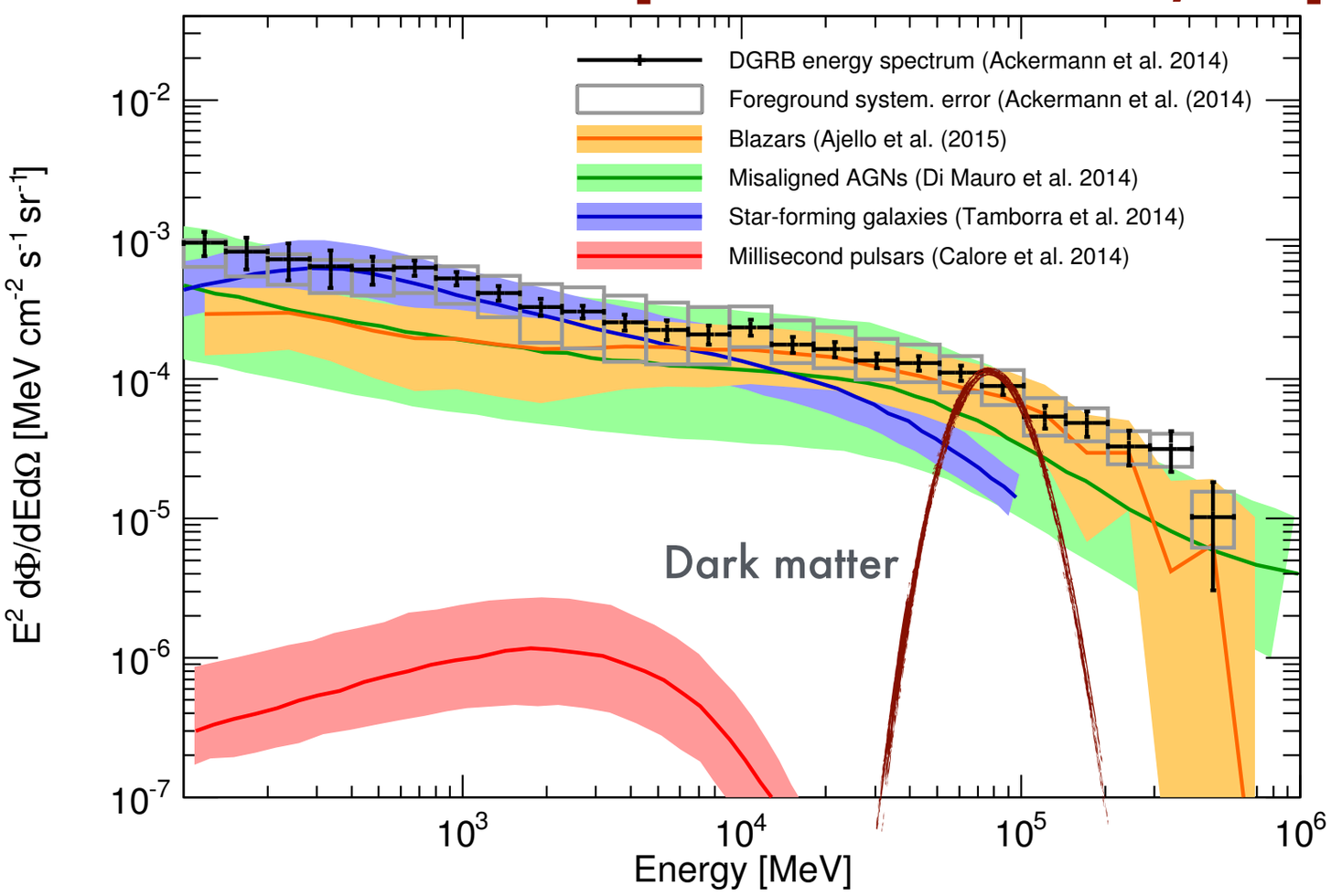

DM-sourced γ rays

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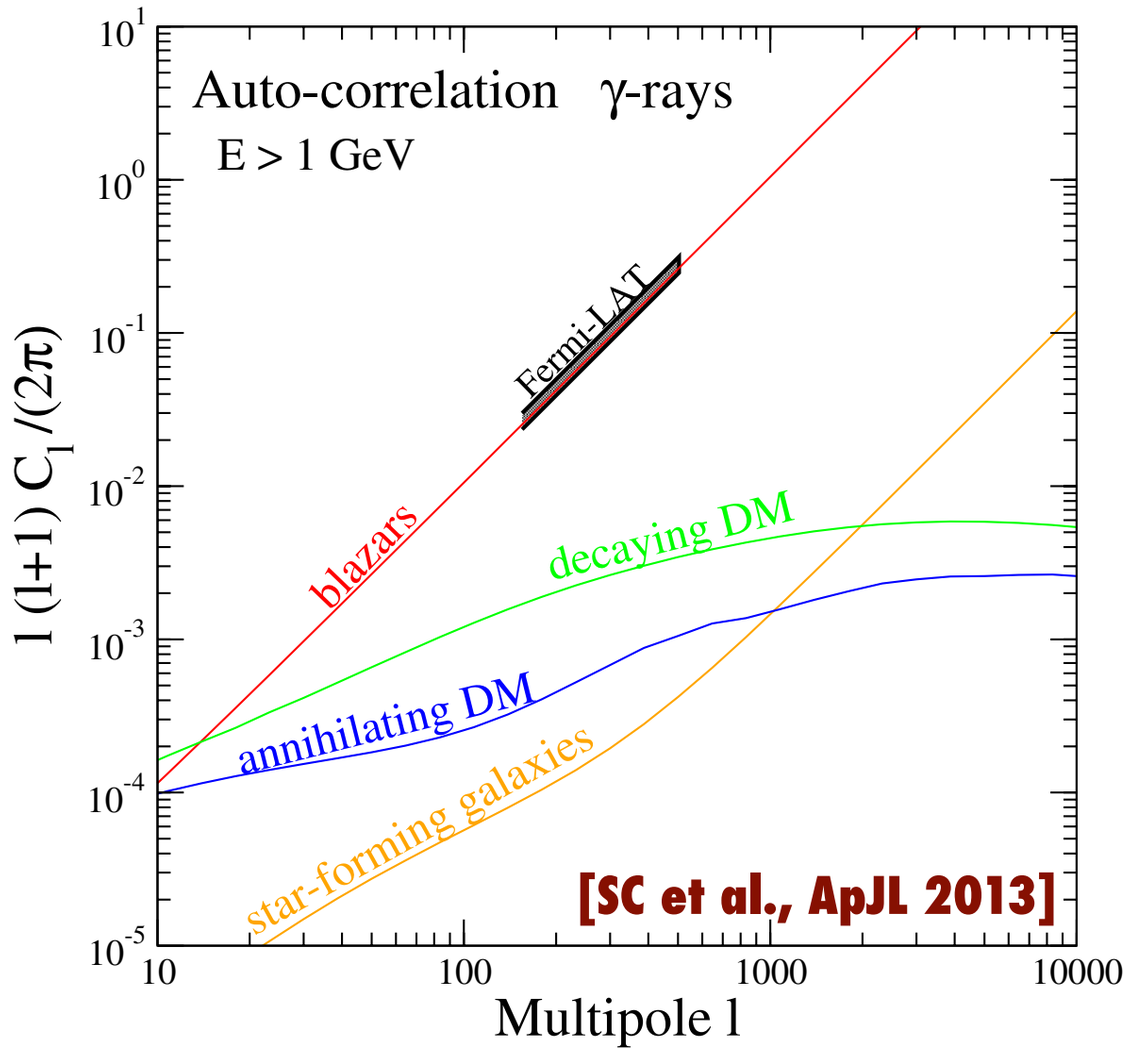
- Hunting down signals of WIMP annihilation/decay
  - γ-ray anisotropy angular power spectrum



DM gravitational probes

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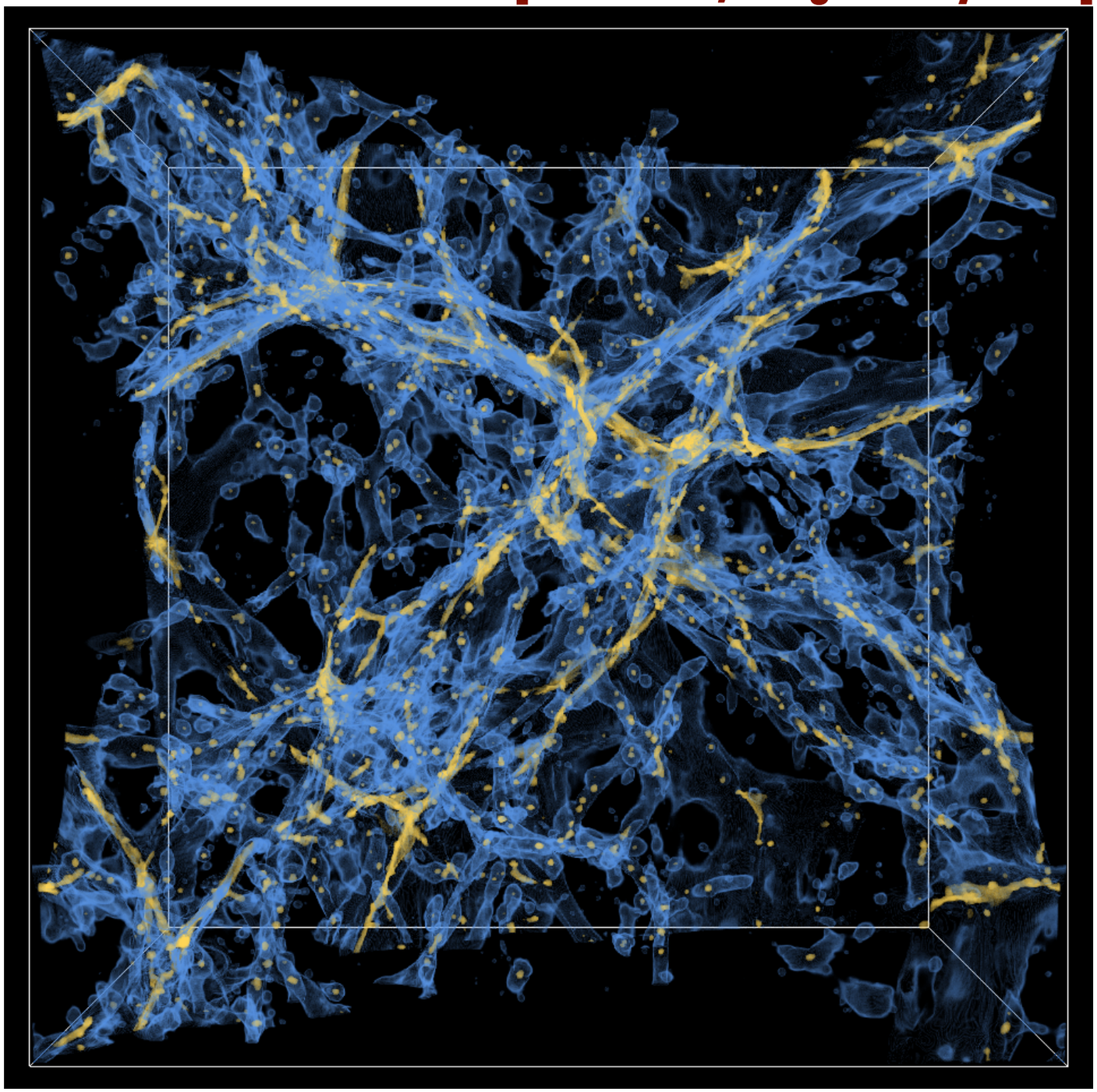
[Lukic et al.; Image: Casey Stark]



DM gravitational probes

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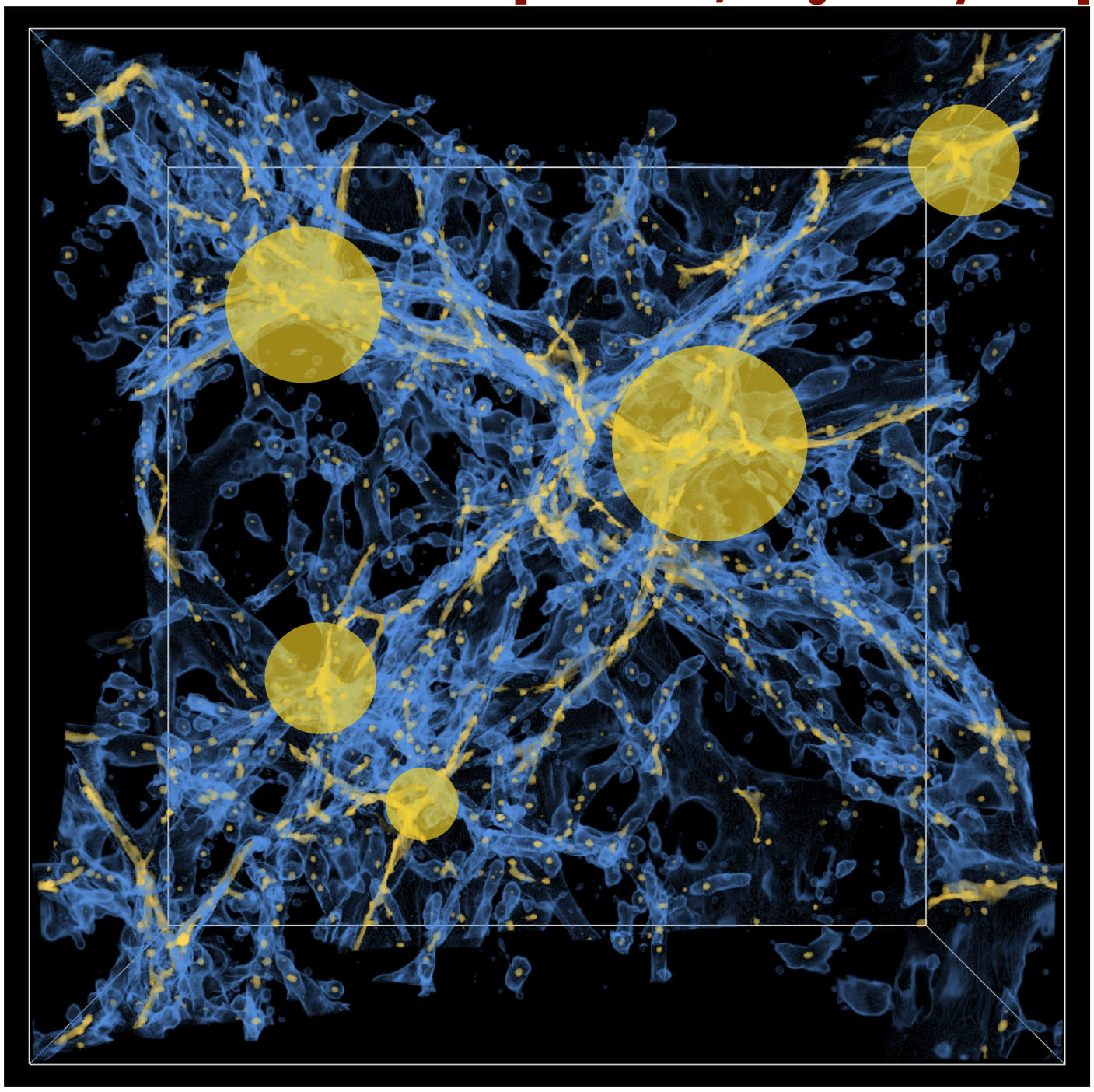

DM gravitational probes

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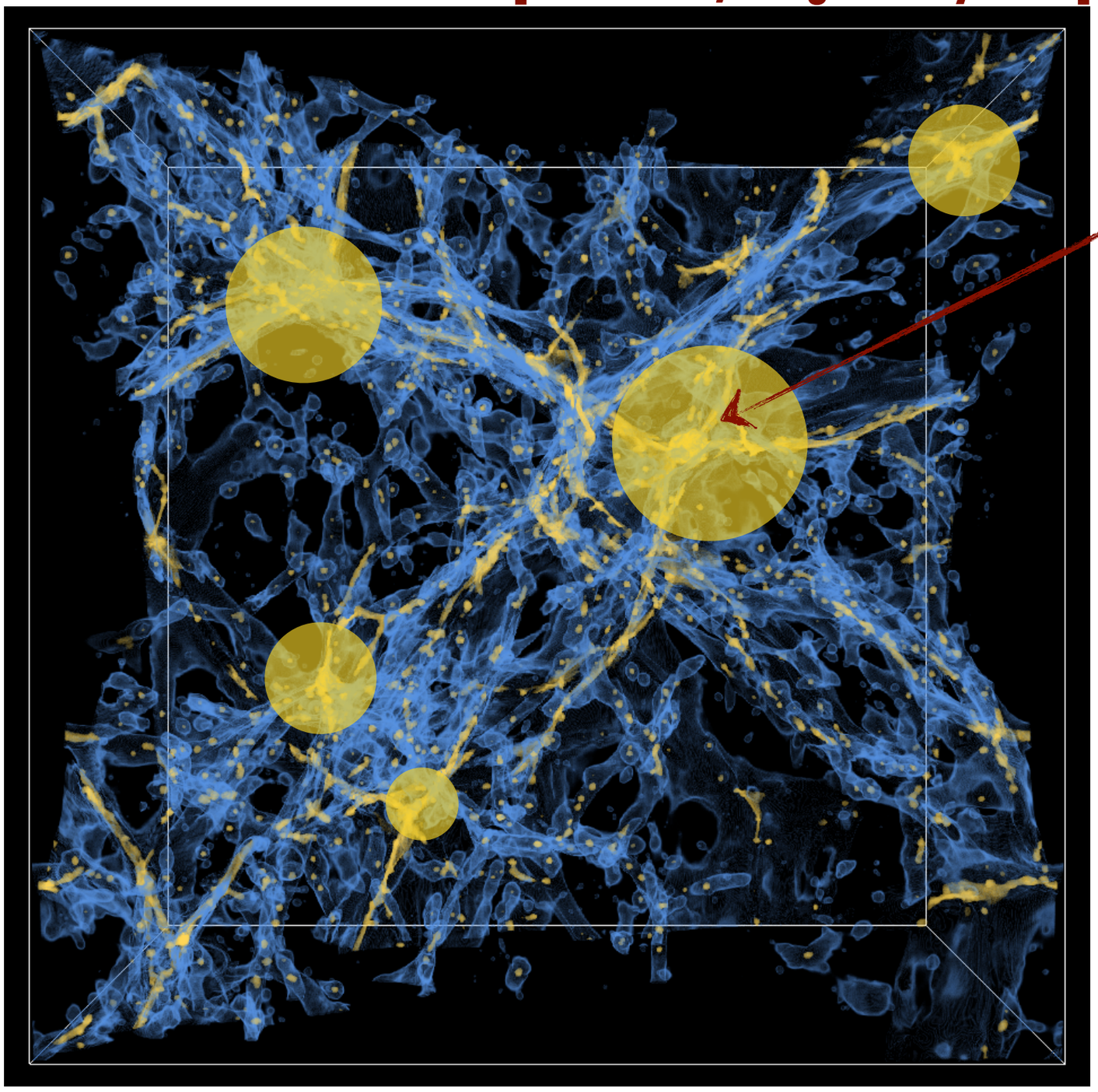

Galaxies,
galaxy clusters,
gravitational lensing

DM gravitational probes

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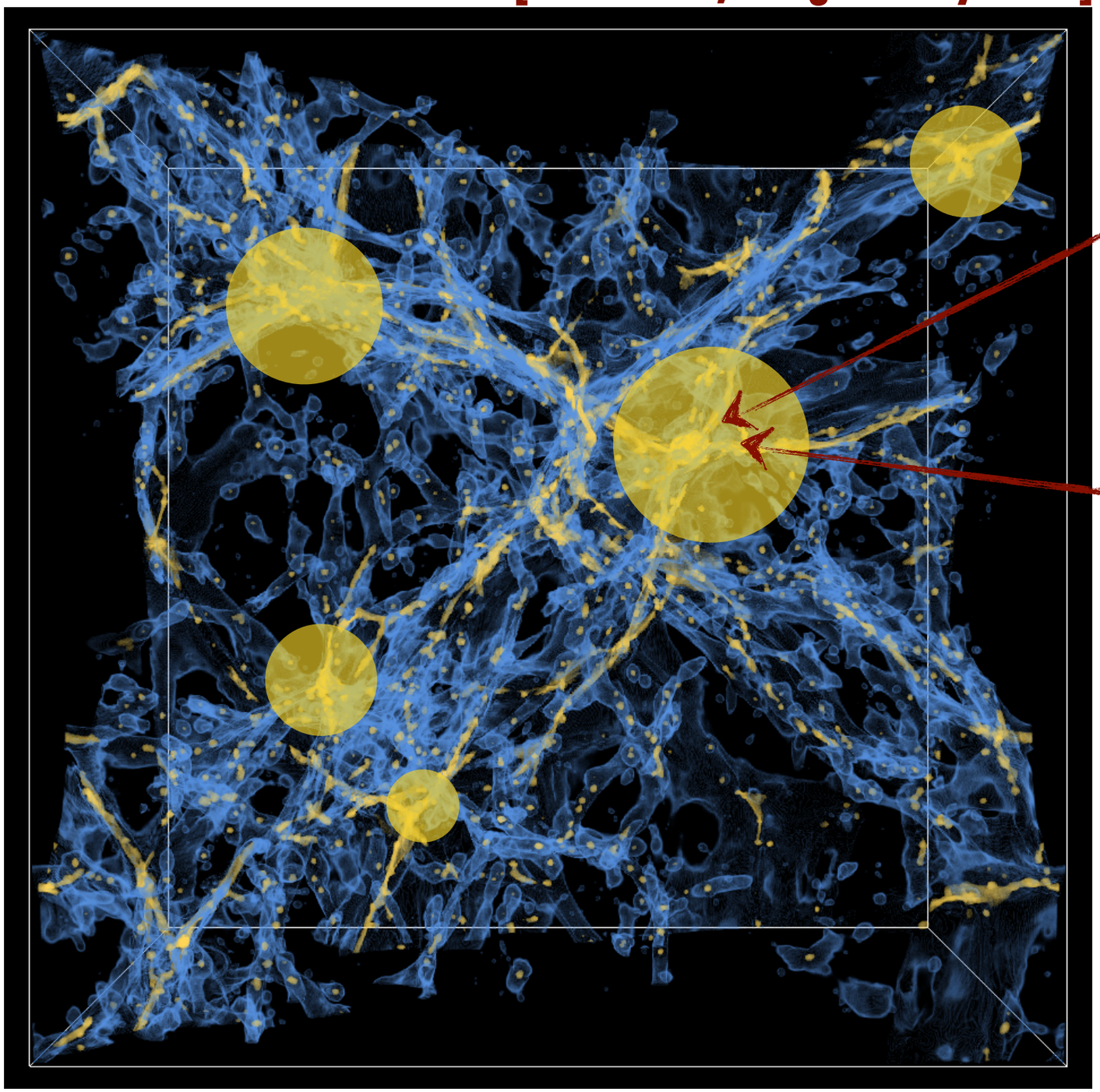

Galaxies,
galaxy clusters,
gravitational lensing

γ rays from
astrophysical sources
hosted within the
dark matter halo

DM gravitational probes

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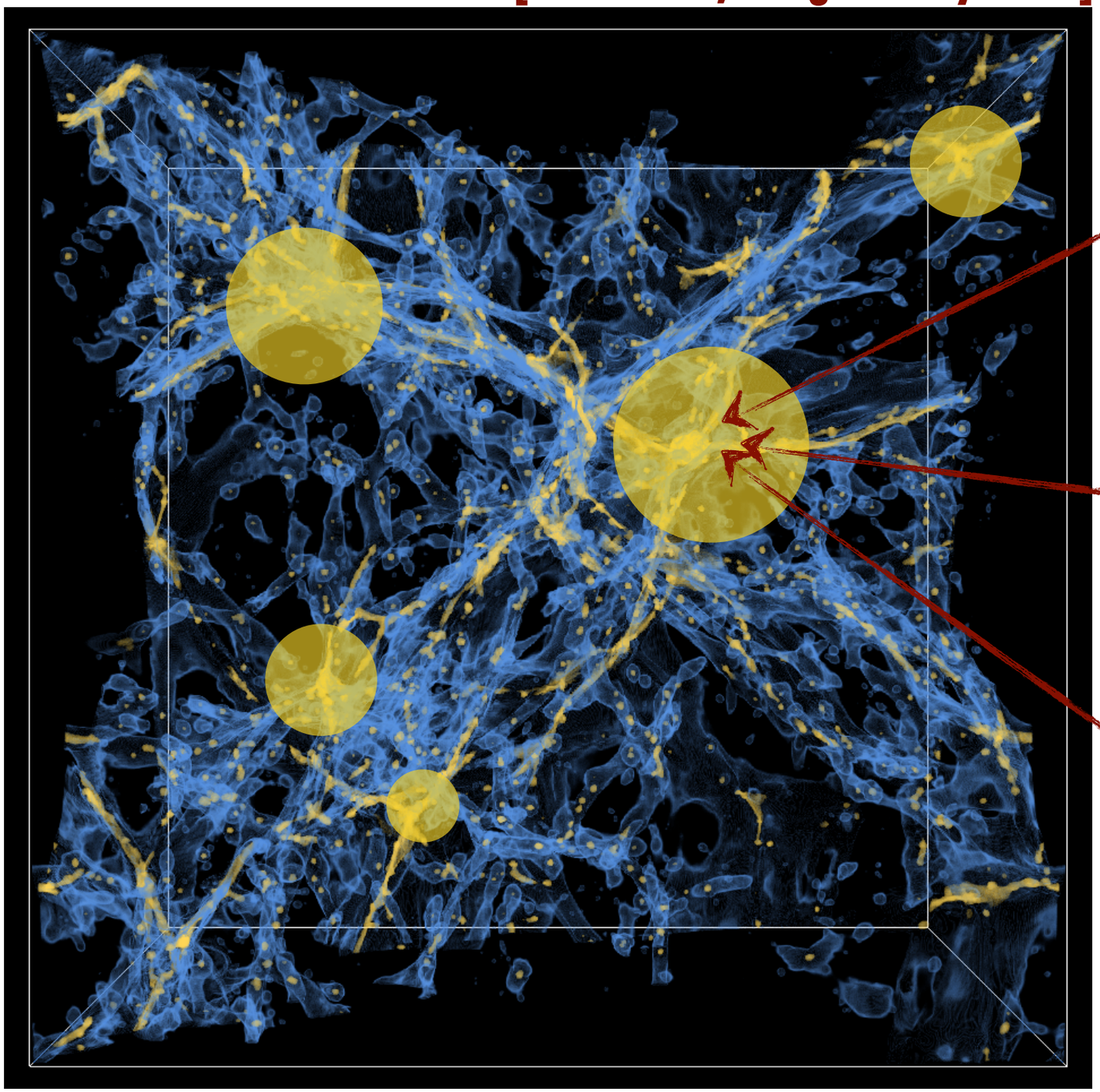

Galaxies,
galaxy clusters,
gravitational lensing

γ rays from
astrophysical sources
hosted within the
dark matter halo

γ rays from
annihilations/decays of
dark matter particles
forming the halo

DM gravitational probes

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- Find an optimal tracer of the cosmic dark matter distribution on large scale to filter out astrophysical non-thermal emission from the dark matter gamma-ray signal

DM gravitational probes

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- Find an optimal tracer of the cosmic dark matter distribution on large scale to filter out astrophysical non-thermal emission from the dark matter gamma-ray signal

- Main tracers of the cosmic large-scale structure:

  - Weak gravitational lensing (cosmic shear, CMB lensing…)
    [SC et al., ApJL 2013; Fornengo, SC et al., ApJL 2015; Shirasaki et al. 2013; 2015; 2018; Tröster, SC et al., 2017; Ammazzalorso, SC et al., PRL 2020]

  - Clustering of structures (galaxies, galaxy clusters…)
    [Fornengo & Regis, 2014; Ando et al., 2014; Xia et al., ApJS 2015; Regis et al., PRL 2015; Shirasaki et al., 2015, Branchini, SC et al., ApJS 2017; Colavincenzo, SC et al., 2019]

Cosmic shear & γ rays

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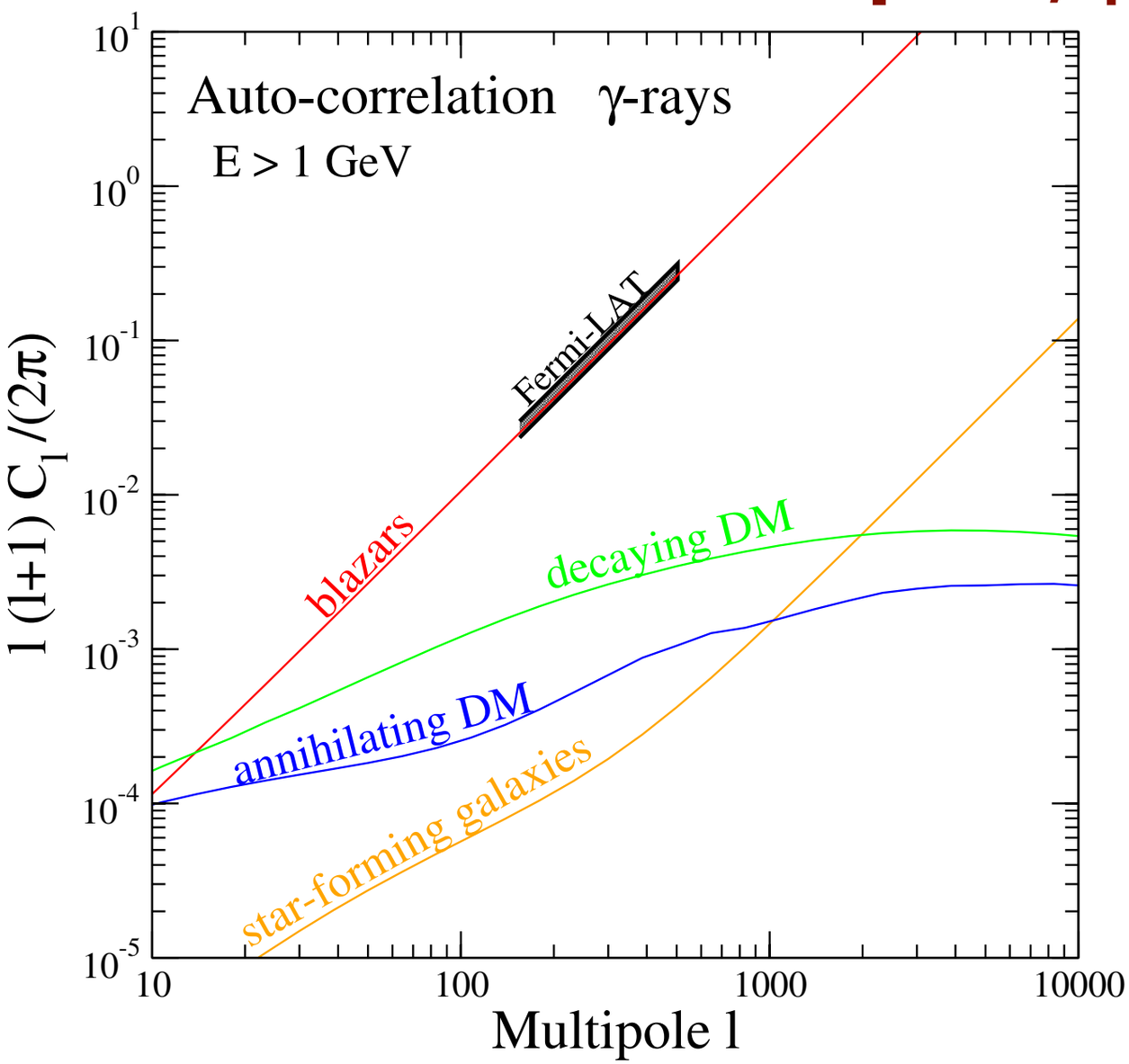
Fermi Gamma-ray Space Telescope

[SC et al., ApJL 2013]



Cosmic shear & γ rays

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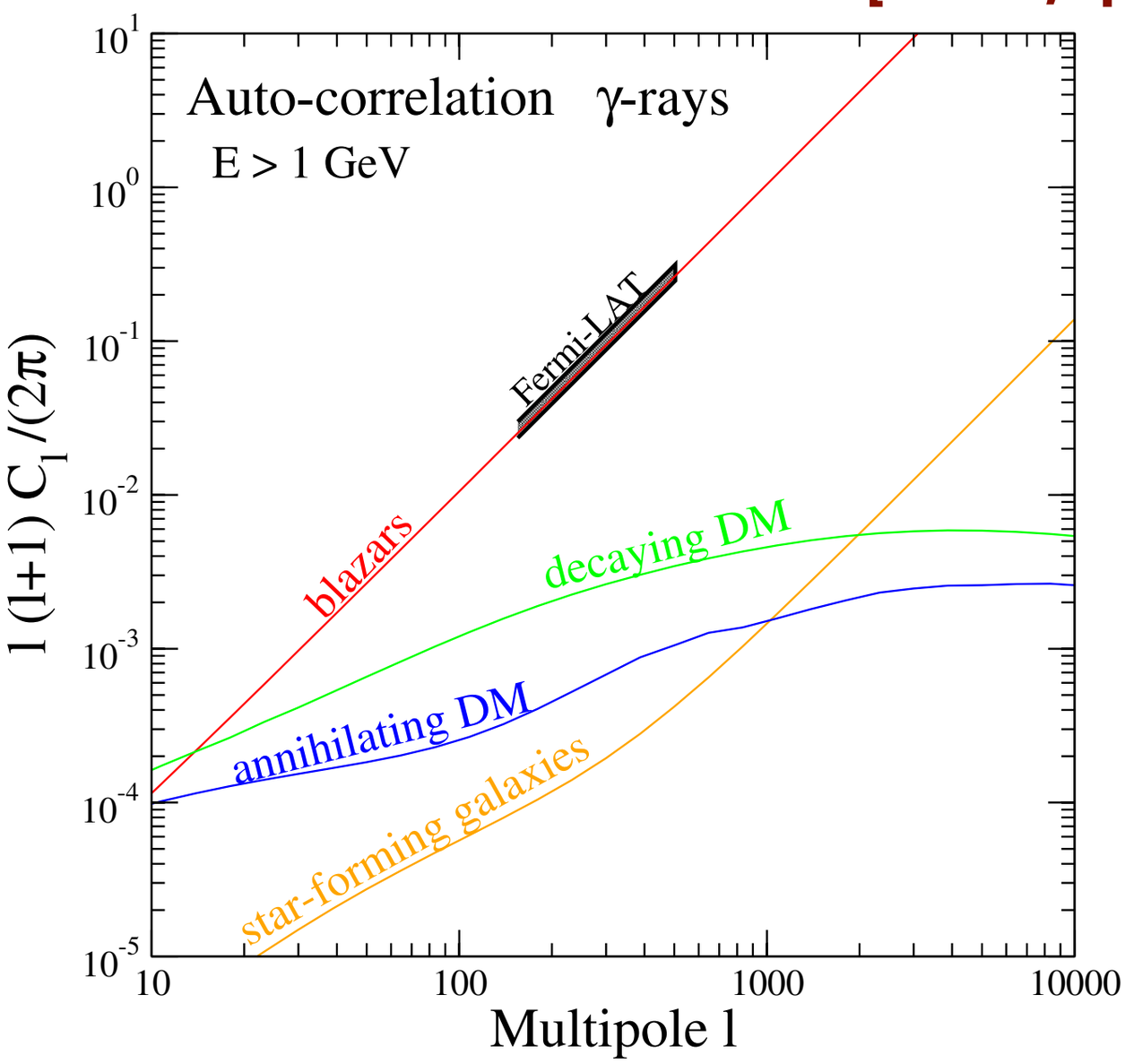
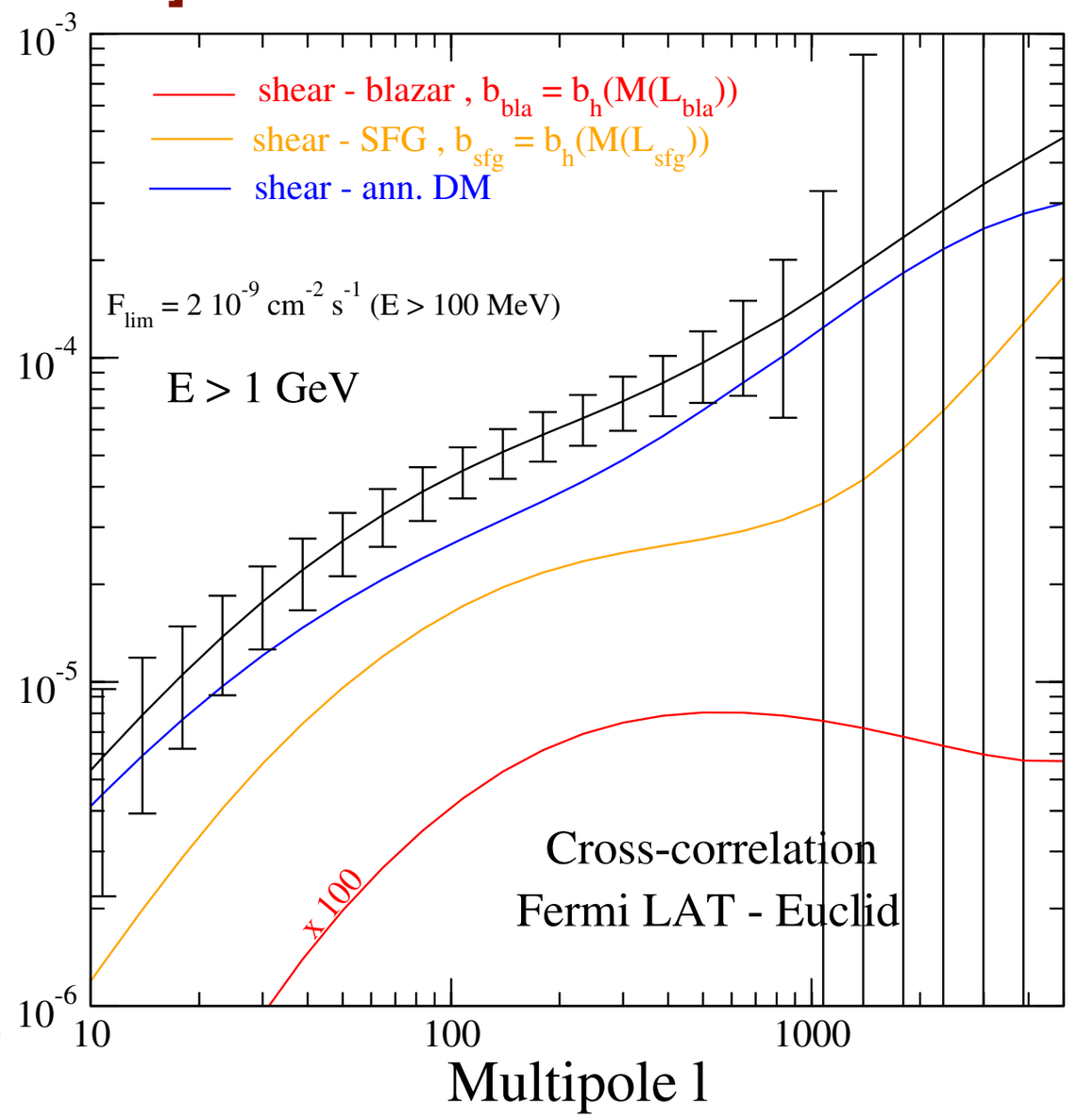
euclid

[SC et al., ApJL 2013]





Cosmic shear & γ rays

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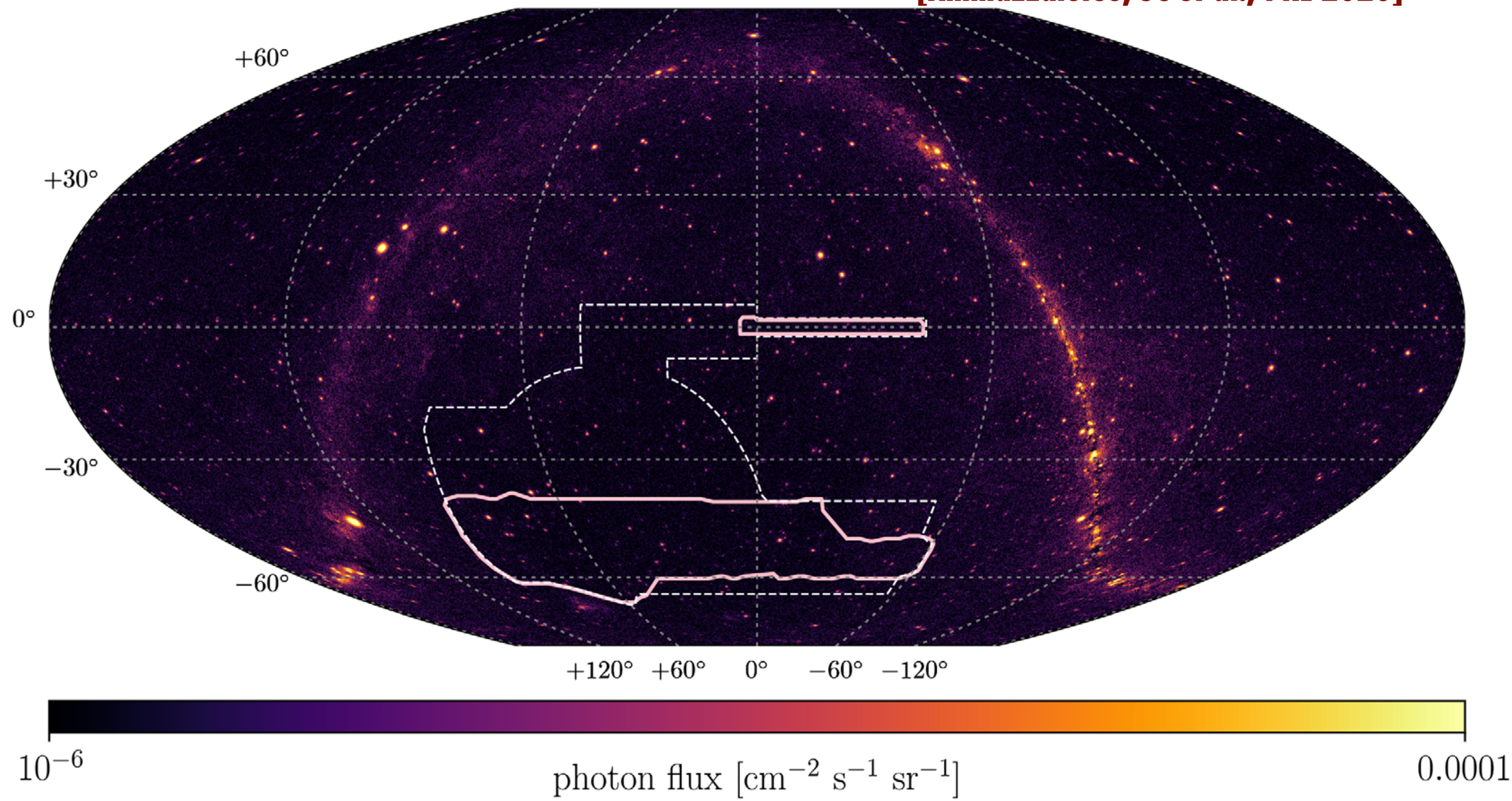
[Ammazzalorso, SC et al., PRL 2020]



Cosmic shear & γ rays

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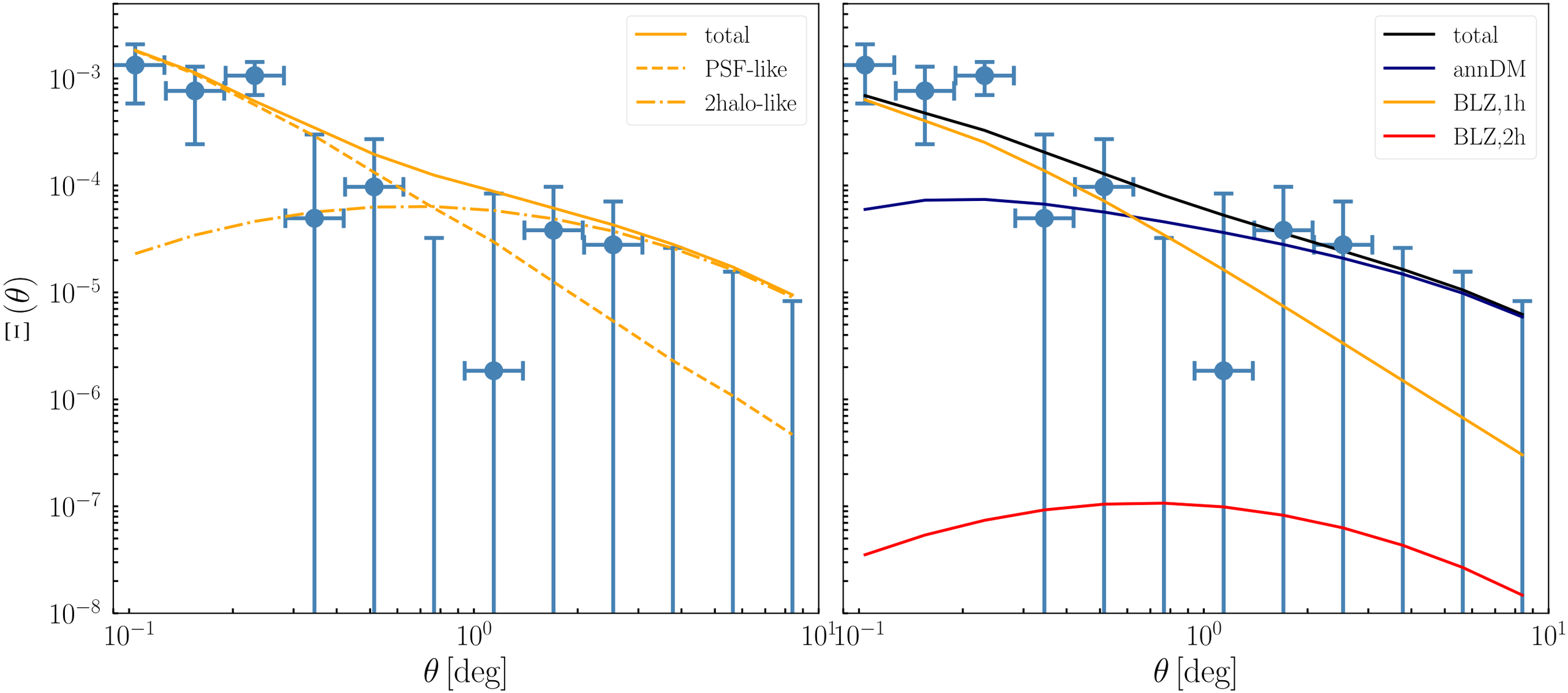
Fermi Gamma-ray Space Telescope

THE DARK ENERGY SURVEY

[Ammazzalorso, SC et al., PRL 2020]



Cosmic shear & γ rays

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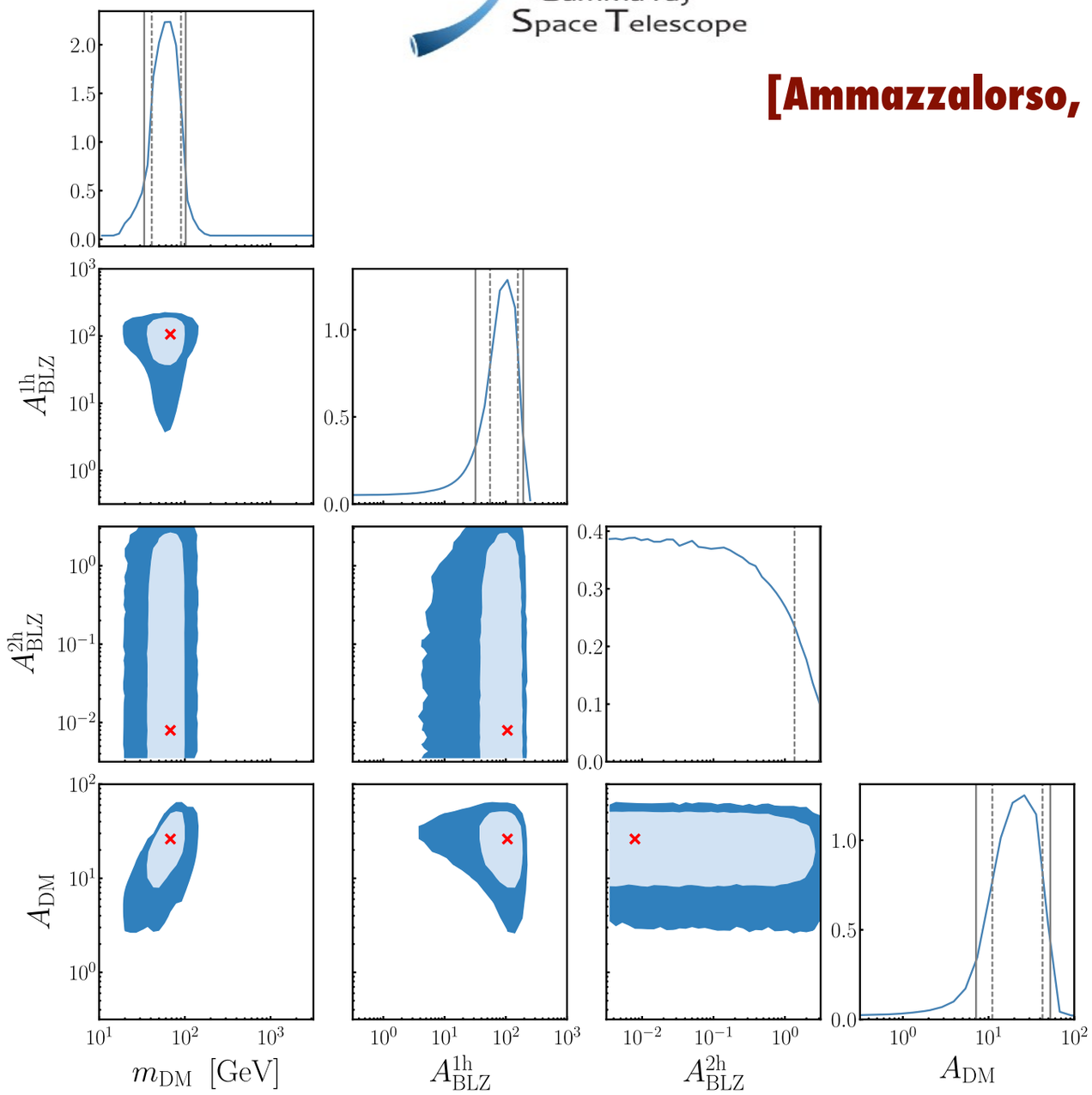

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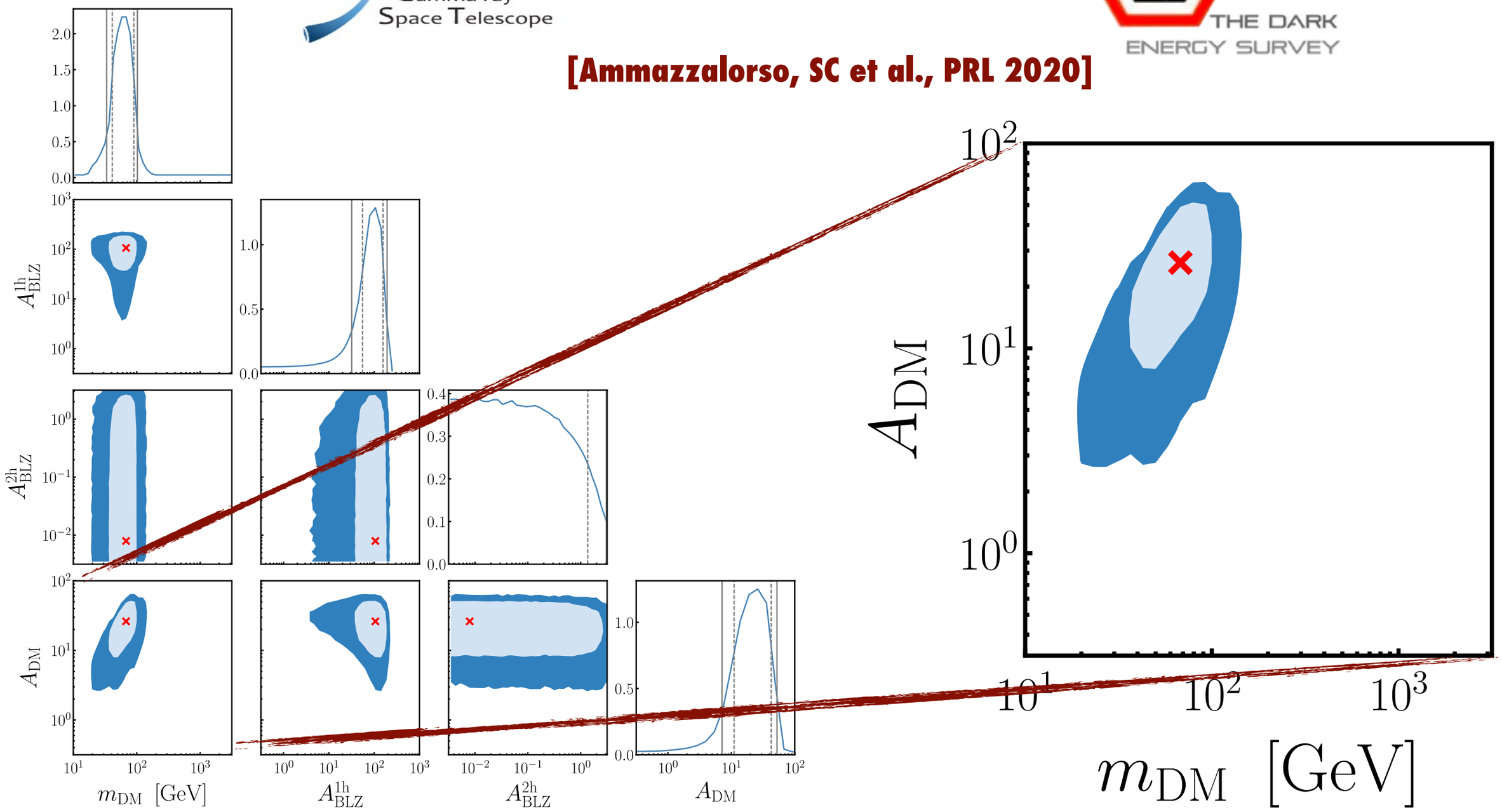

Summary

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- Great time for cosmological synergies at various wavelengths

- Cross-correlations crucial for:

  - Cross-checking validity of cosmological results

  - Accessing signal buried in noise or cosmic variance
    [e.g. particle dark matter, multi-tracing for non-Gaussianity]

  - Removing/alleviating contamination from systematic effects
    [e.g. radio-optical cosmic shear]