

Probing localized structures using weak-lensing of 21cm fluctuations

Ely D. Kovetz

University of Texas at Austin

BCCP Workshop, April 18th, 2013

Based on:

“Galaxy-cluster masses via 21st-century measurements of lensing of 21cm fluctuations”

Phys. Rev. D. 87, 063516 [arXiv:1210.3041]

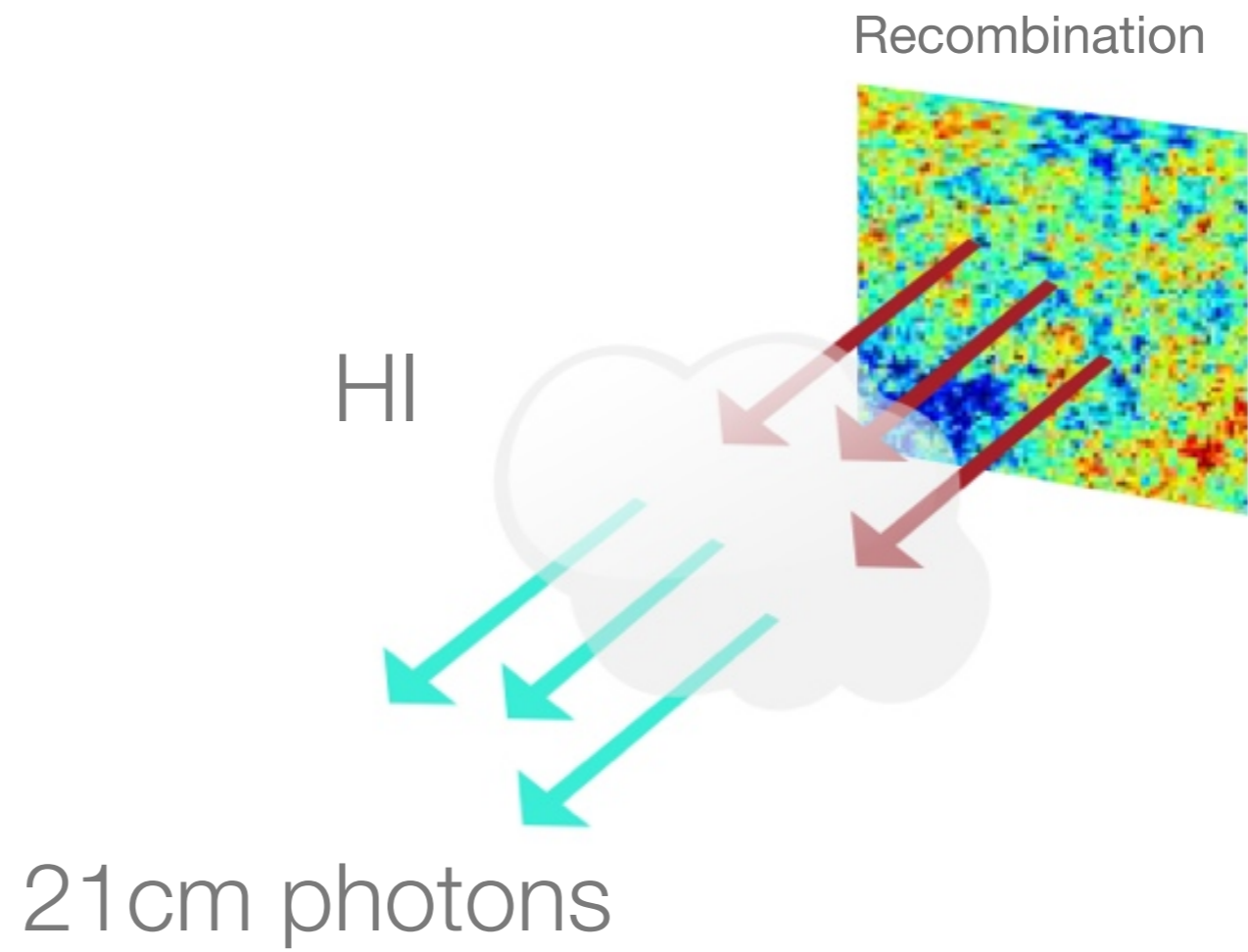
“21cm lensing and the Cold Spot in the Cosmic Microwave Background”

Phys. Rev. Lett., to be published [arXiv:1211.4610]

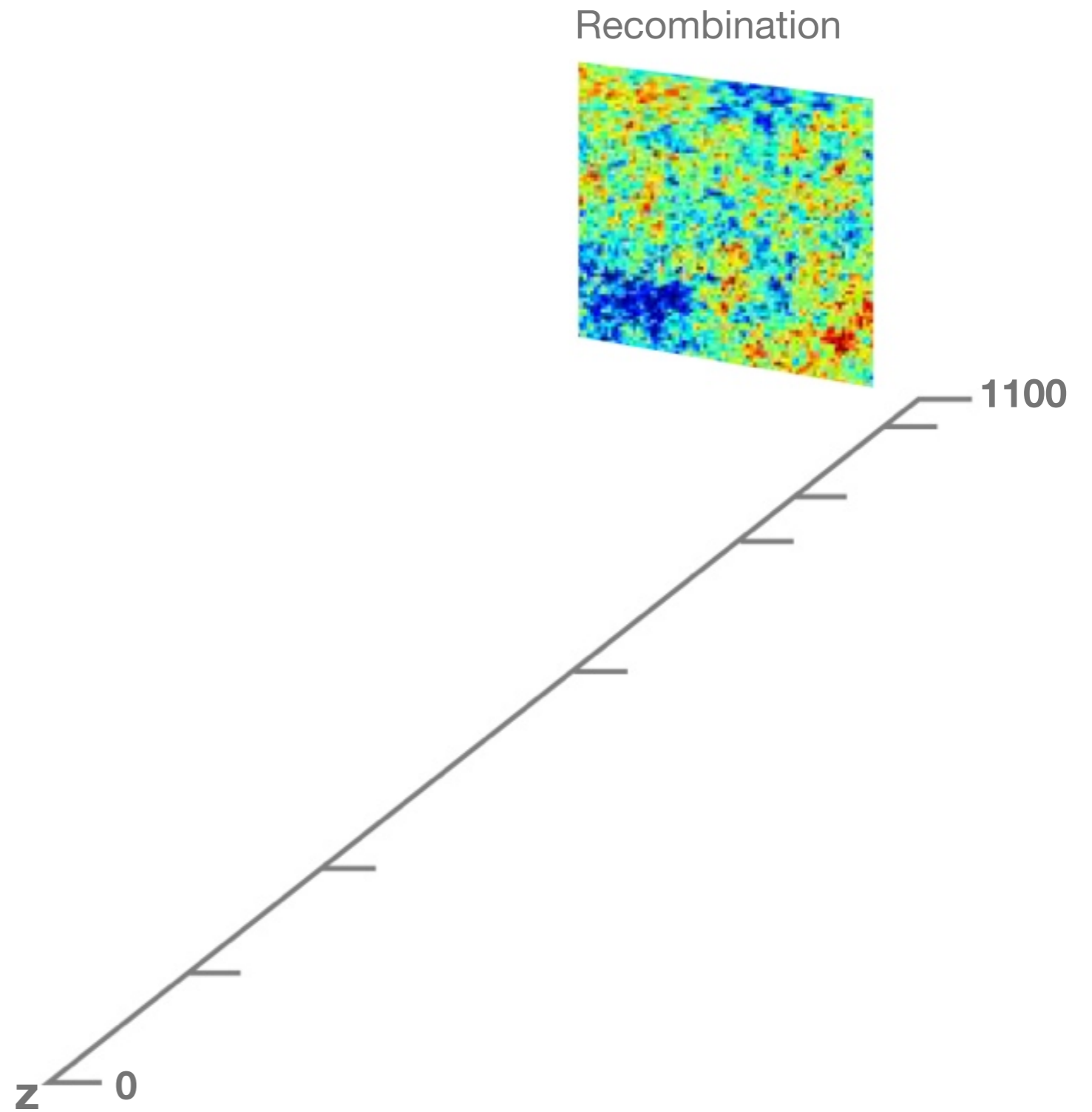
with M. Kamionkowski (JHU)

Lightning Review

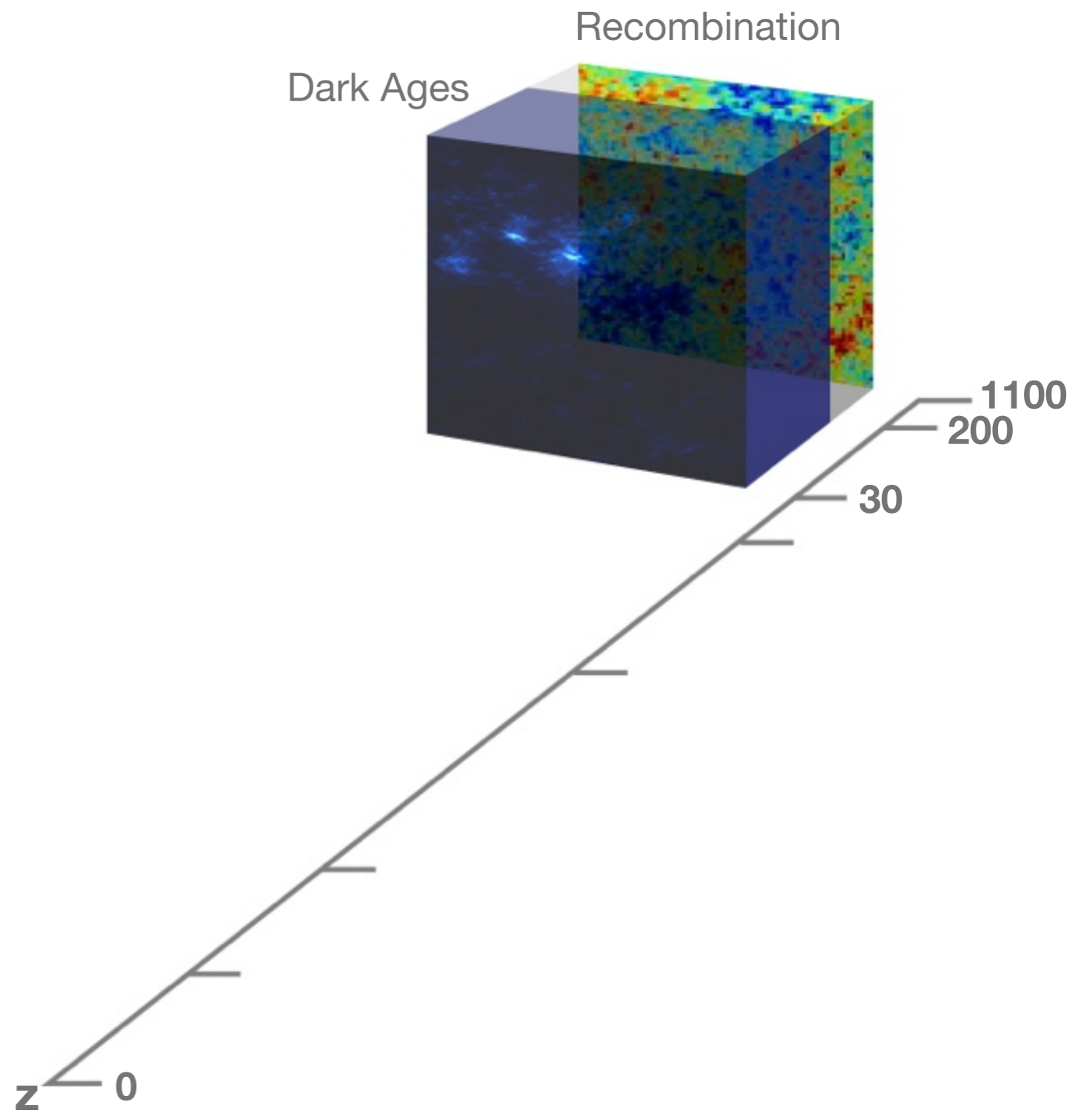
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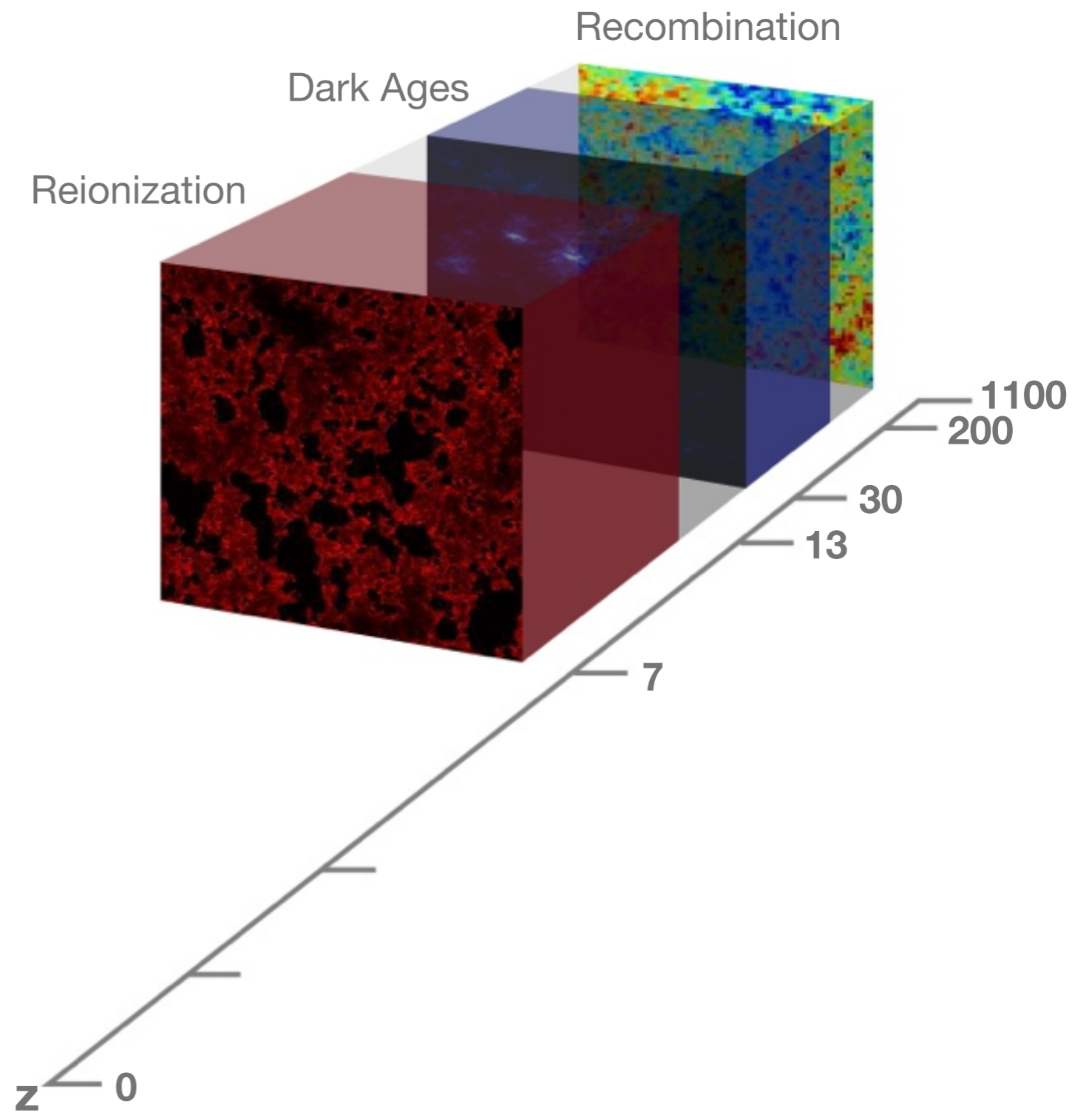
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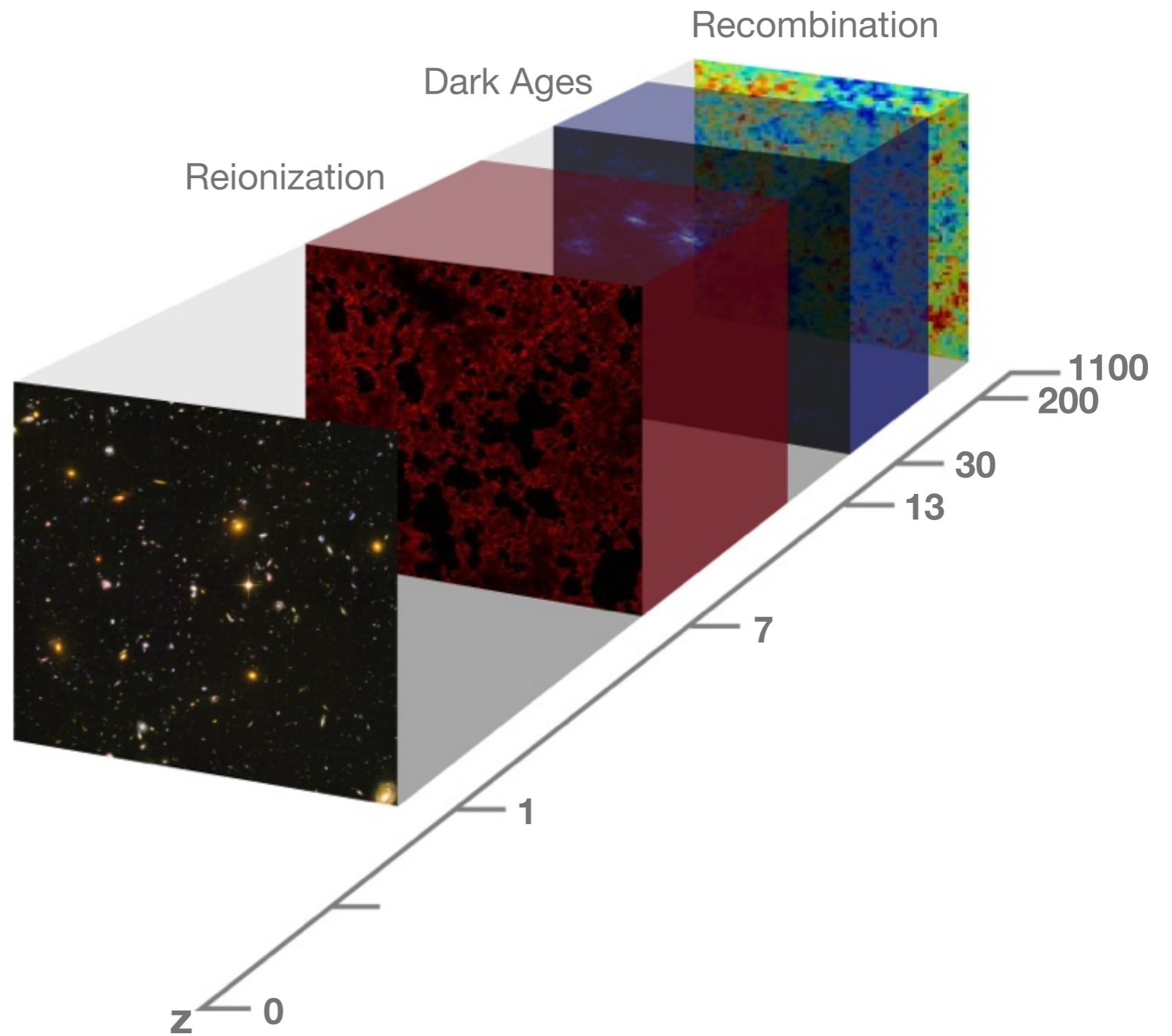
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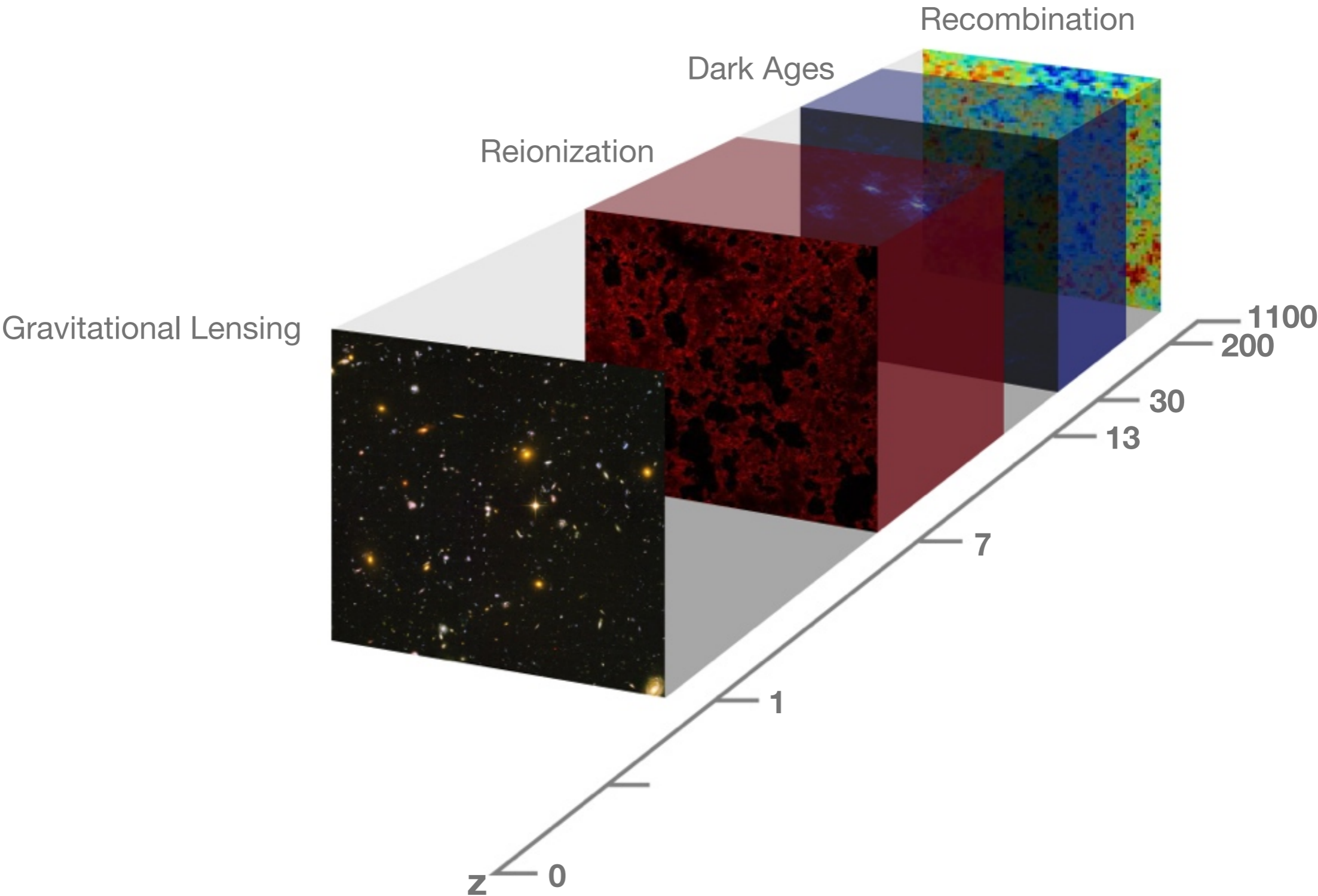
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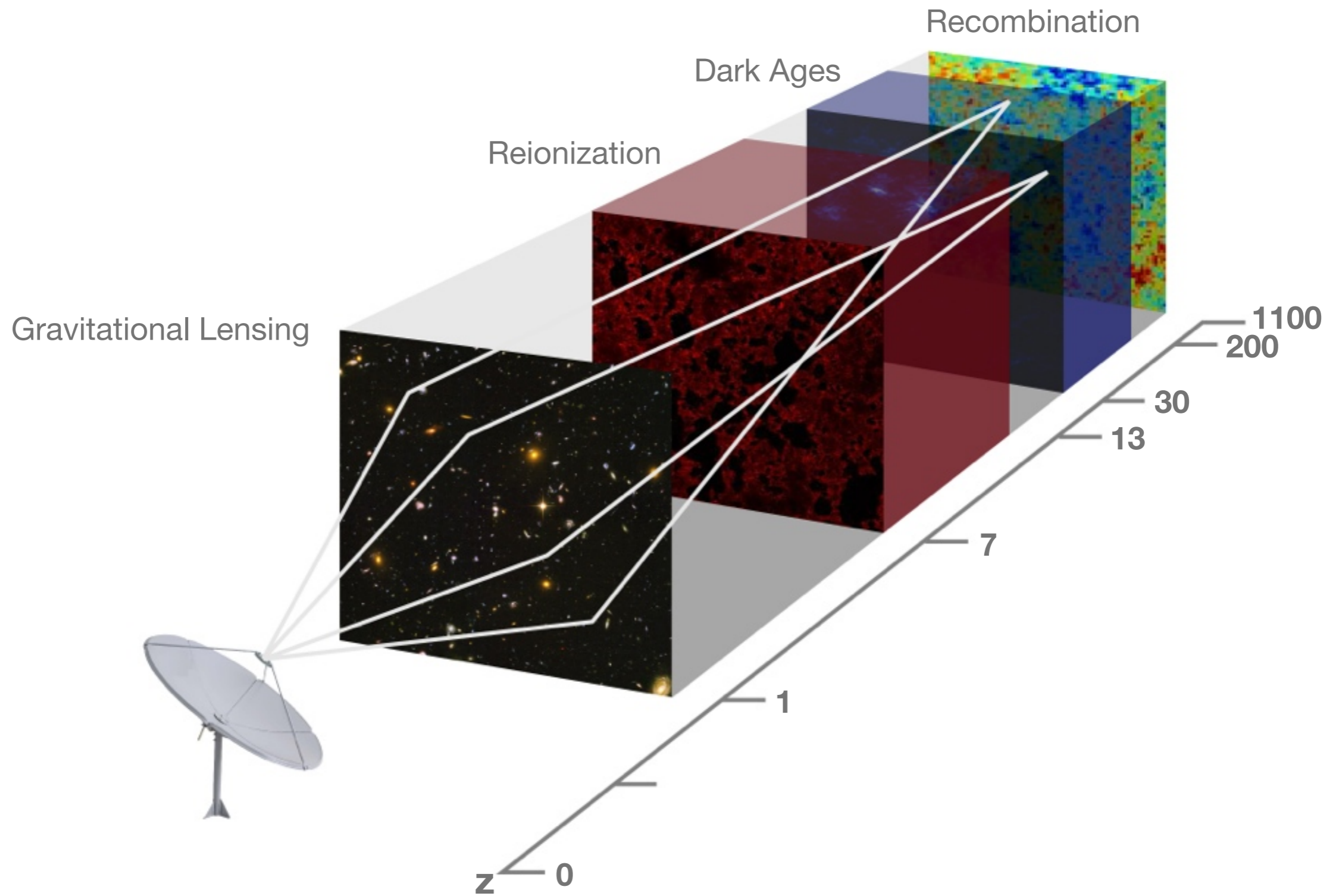
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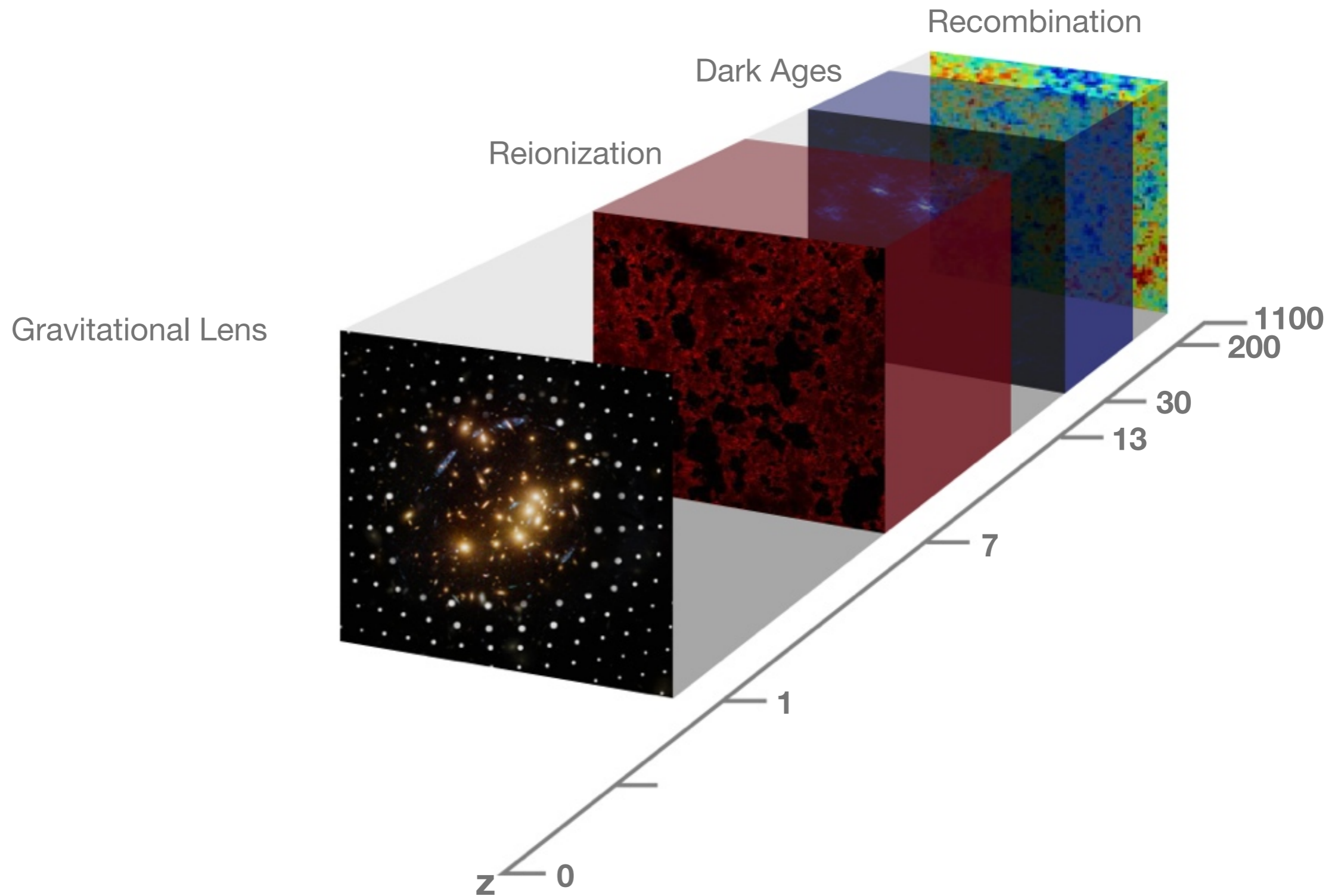
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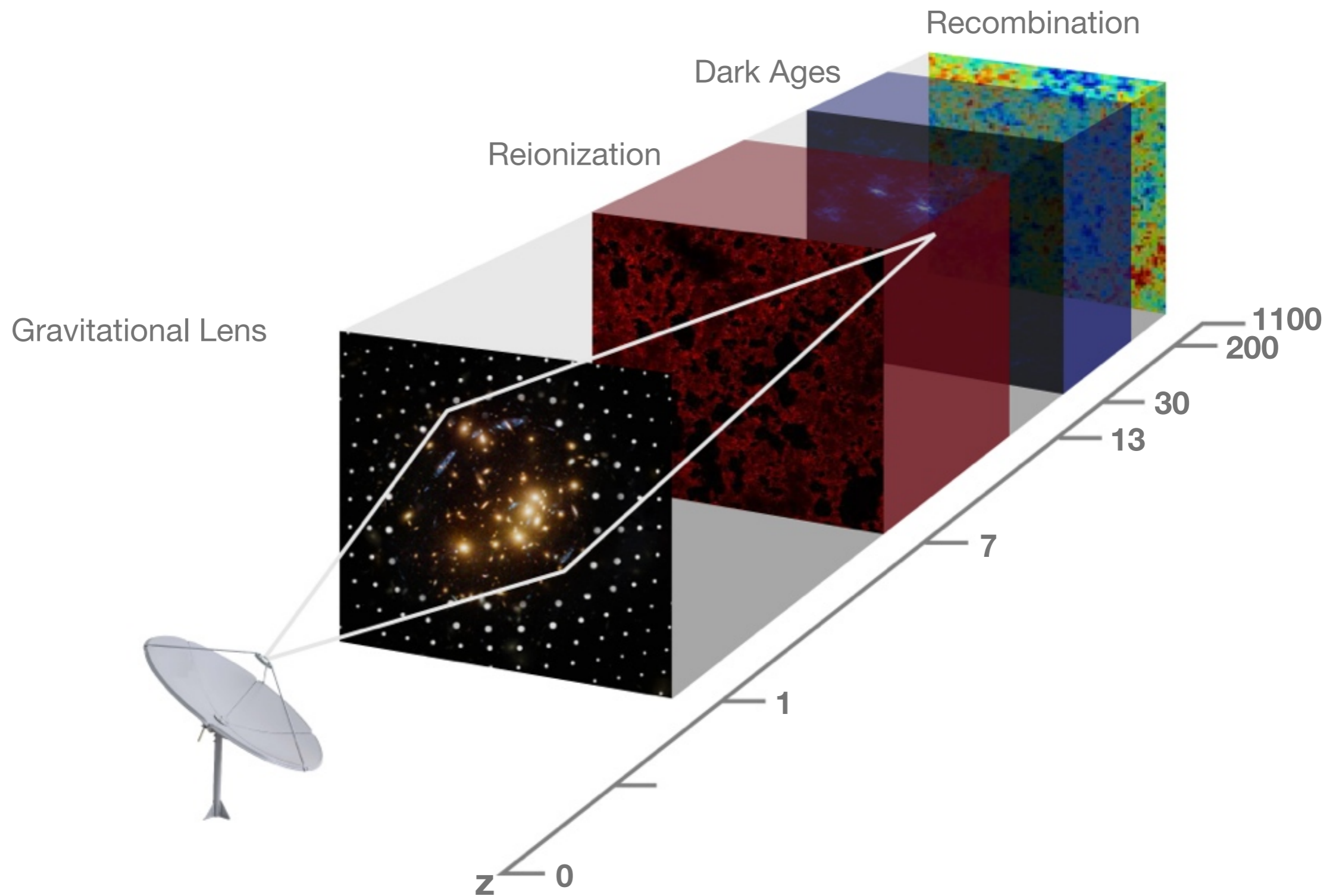
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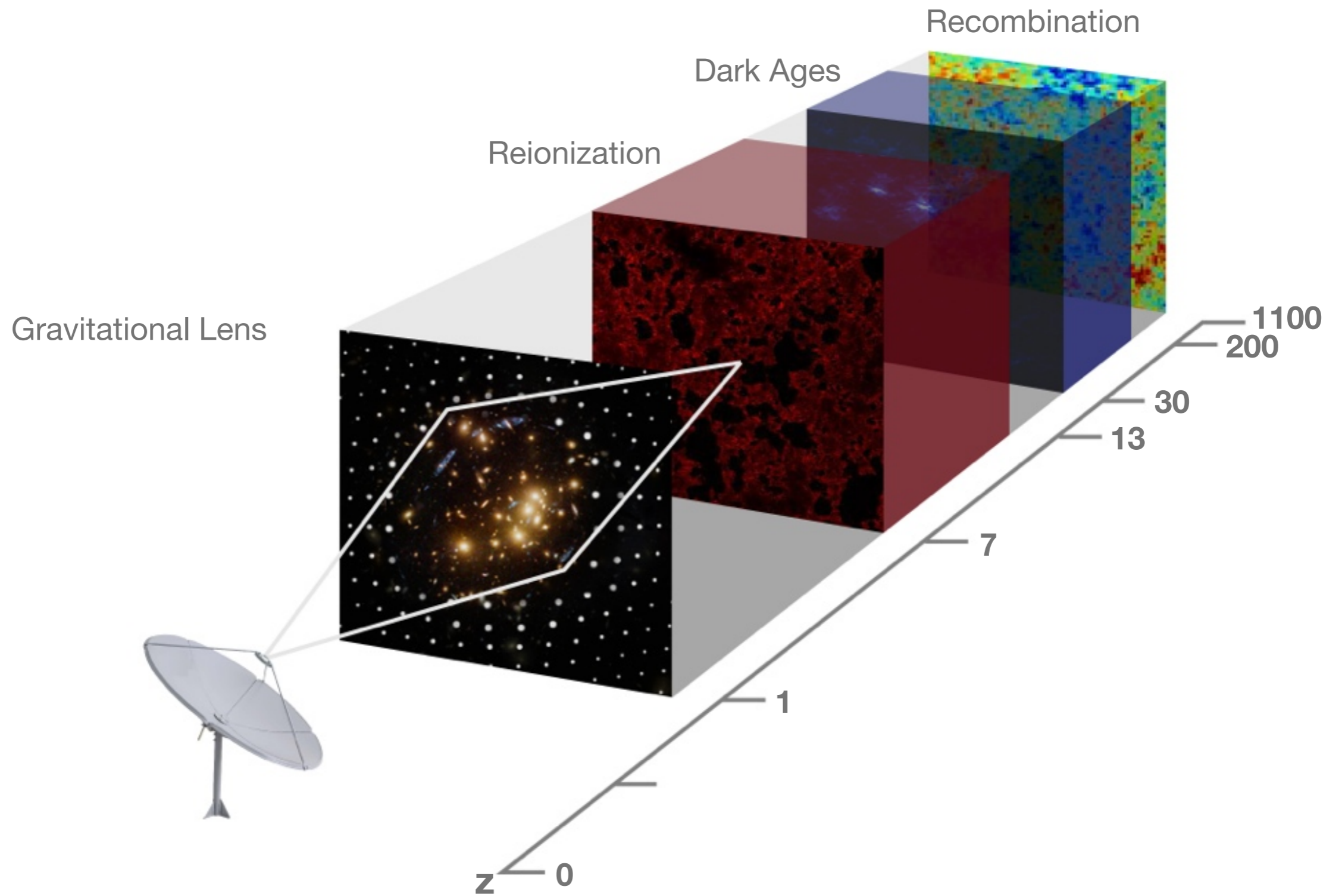
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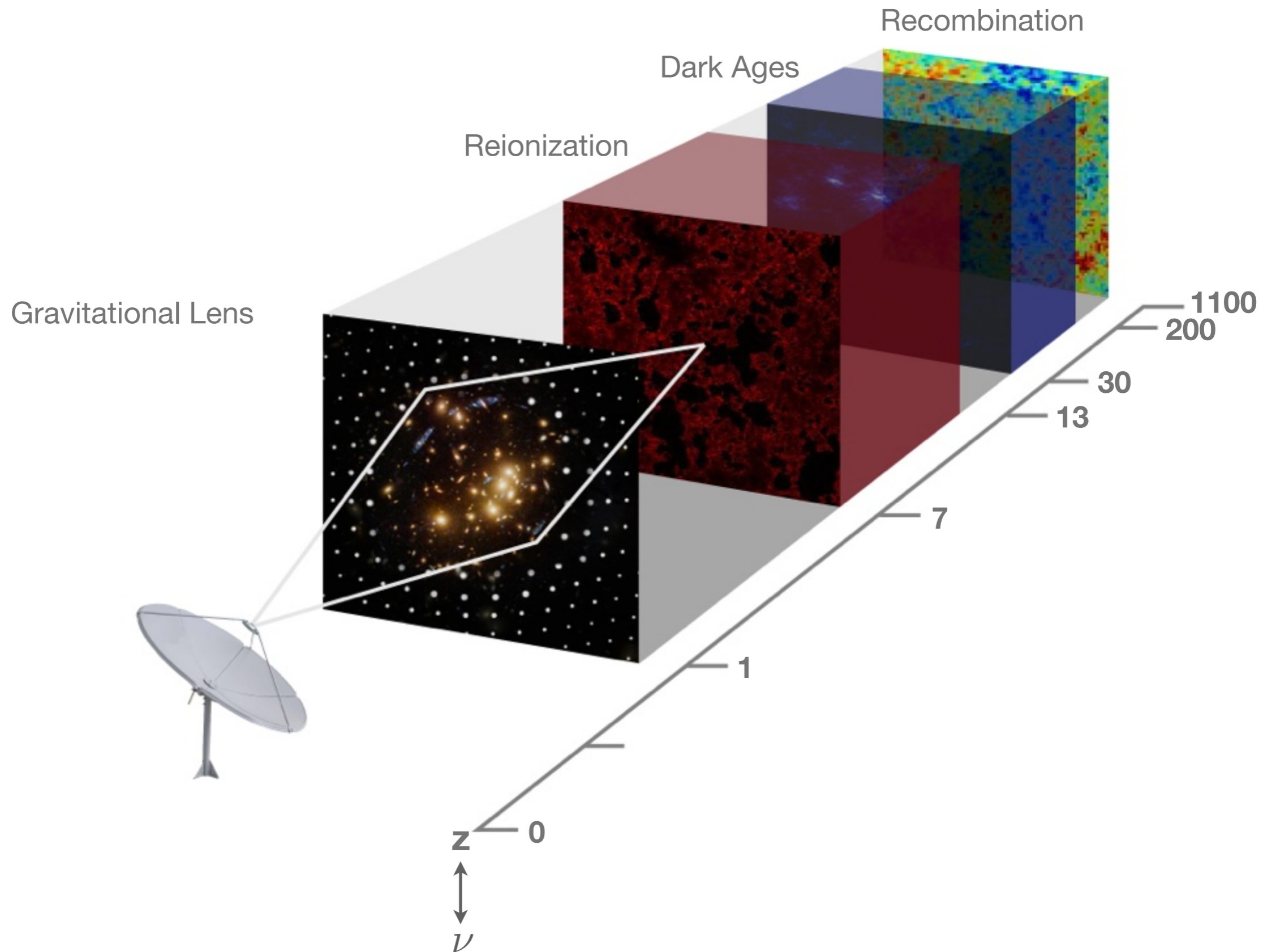
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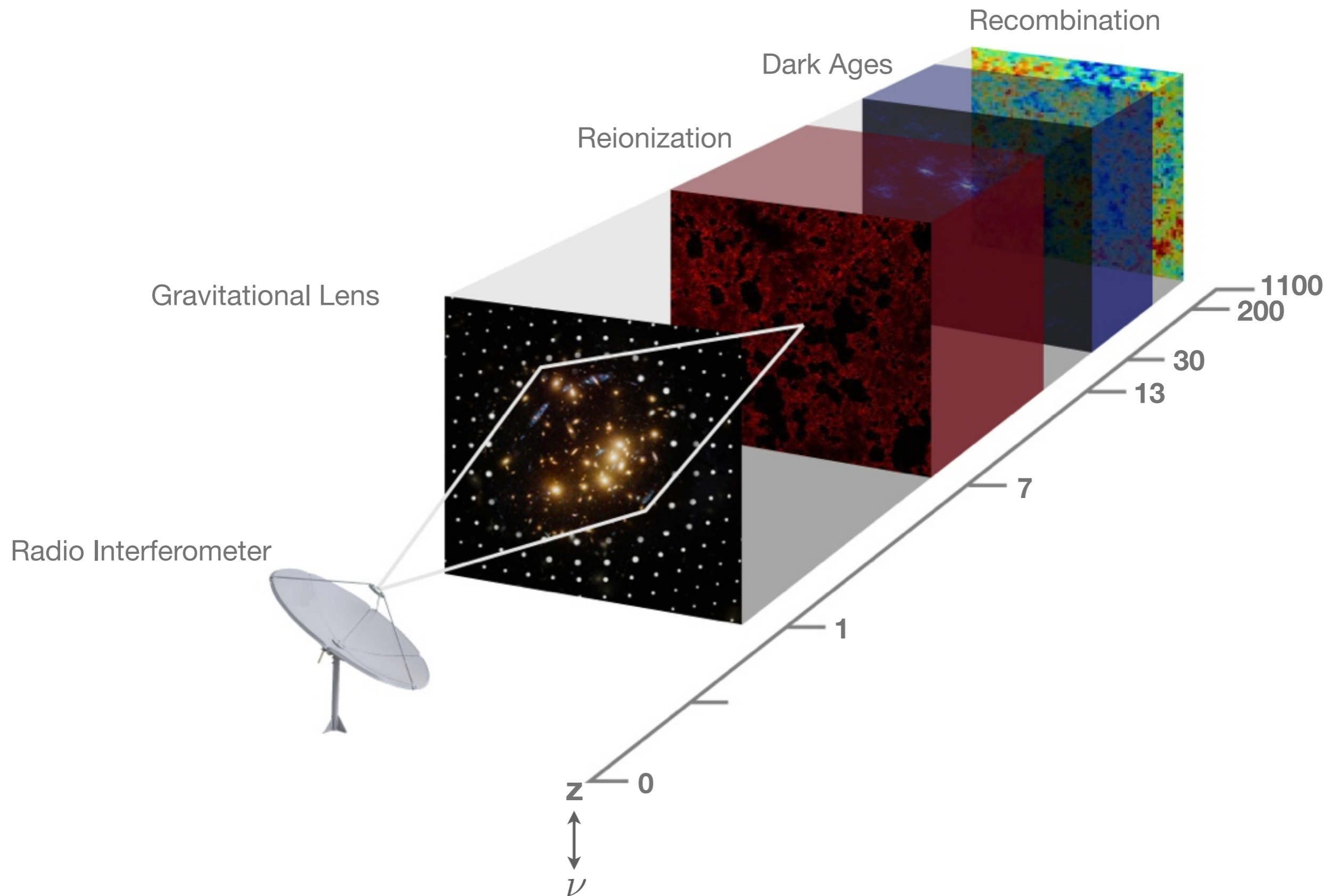
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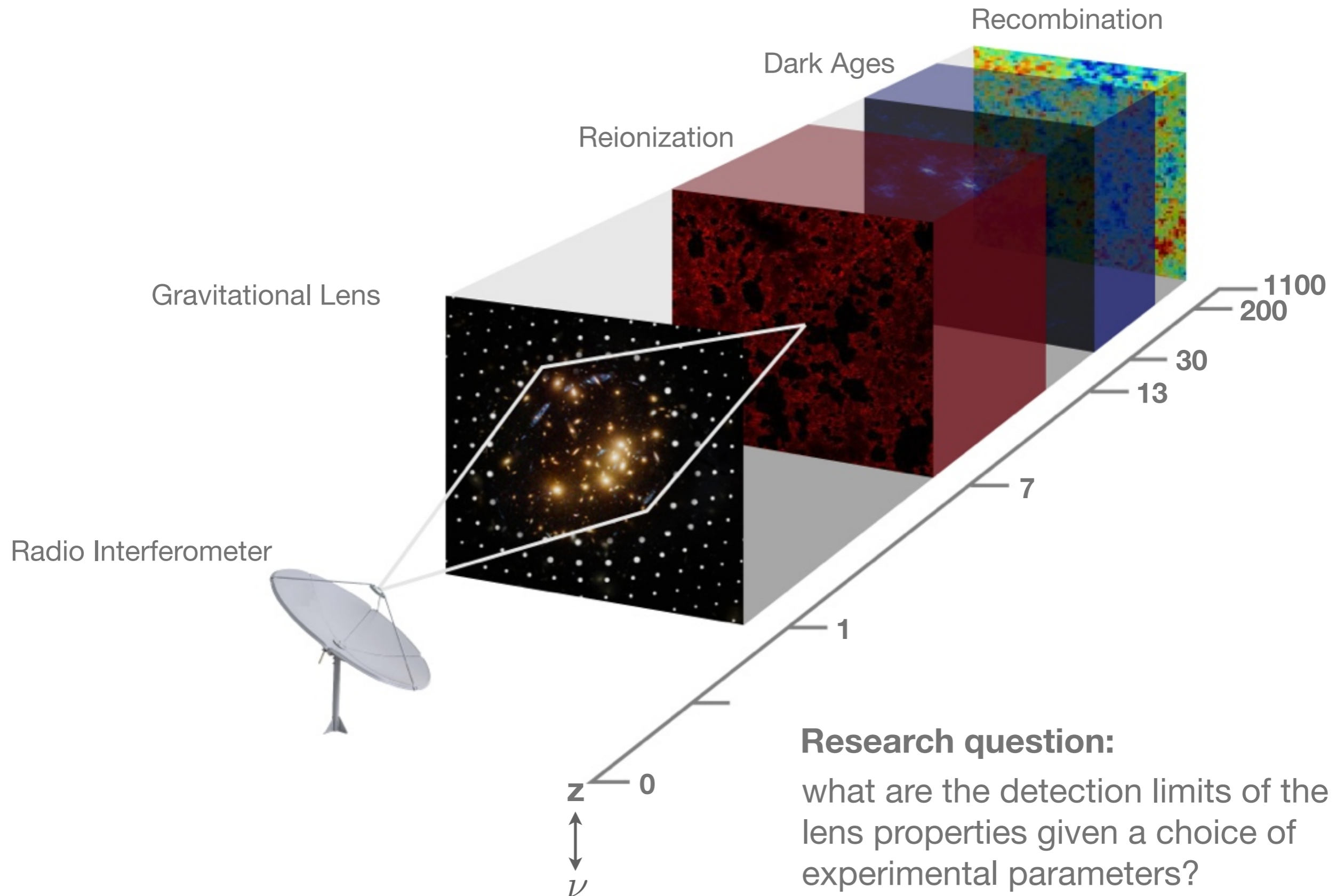
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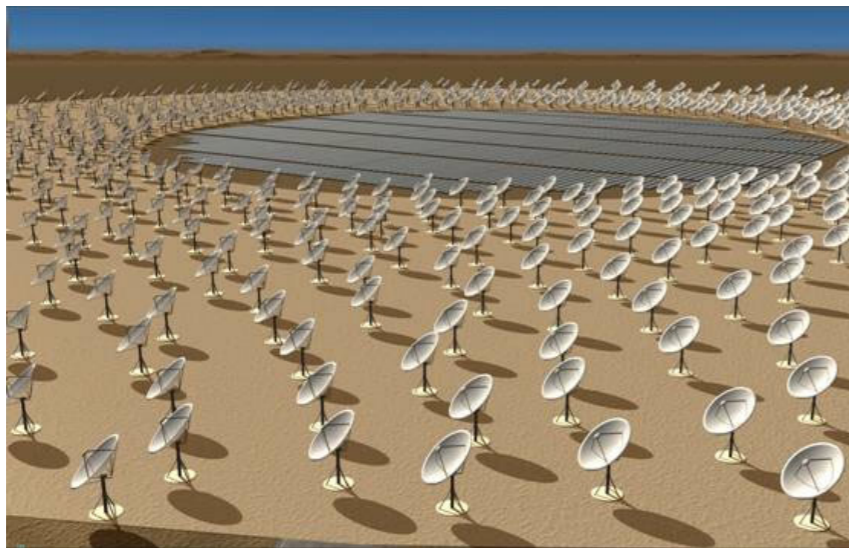
Lightning Review



Radio Interferometers

Radio Interferometers

- Experimental parameters: ν , $\Delta\nu$, f_{cover} , t_o , $B \rightarrow l_{\text{cover}}(\nu)$



21cm: The Reality Gap

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Ideally

Realistically

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Ideally

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Damping:

21 cm: The Reality Gap

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Realistically

Damping:

$$l \gtrsim 10^6$$

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3D info:

21 cm: The Reality Gap

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Realistically

Damping:

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$$\ell \gtrsim 10^4$$

3D info:

$$N_z = \begin{cases} 1500 \text{ (EoR)} \\ 10,000 \text{ (dark ages)} \end{cases}$$

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Ideally

Realistically

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reionization?

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Foregrounds:

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$$T_{\text{sys}} \sim 180 (\nu / 180 \text{ MHz})^{-2.6}$$

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$$\text{dark ages} \sim 10^4 - 10^6 \text{ K} \gg \delta T_b \sim 1 \text{ mK}$$

Projected signal and noise power spectra

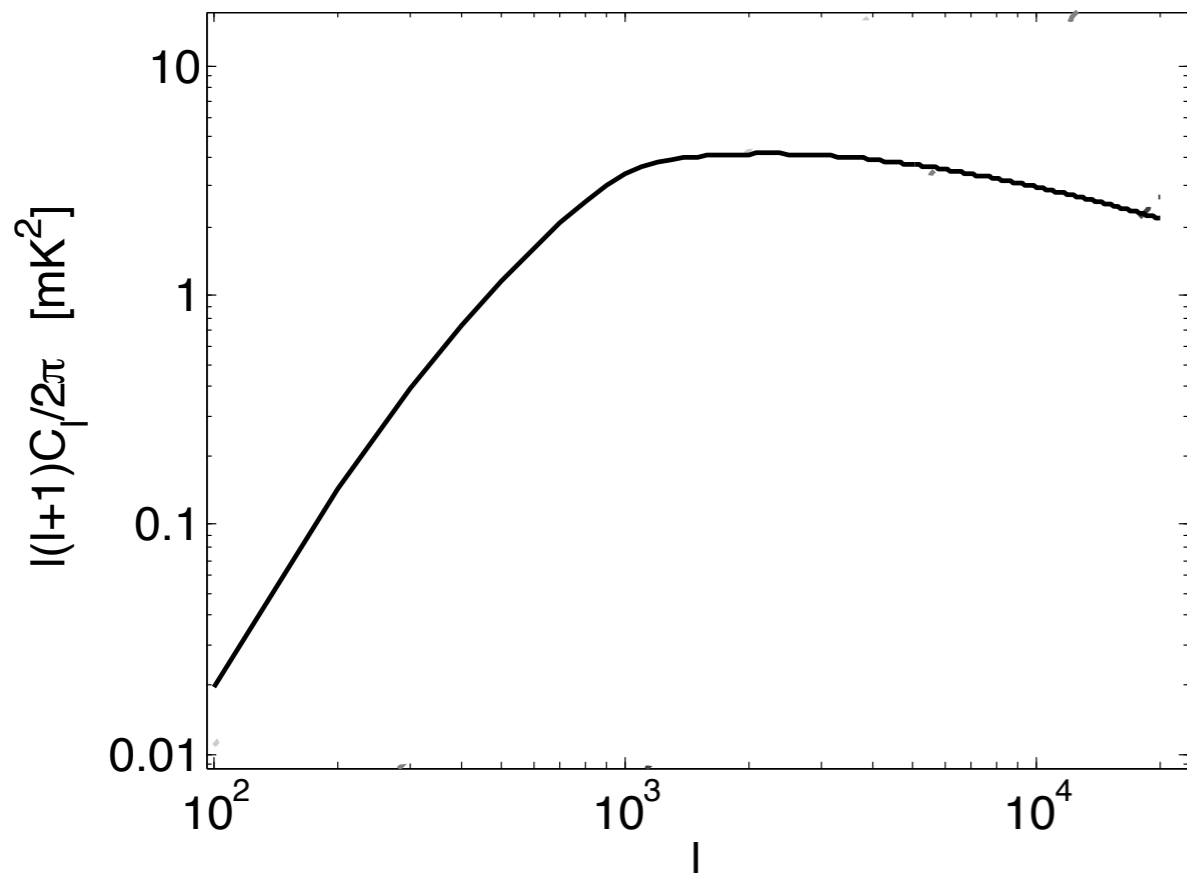
Projected signal and noise power spectra

- Signal:

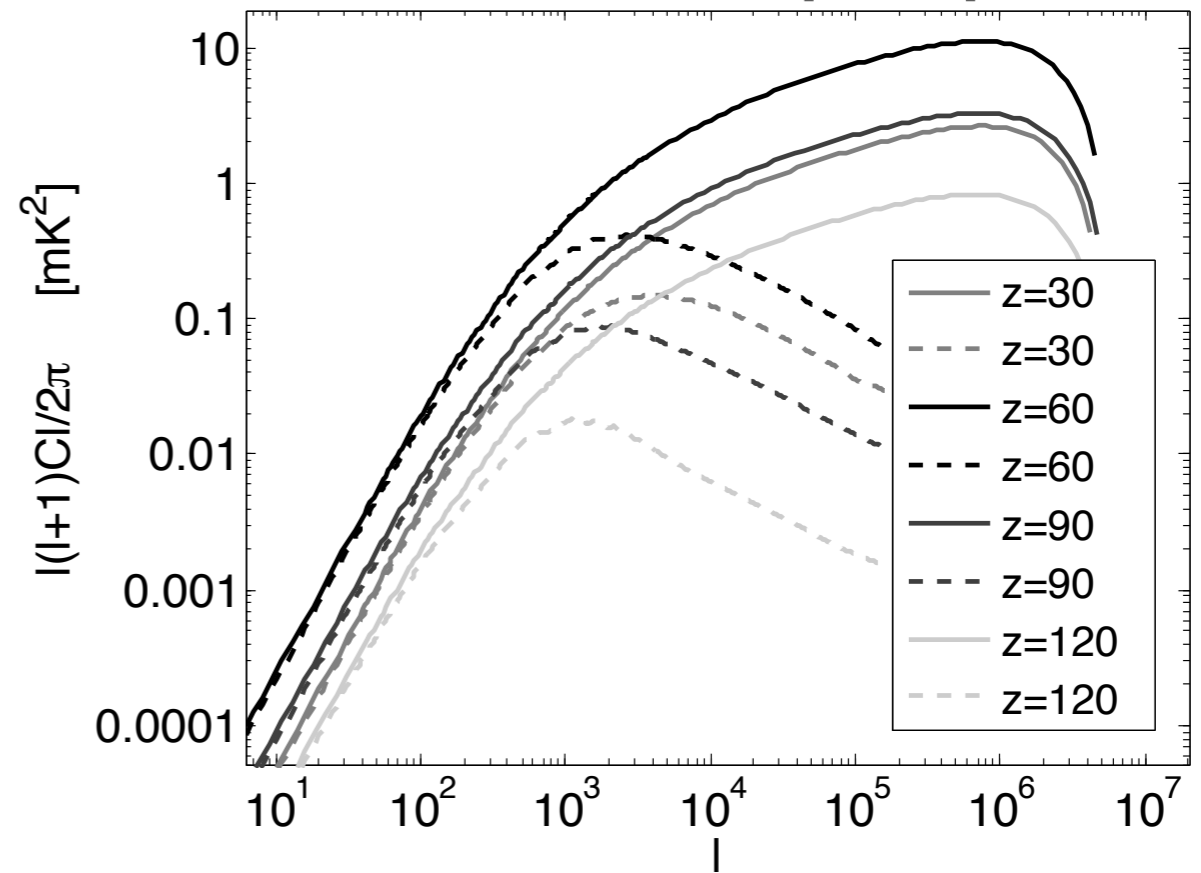
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Reionization $\Delta\nu = 1$ Mhz; $z = 7$



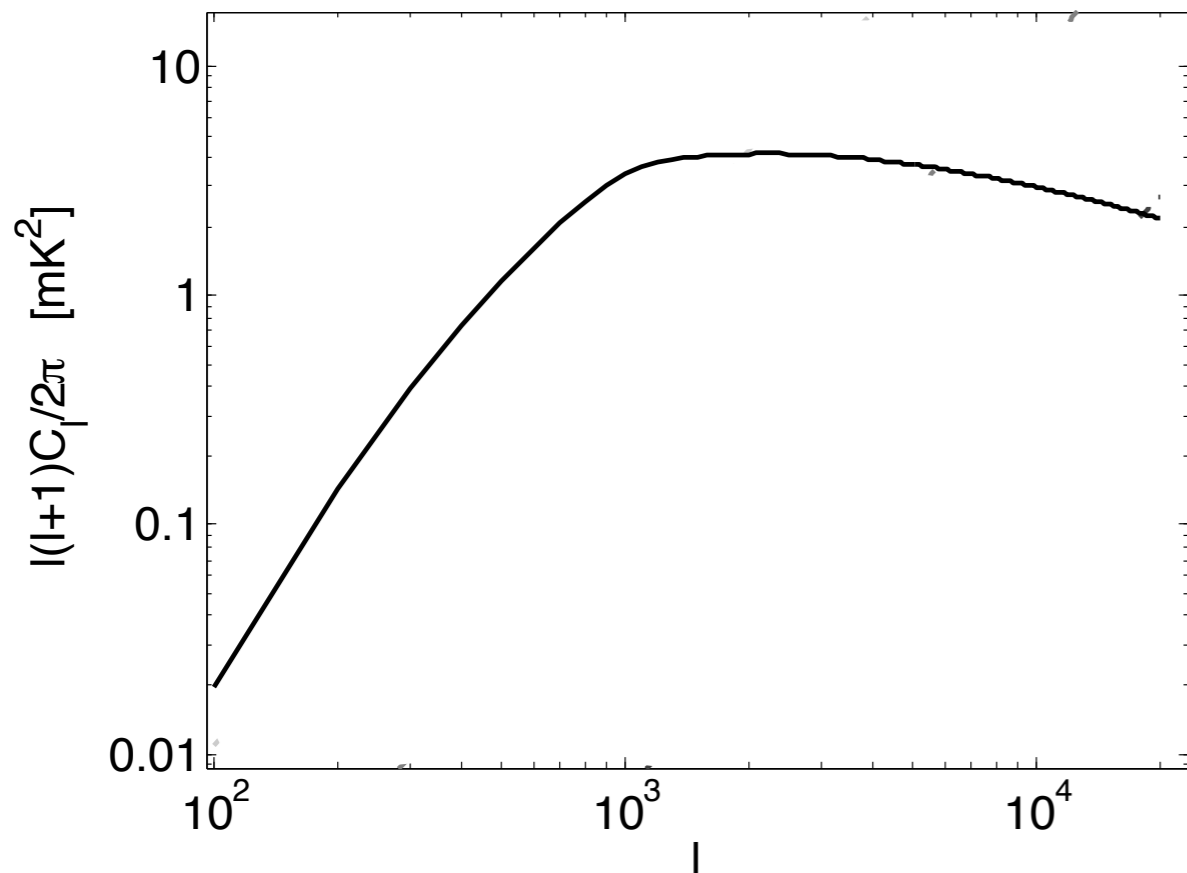
Dark Ages $\Delta\nu = [0, 0.1]$ Mhz



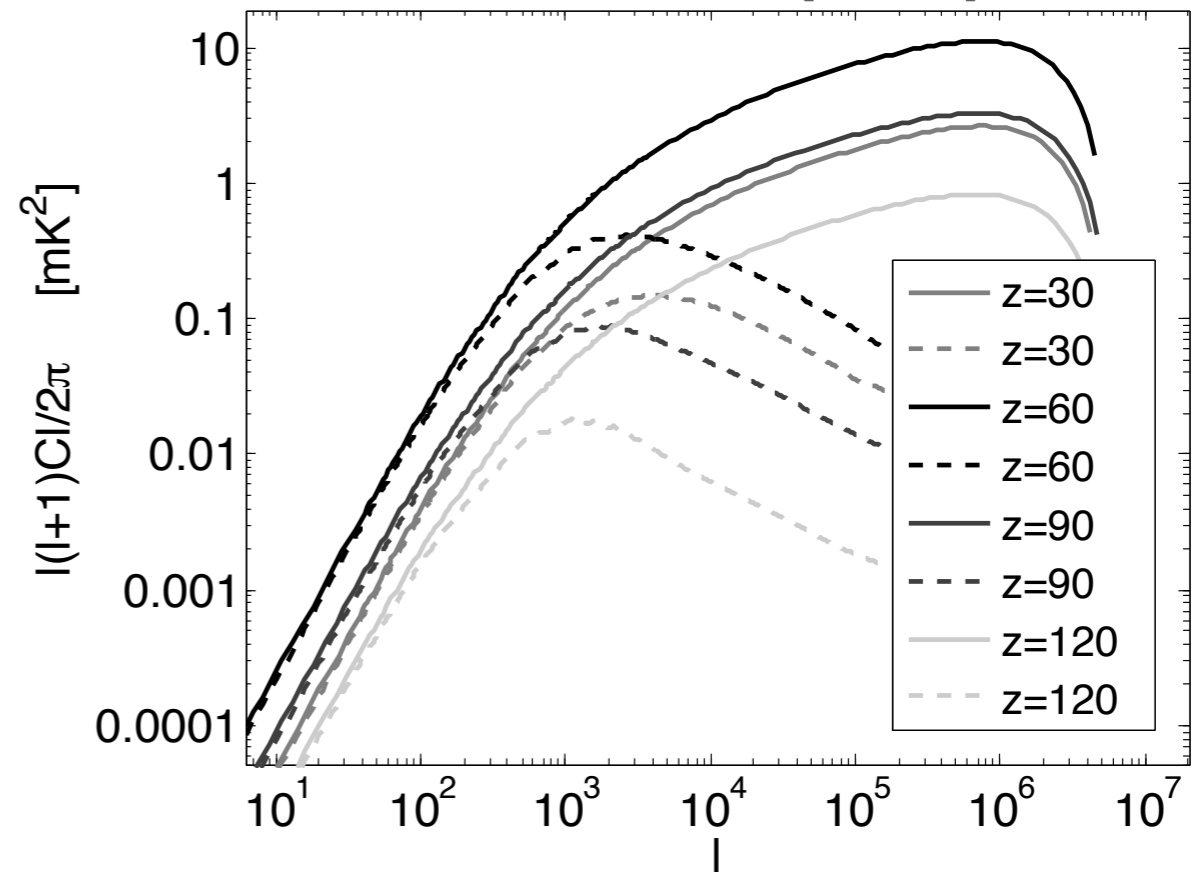
Projected signal and noise power spectra

- Signal: $l^2 C_l \sim \text{const} \equiv 2\pi\alpha(\nu, \Delta\nu)$

Reionization $\Delta\nu = 1 \text{ Mhz}$; $z = 7$



Dark Ages $\Delta\nu = [0, 0.1] \text{ Mhz}$

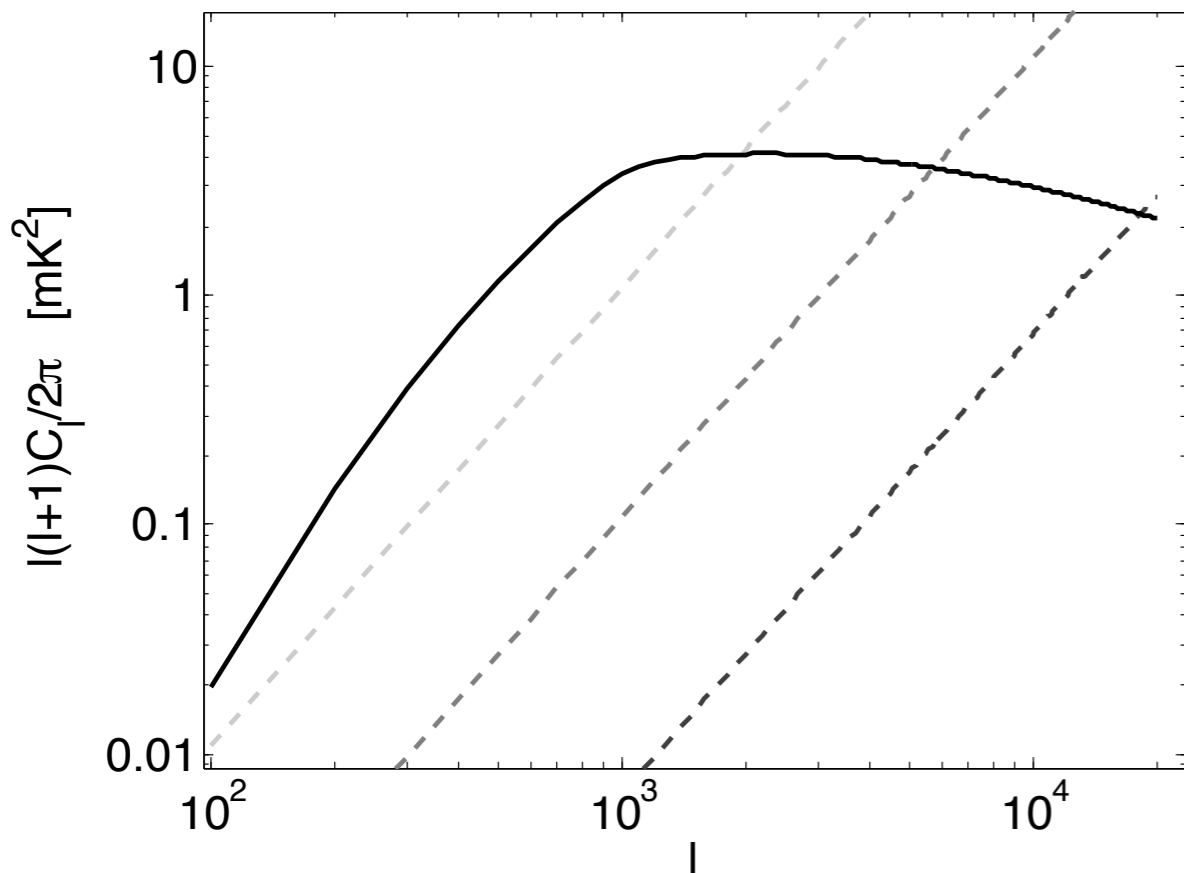


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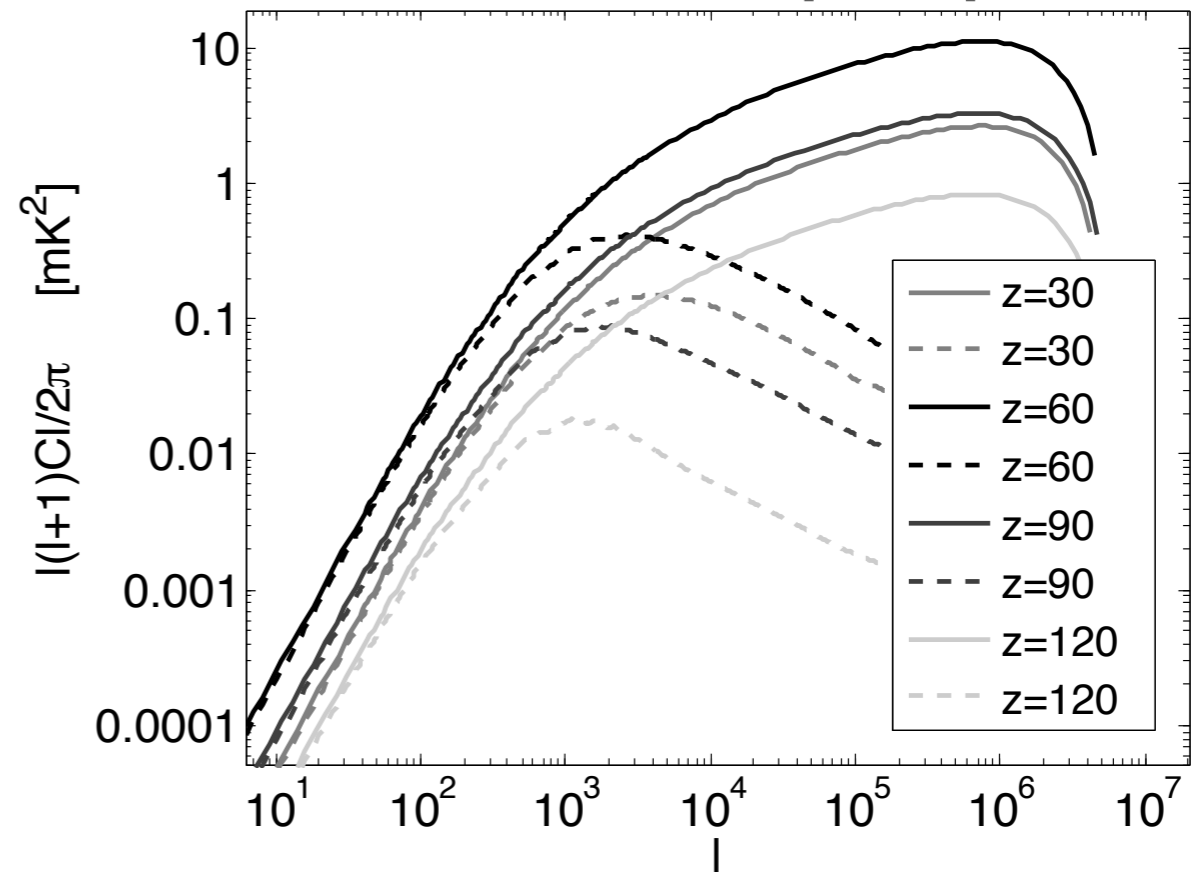
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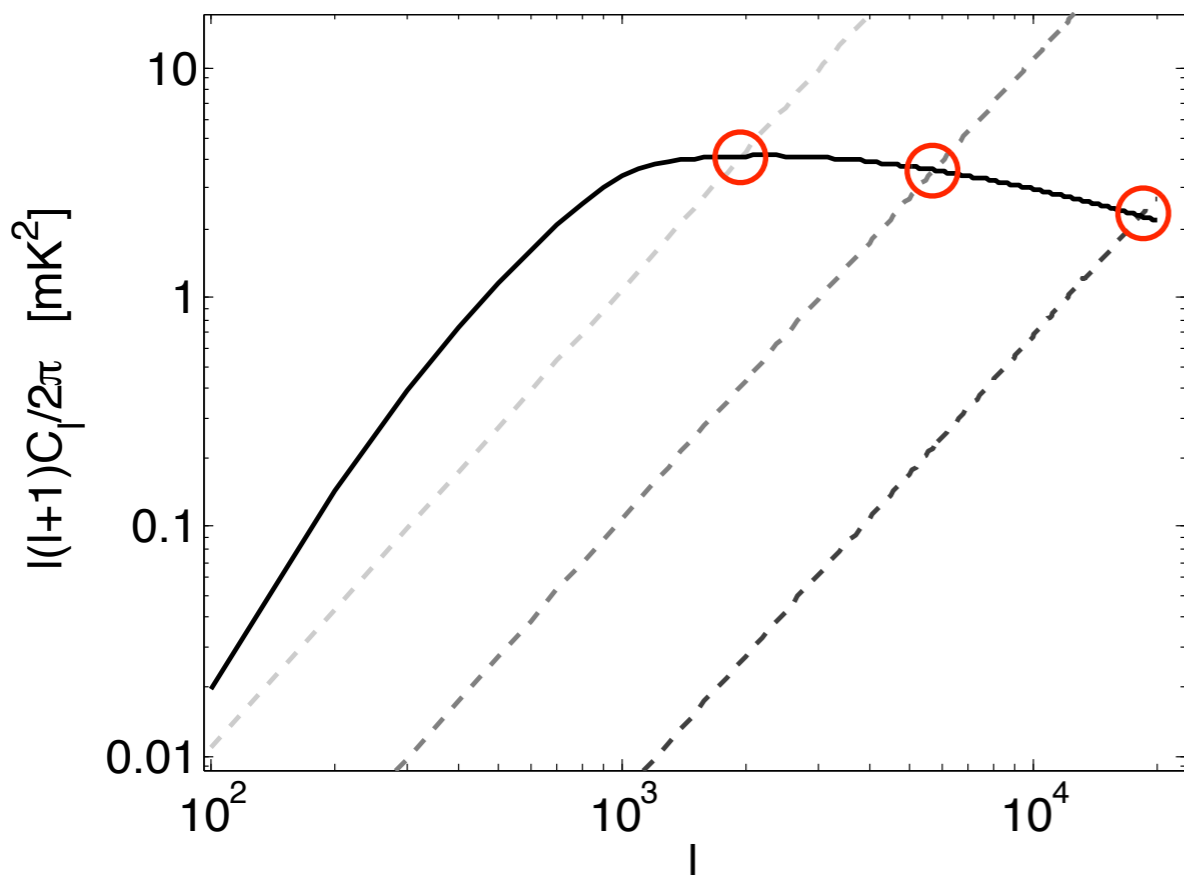
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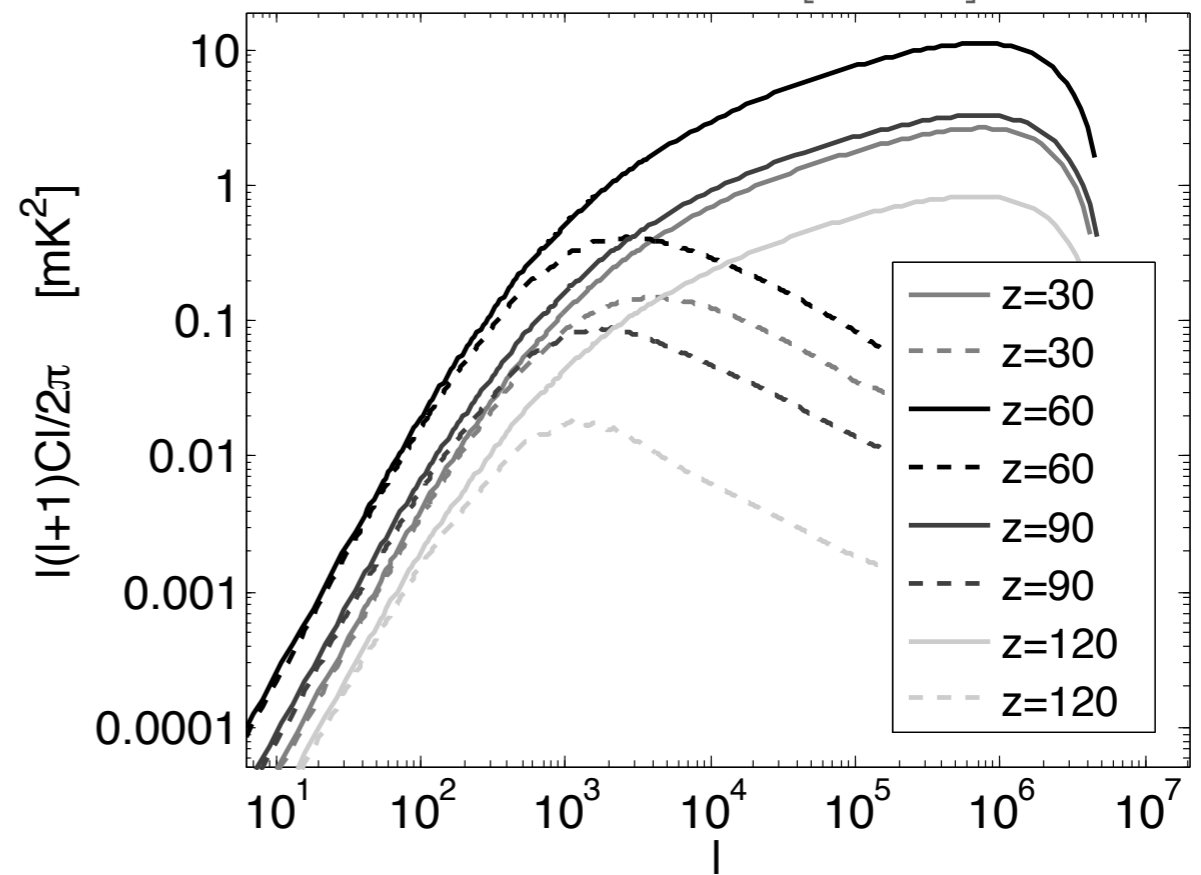
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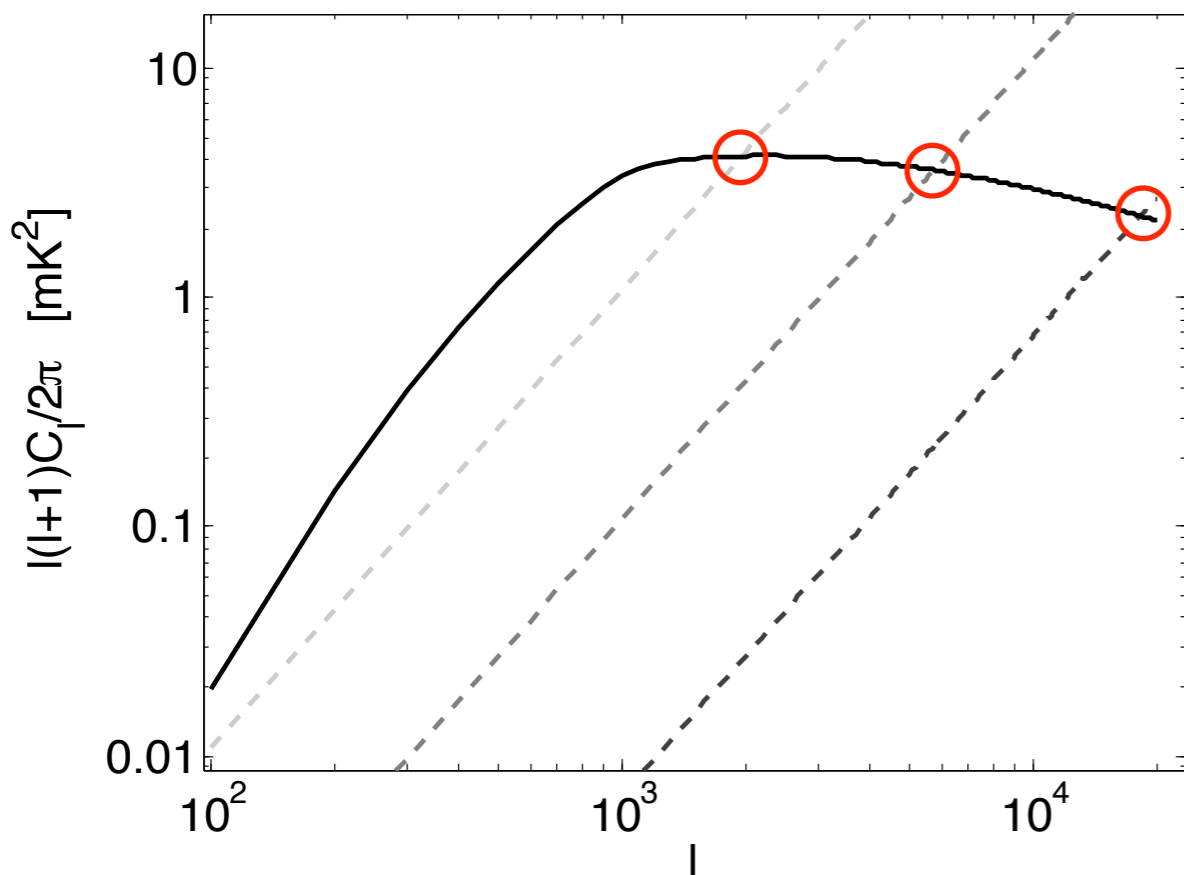
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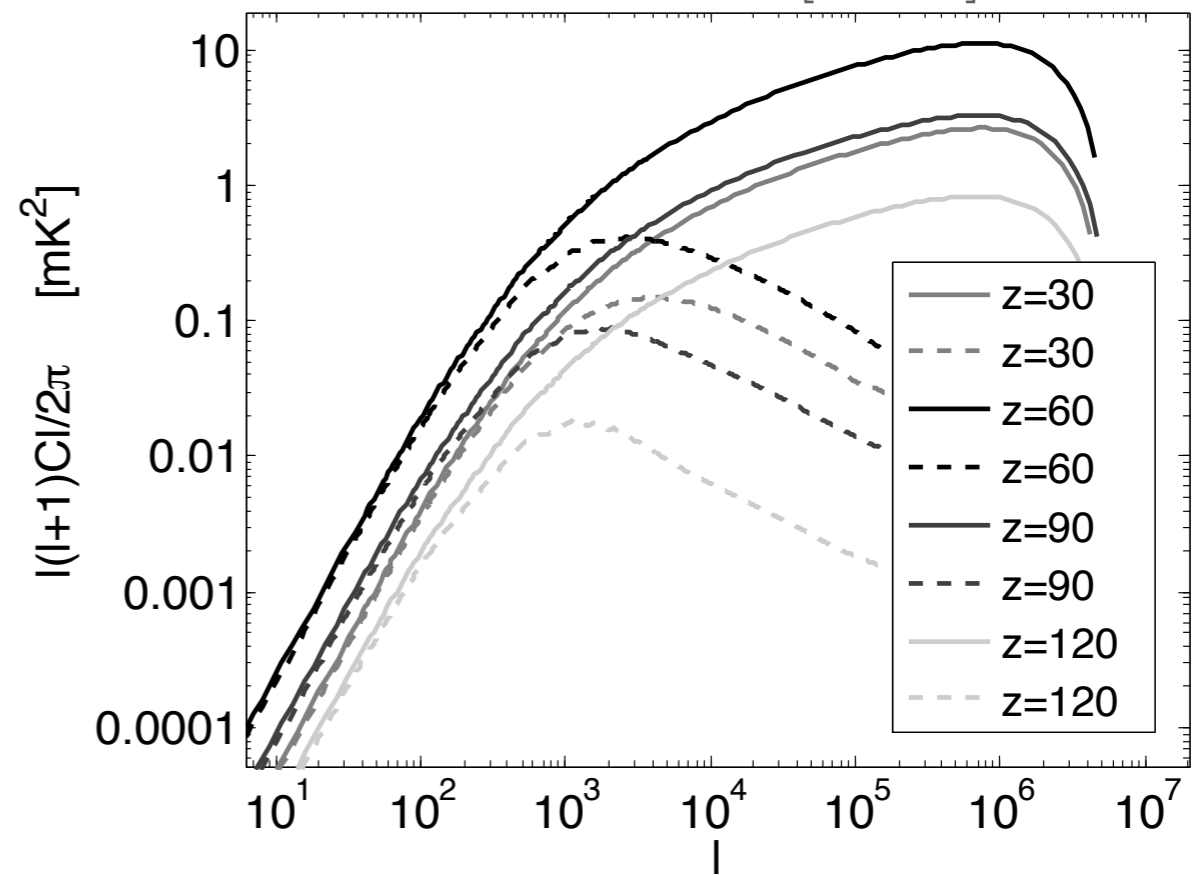
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Lens Estimator

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- Quadratic estimator at $\vec{L} = \vec{l}_1 + \vec{l}_2$:

Hu & Okamoto (2001) $\widehat{\phi}(\vec{L}) = N(\vec{L}) \int \frac{d^2l_1}{(2\pi)^2} T(\vec{l}_1) T(\vec{l}_2) \left[\frac{\tilde{C}_{l_1}(\vec{L} \cdot \vec{l}_1) + \tilde{C}_{l_2}(\vec{L} \cdot \vec{l}_2)}{2C_{l_1} C_{l_2}} \right]$

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- A minimum-variance estimator for the lens property:

$$\hat{p}_i = \frac{\widehat{\kappa}_{\vec{L}_i}}{\kappa_{\vec{L}_i}^{\text{th}}(p_{\text{fid}})} p_{\text{fid}}, \quad \langle |\hat{p}_i|^2 \rangle = \frac{\Omega N_{\vec{L}_i}}{|\kappa_{\vec{L}_i}^{\text{th}}(p_{\text{fid}})|^2} p_{\text{fid}}^2 \longrightarrow \hat{p} = \frac{\sum_i \hat{p}_i / \langle |\hat{p}_i|^2 \rangle}{\sum_i 1 / \langle |\hat{p}_i|^2 \rangle}$$

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- The S/N is determined by: $\sigma_p^{-2} = \sum_i 1 / \langle |\widehat{p}_i|^2 \rangle \propto N_z l_{\text{max}}^2 \longleftrightarrow \boxed{\nu, \Delta\nu, f_{\text{cover}}, t_o}$

Galaxy Clusters

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$$\rho(r) = \rho_s \frac{1}{r/r_s (1 + r/r_s)^2}$$

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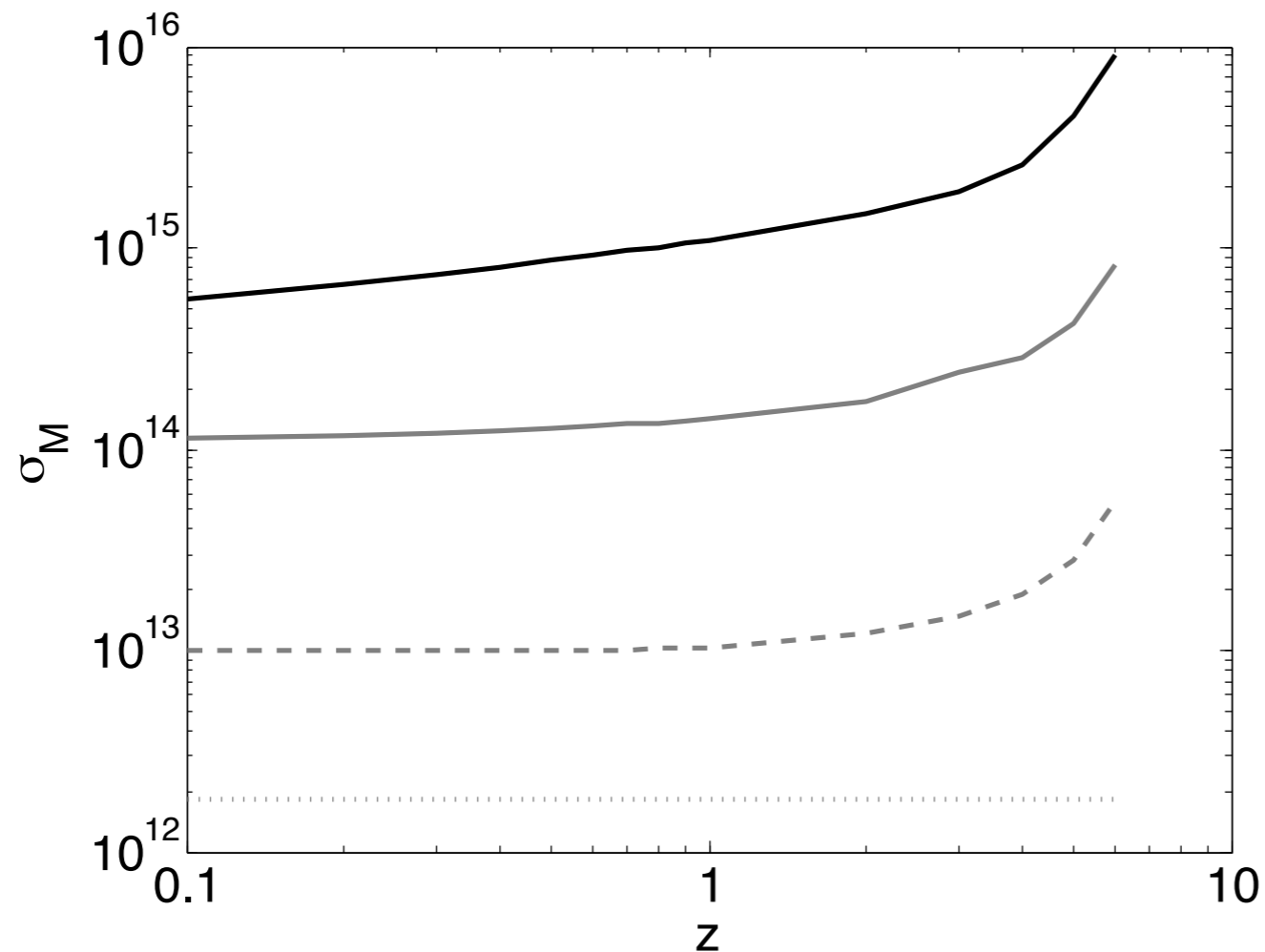
- 1σ detection limits for M : $\Delta\nu = 1 \text{ Mhz}$; $t_0 = 1000 \text{ hrs}$; $f_c = 0.02$

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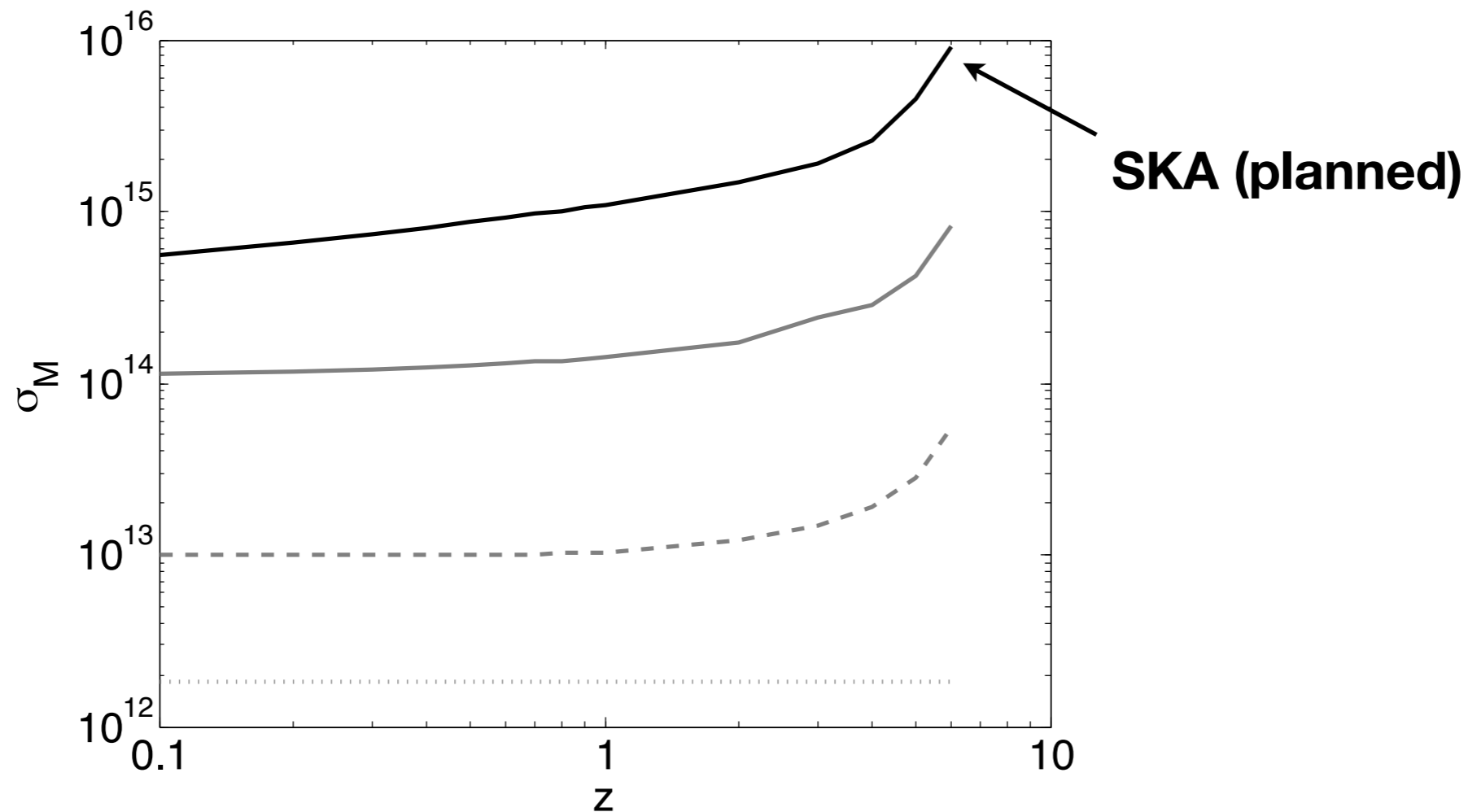


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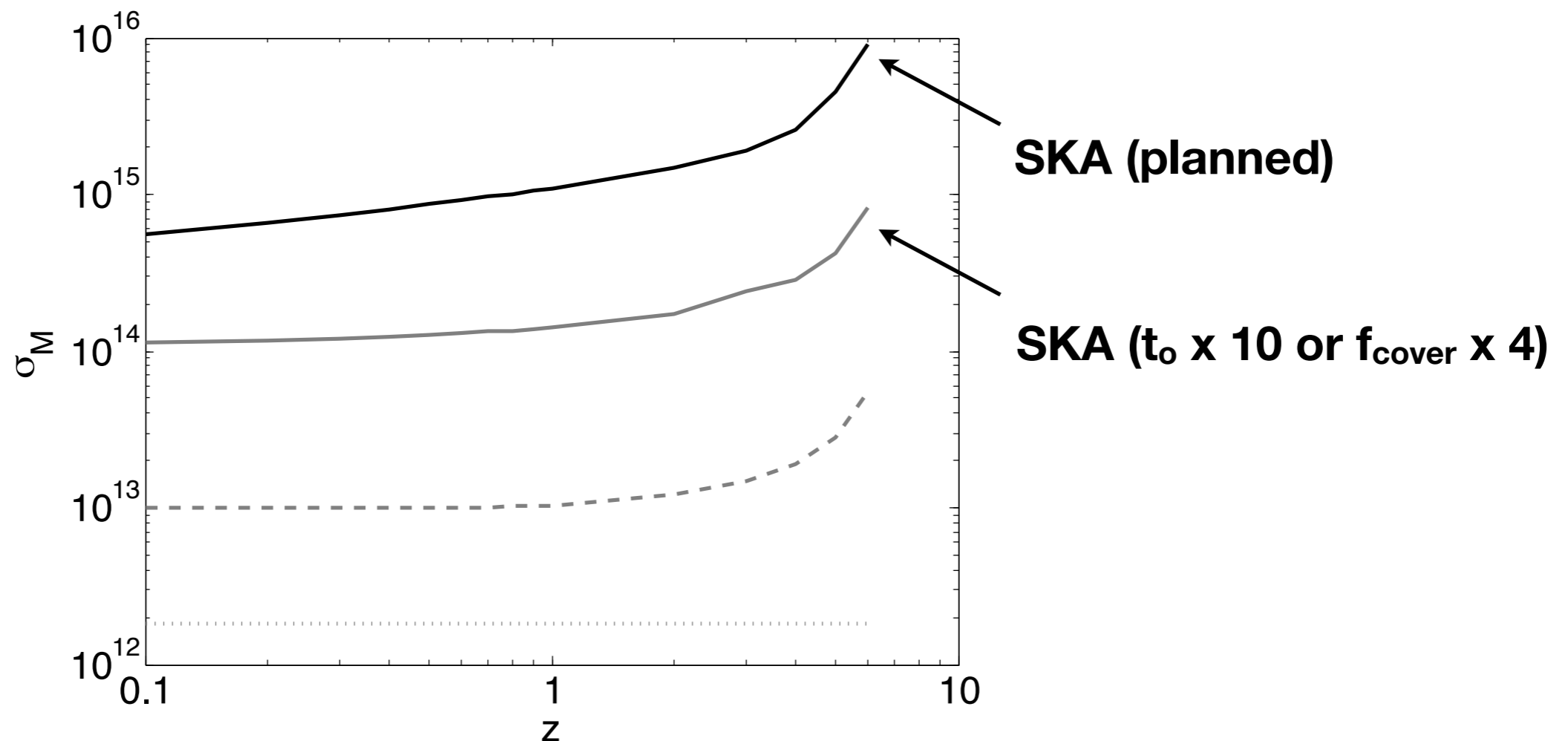


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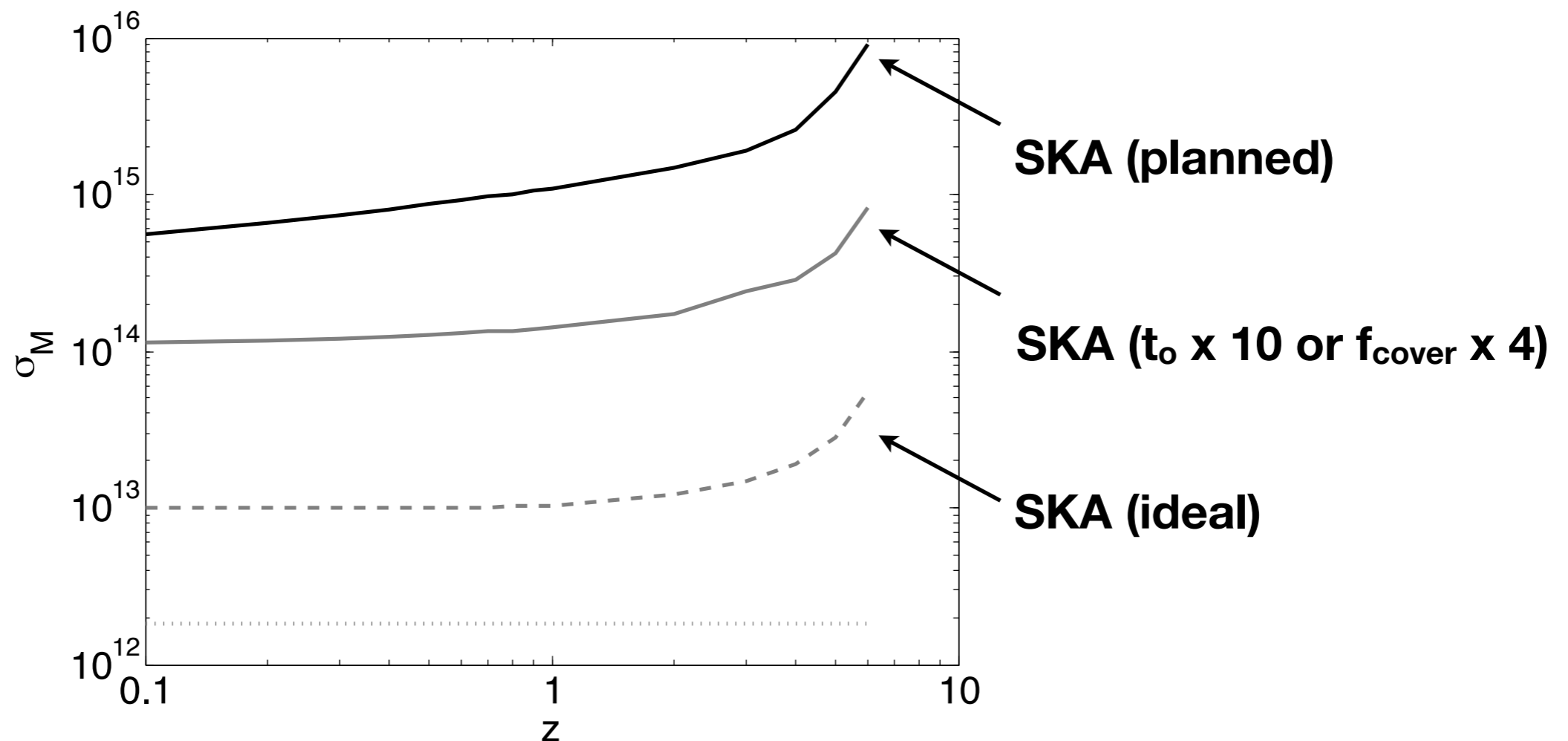


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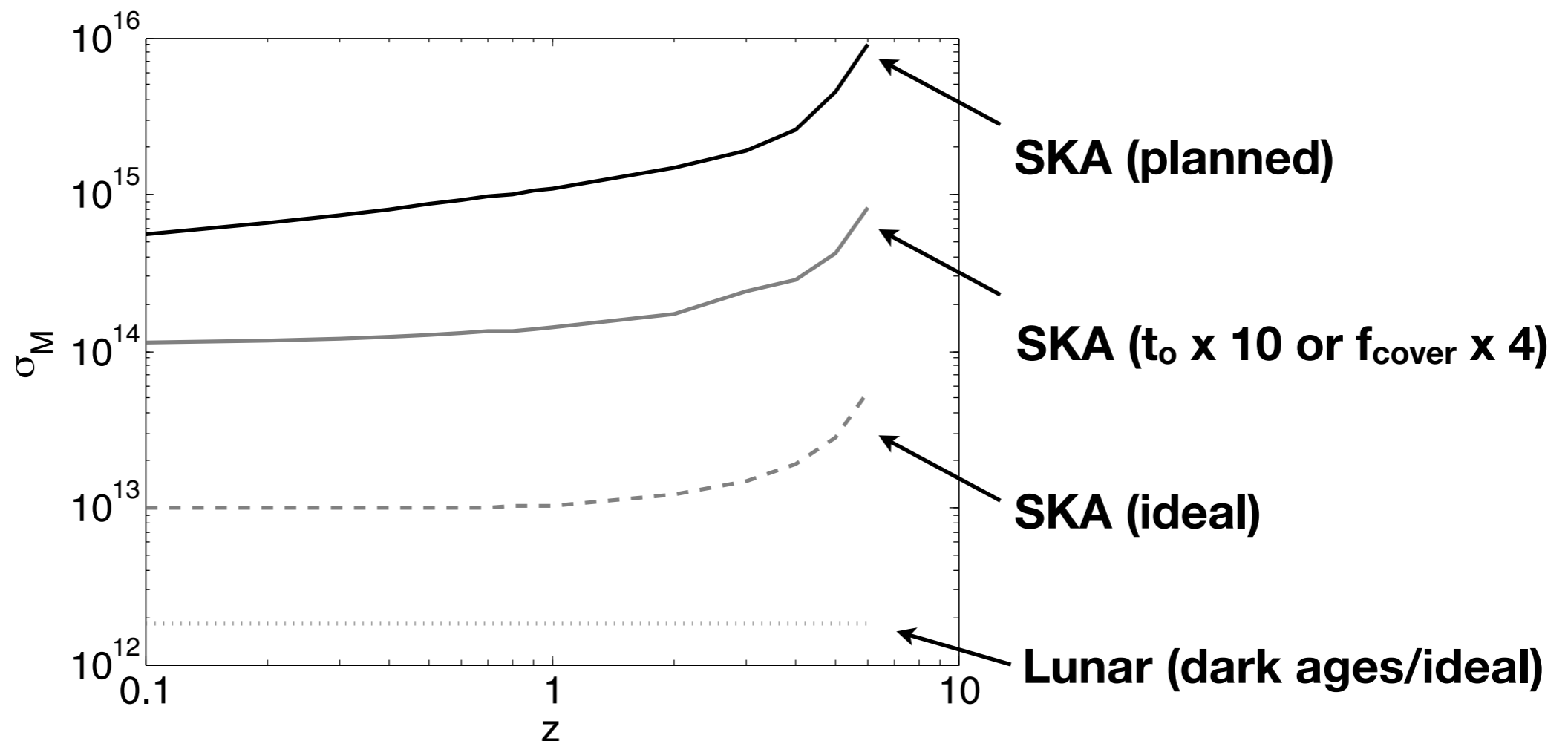


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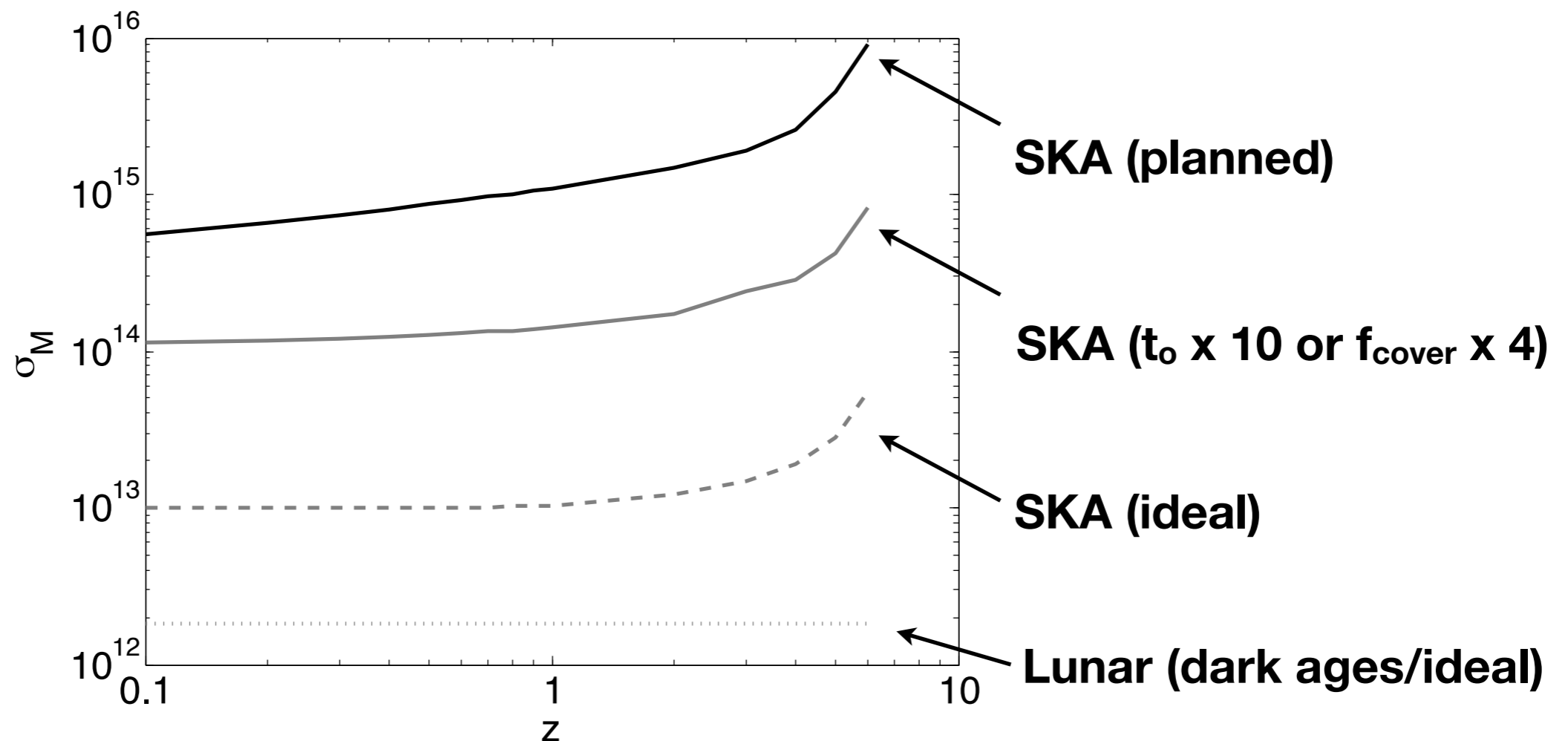


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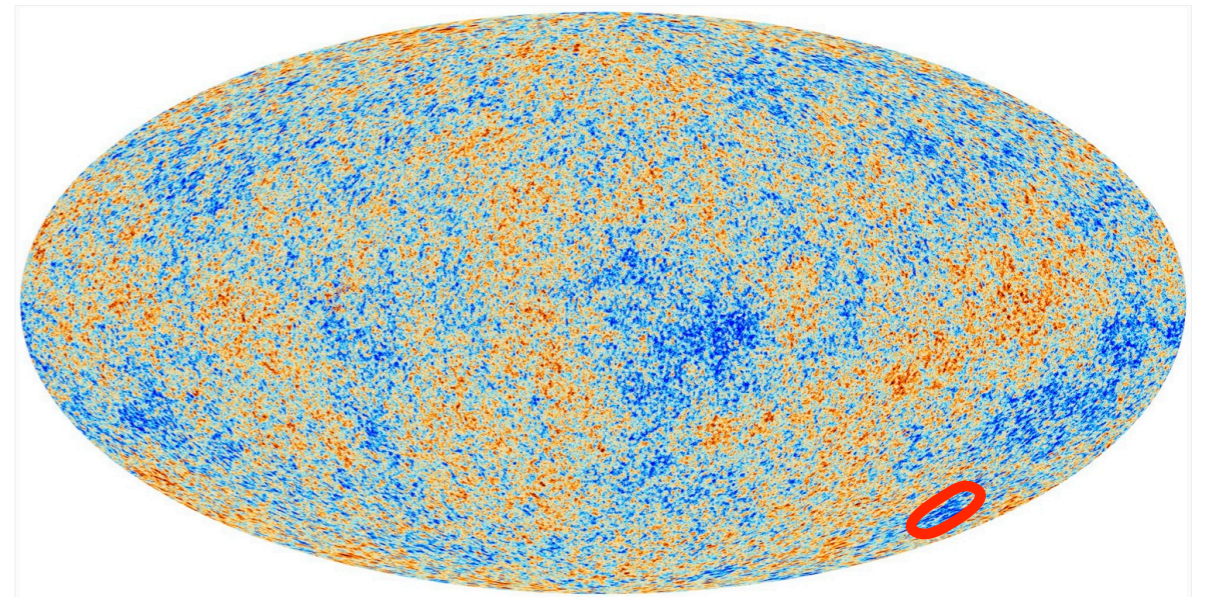
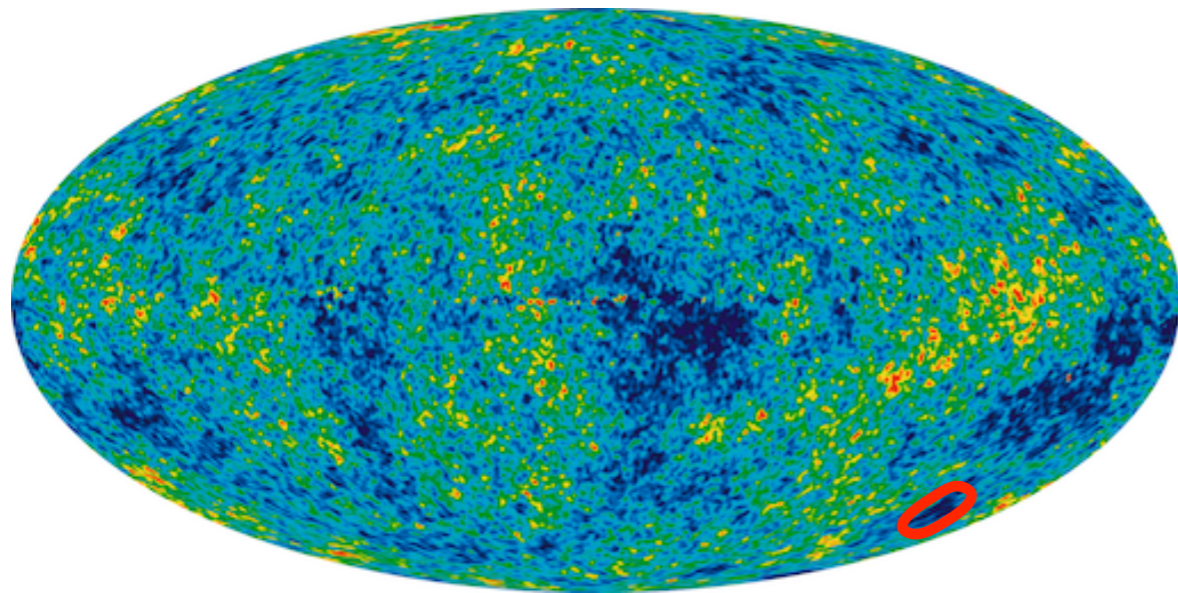


- What can CMB lensing do? Best: $O(10^{14} h^{-1} M_\odot)$ by stacking $> 10^3$ clusters.

Sources of CMB Cold Spot

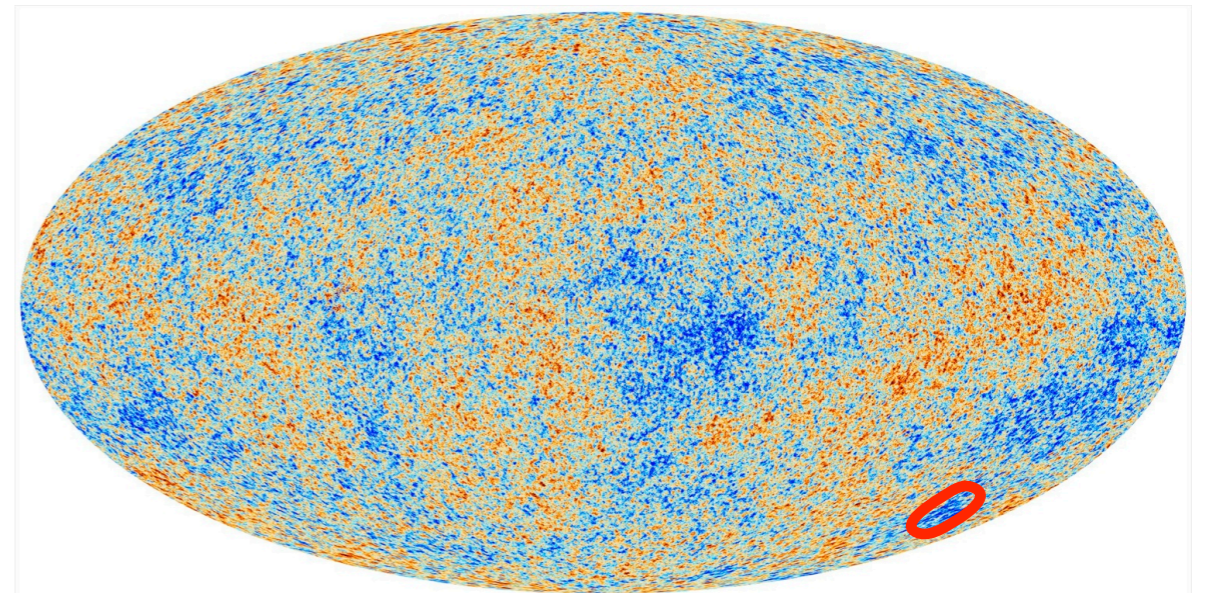
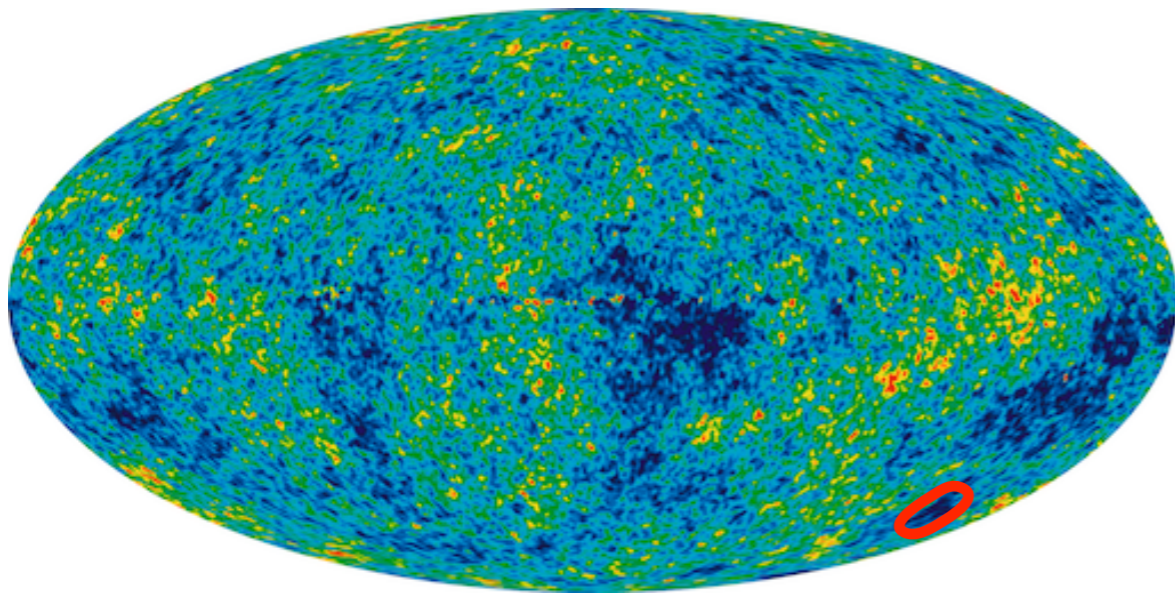
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- This can be explained by the ISW effect if there is an appropriate time-dependent potential well along the line-of-sight.

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- › 19 May 2008 by [Steve Nadis](#)
- › Magazine issue 2656. [Subscribe and save](#)
- › For similar stories, visit the [Cosmology](#) Topic Guide

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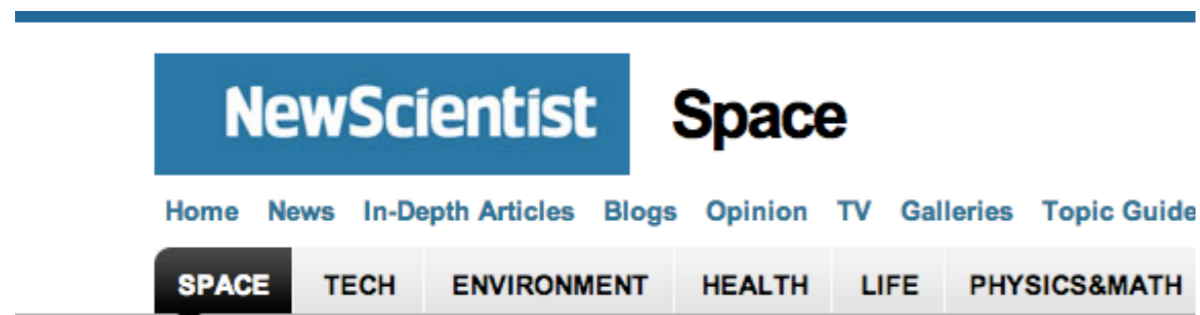
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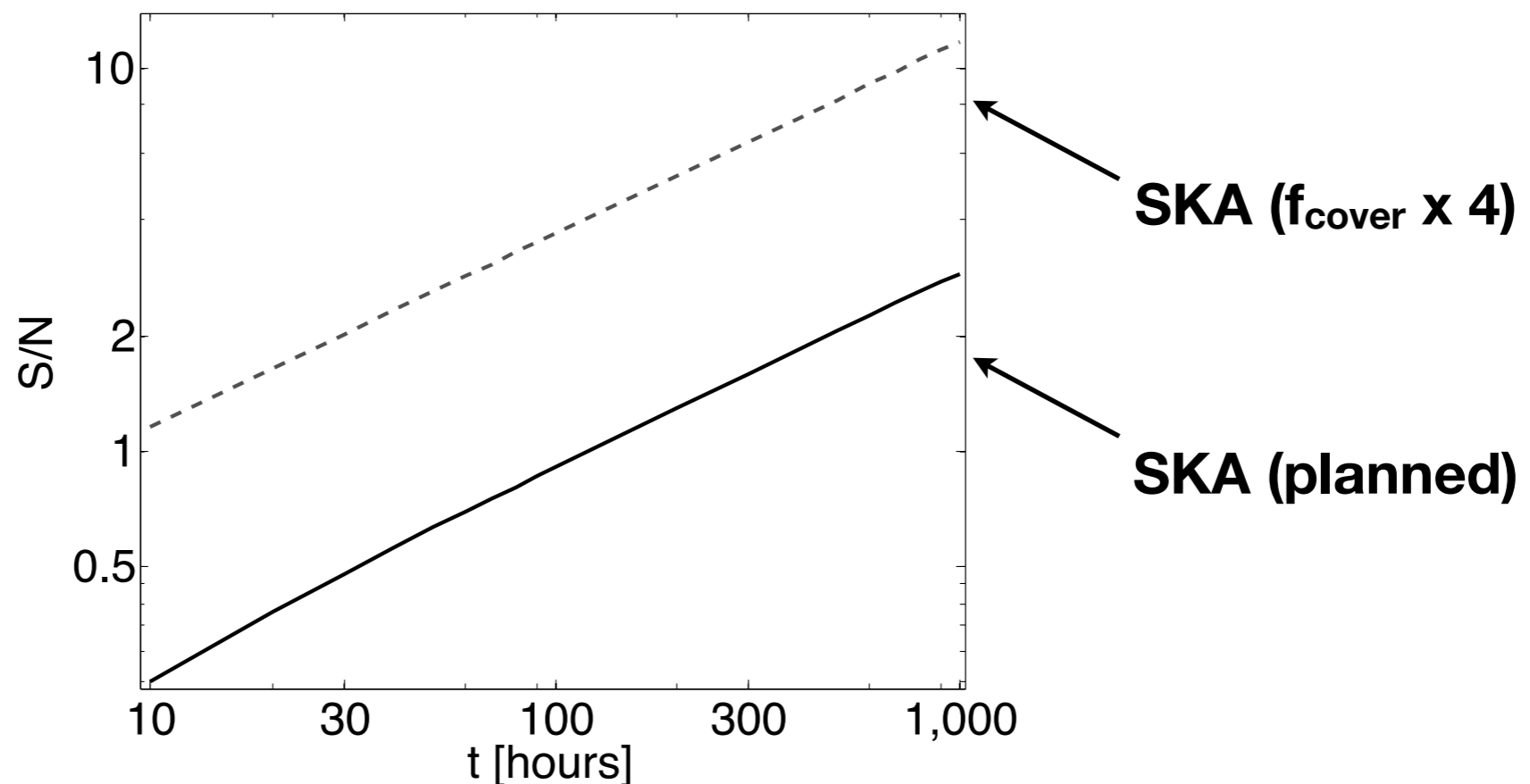
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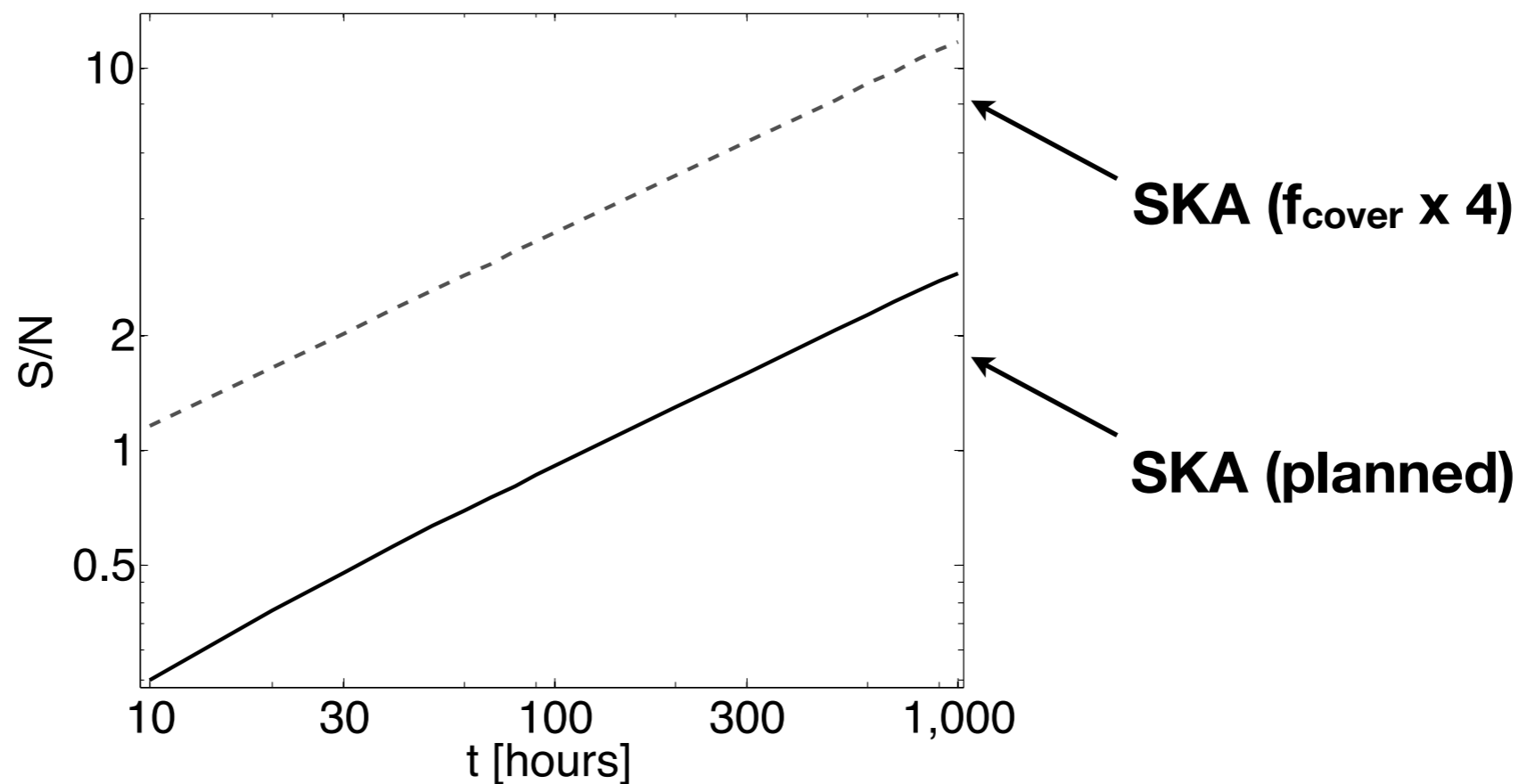
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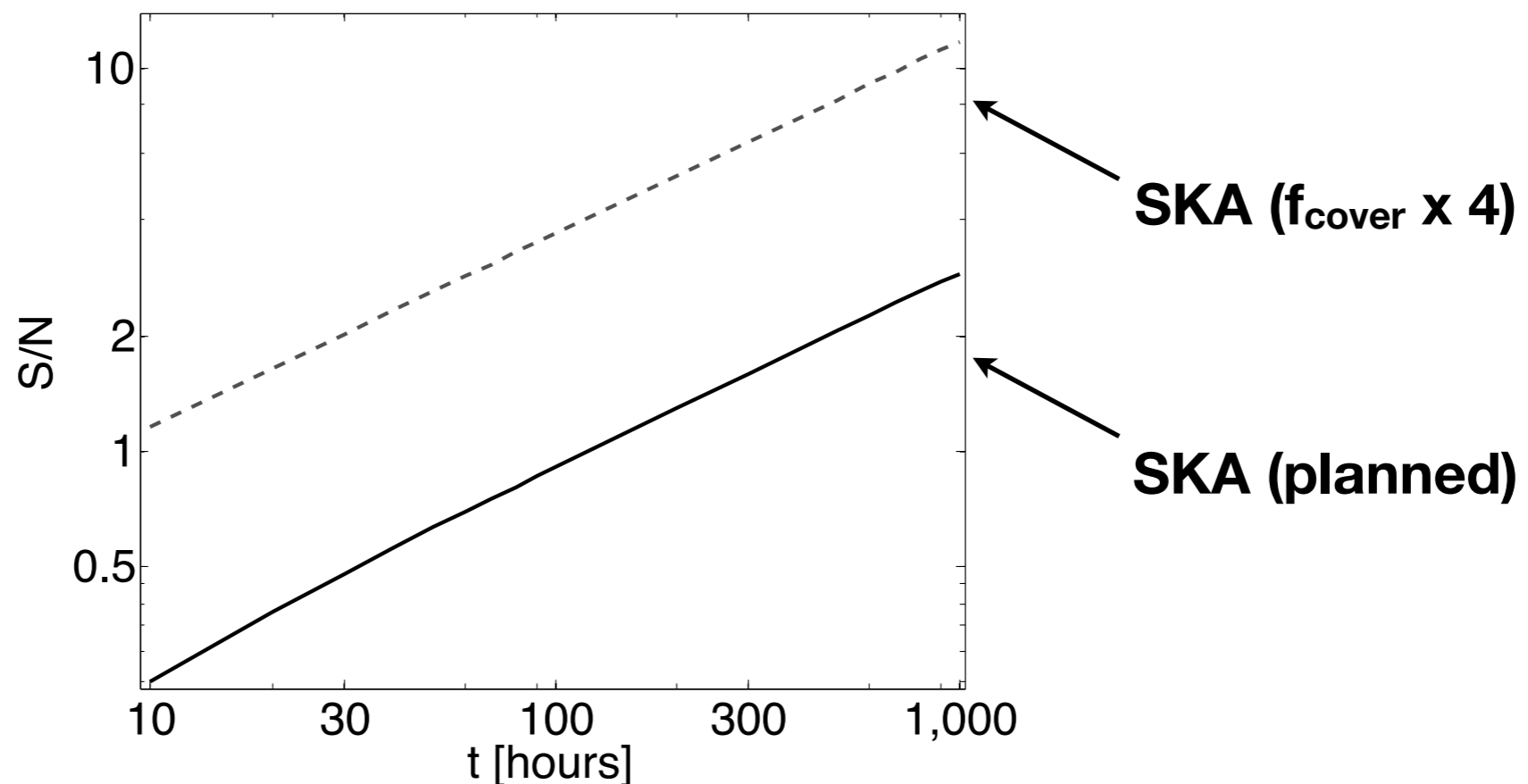
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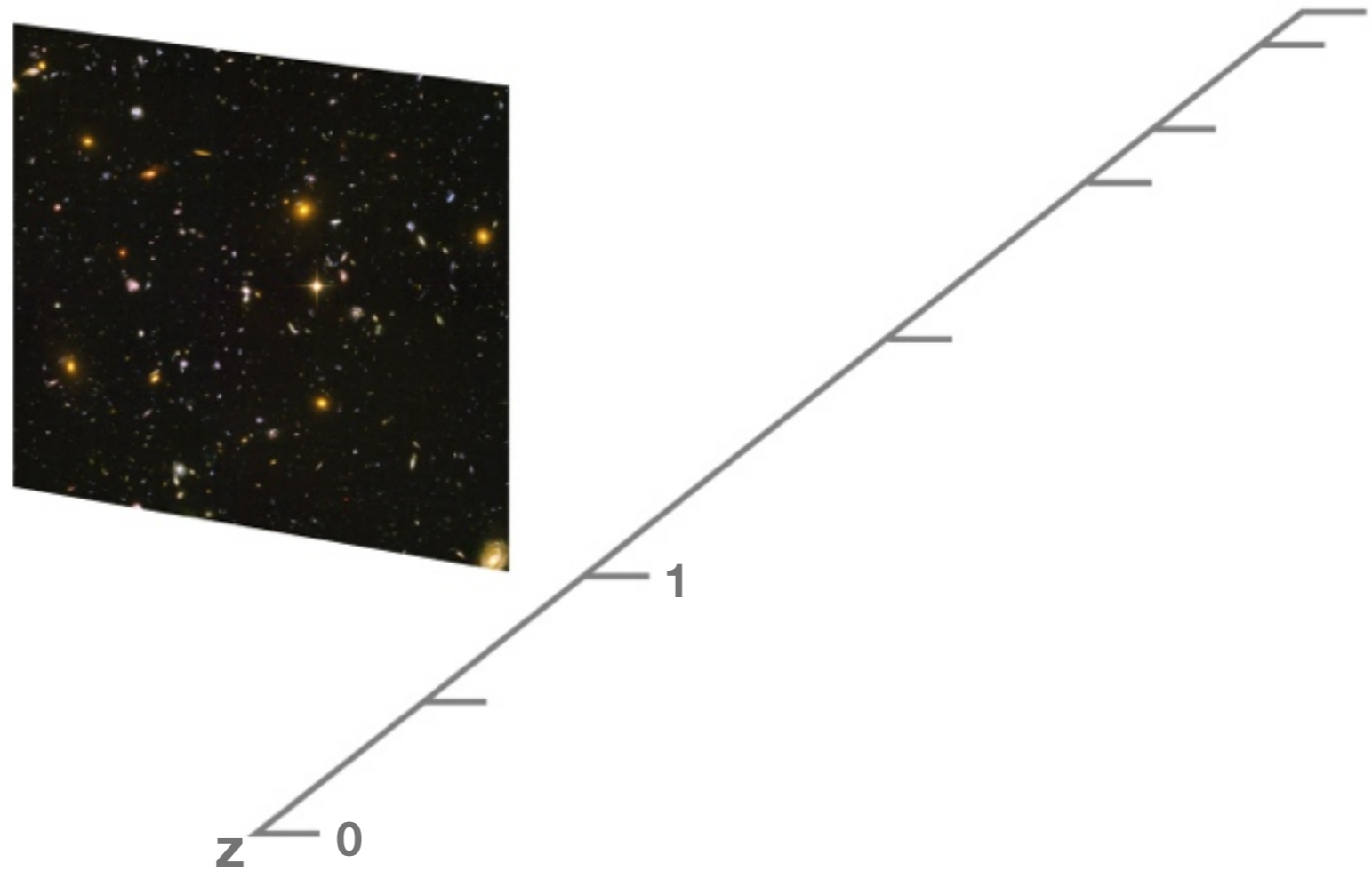
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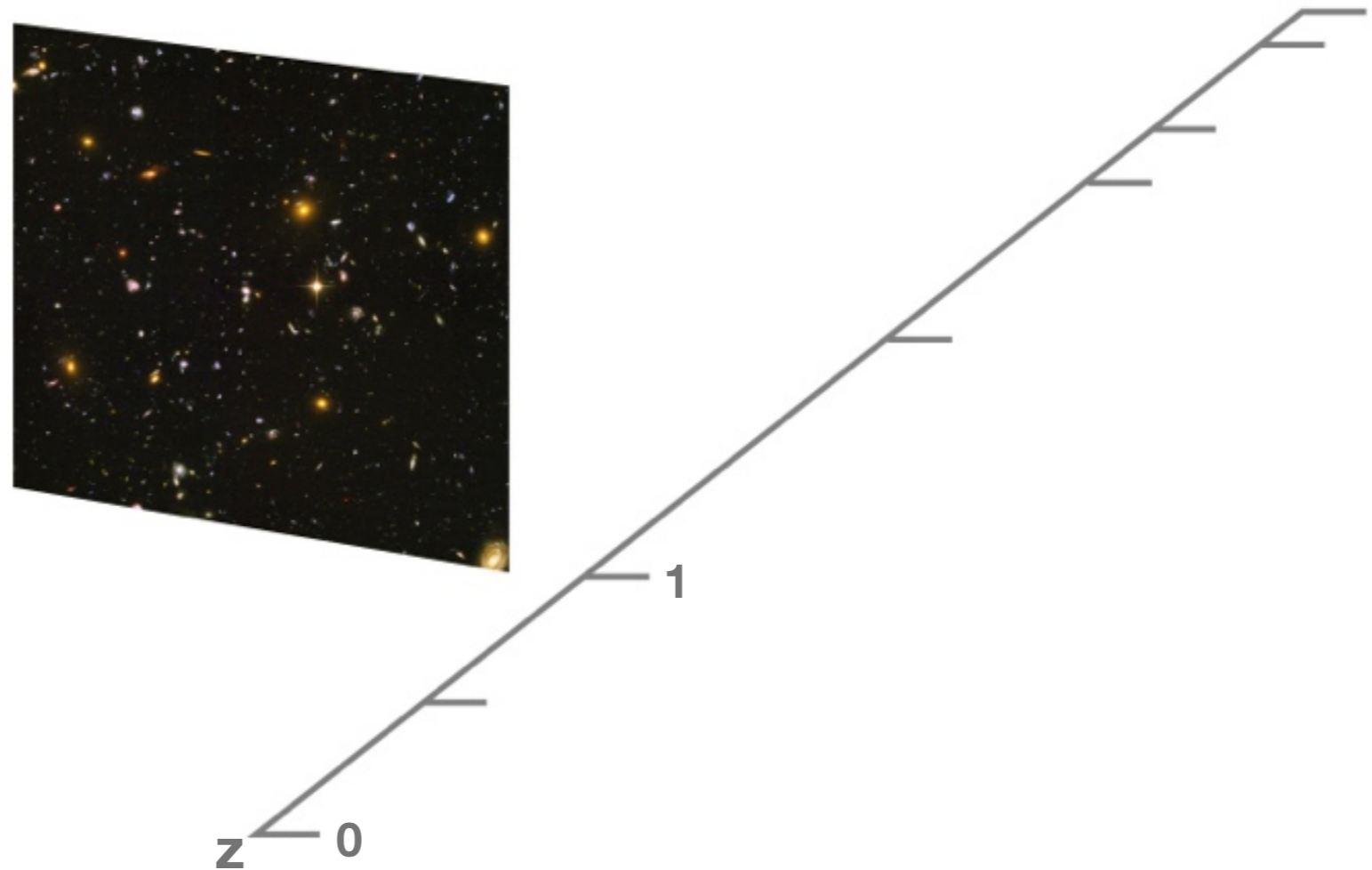


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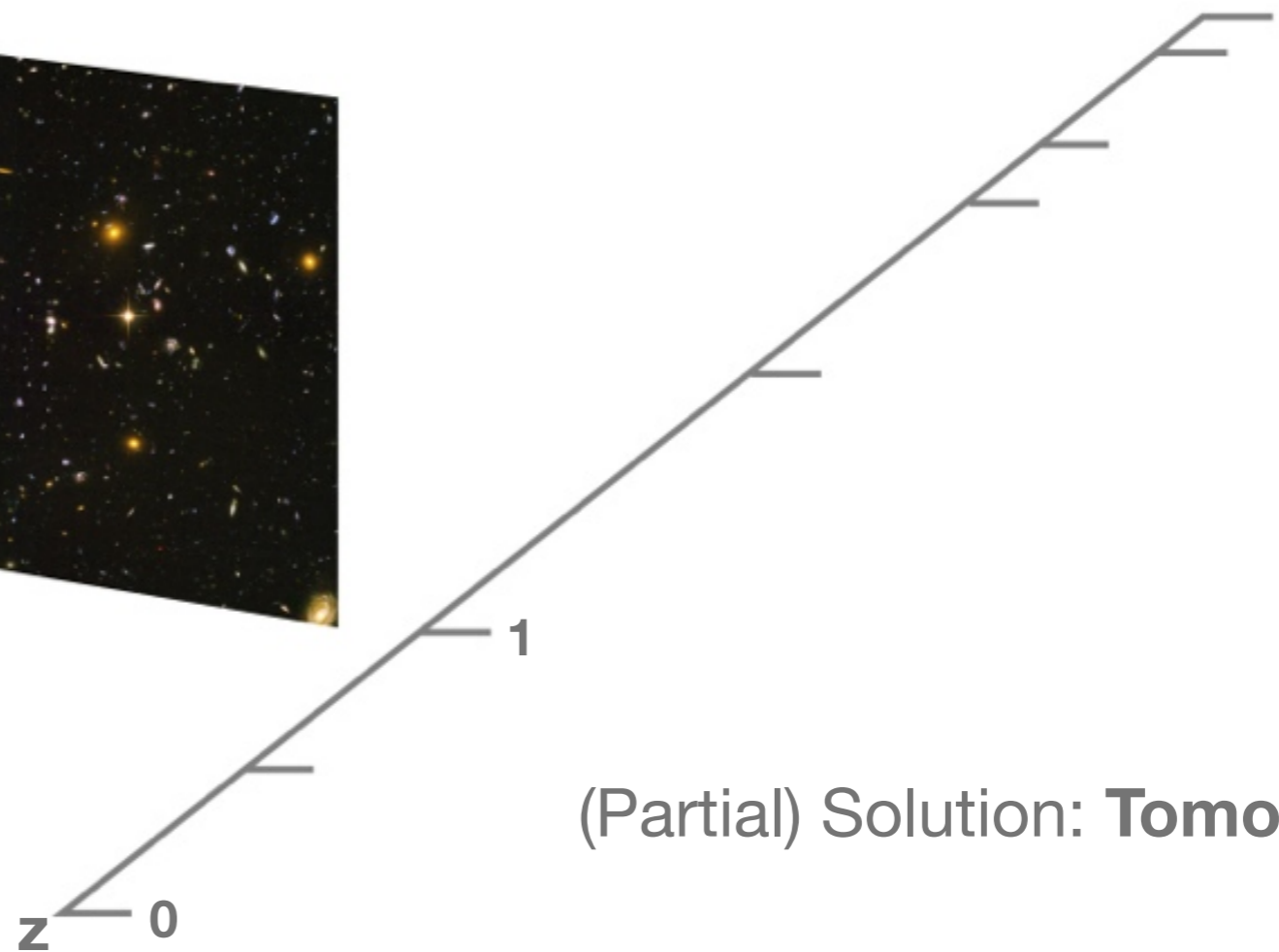
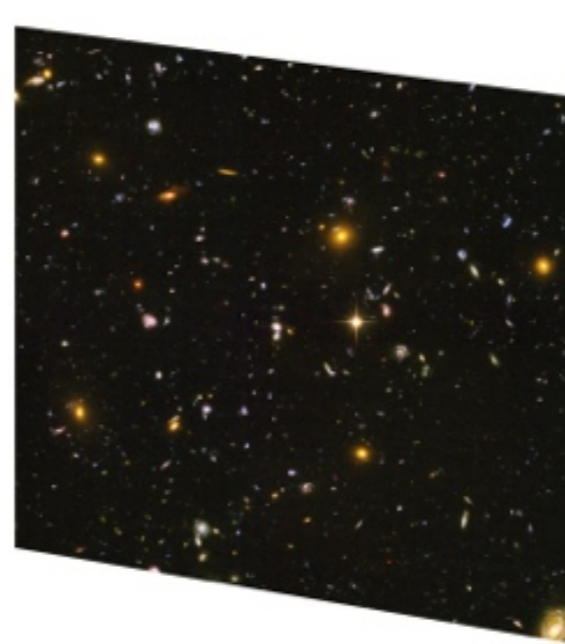


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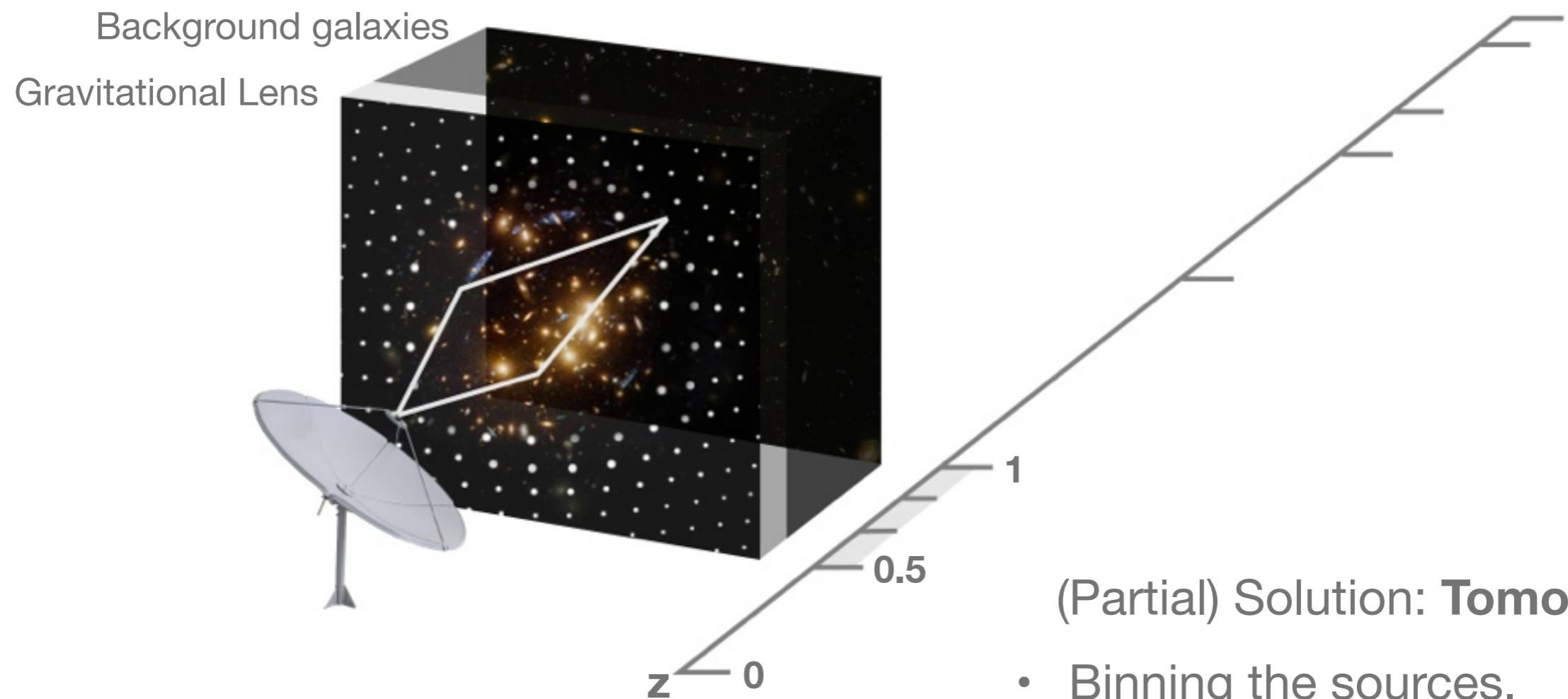


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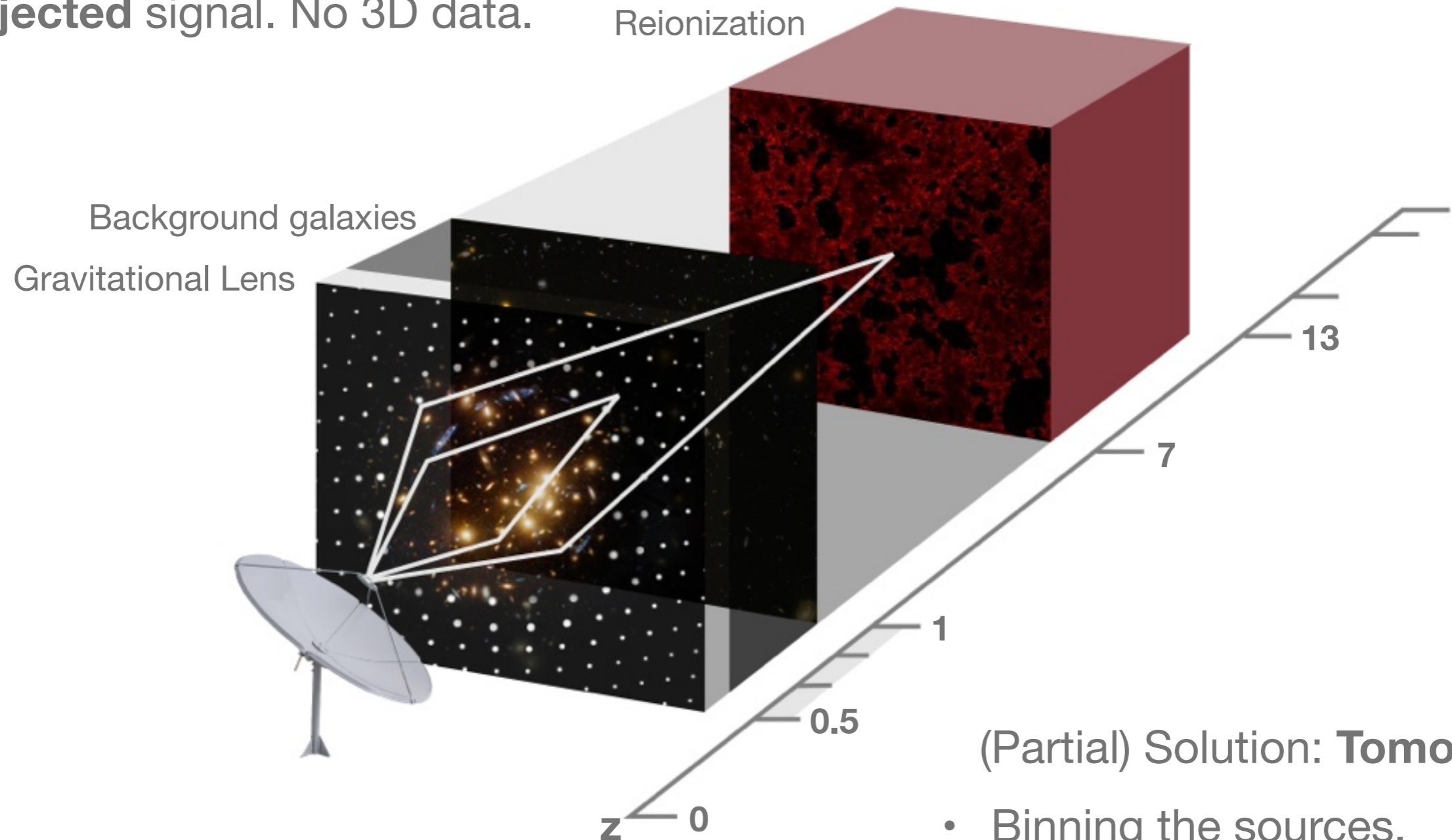
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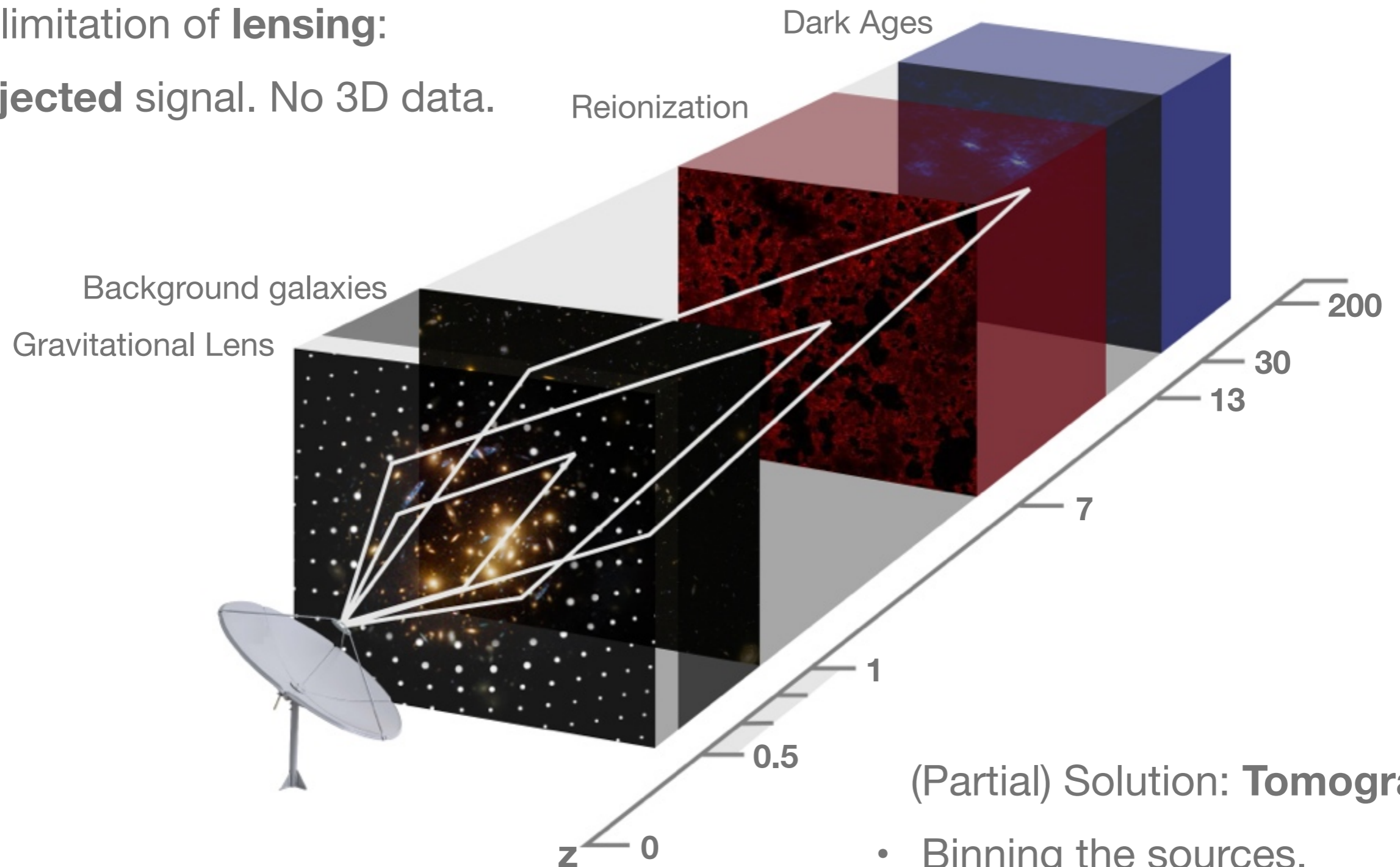
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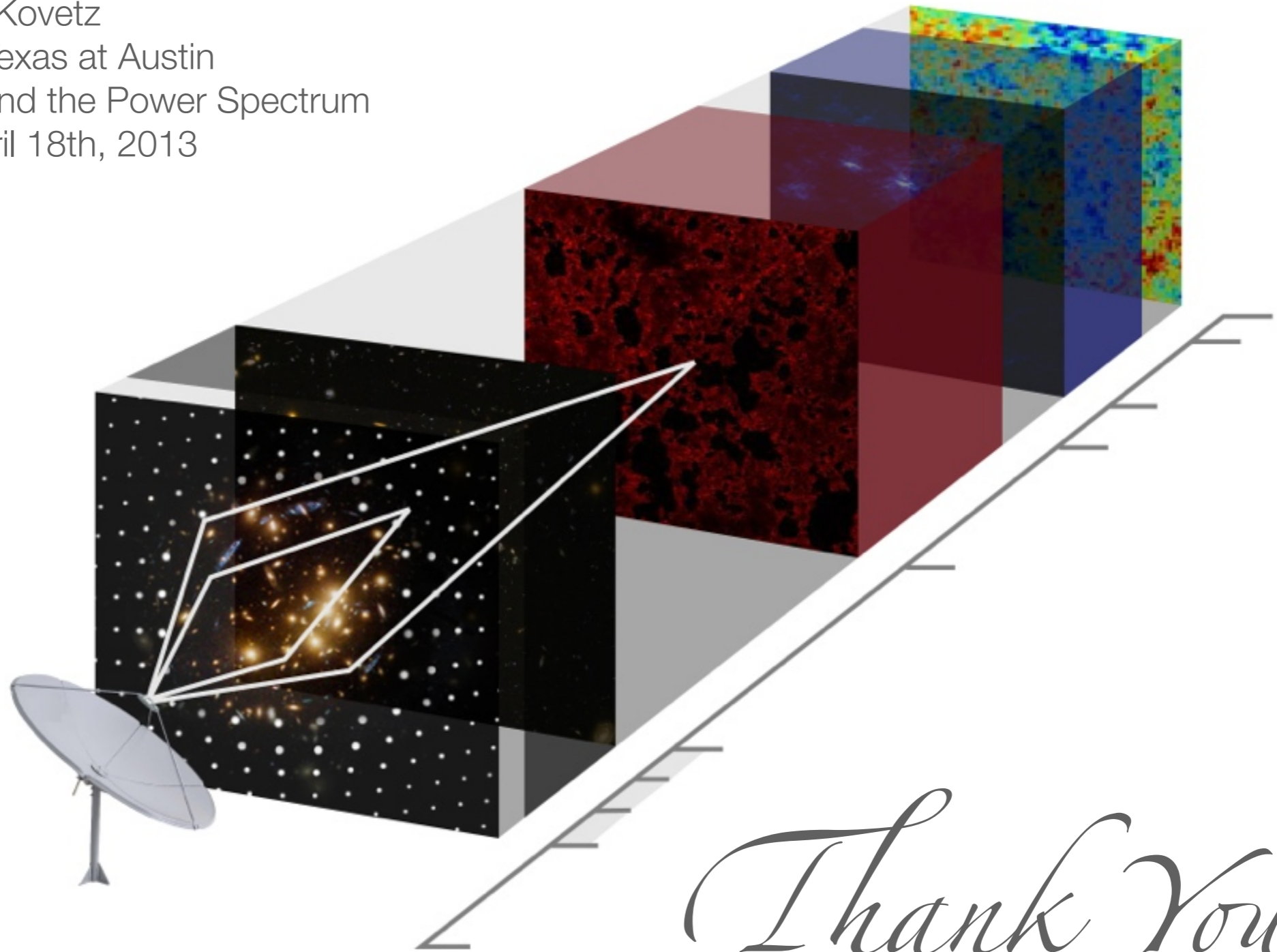
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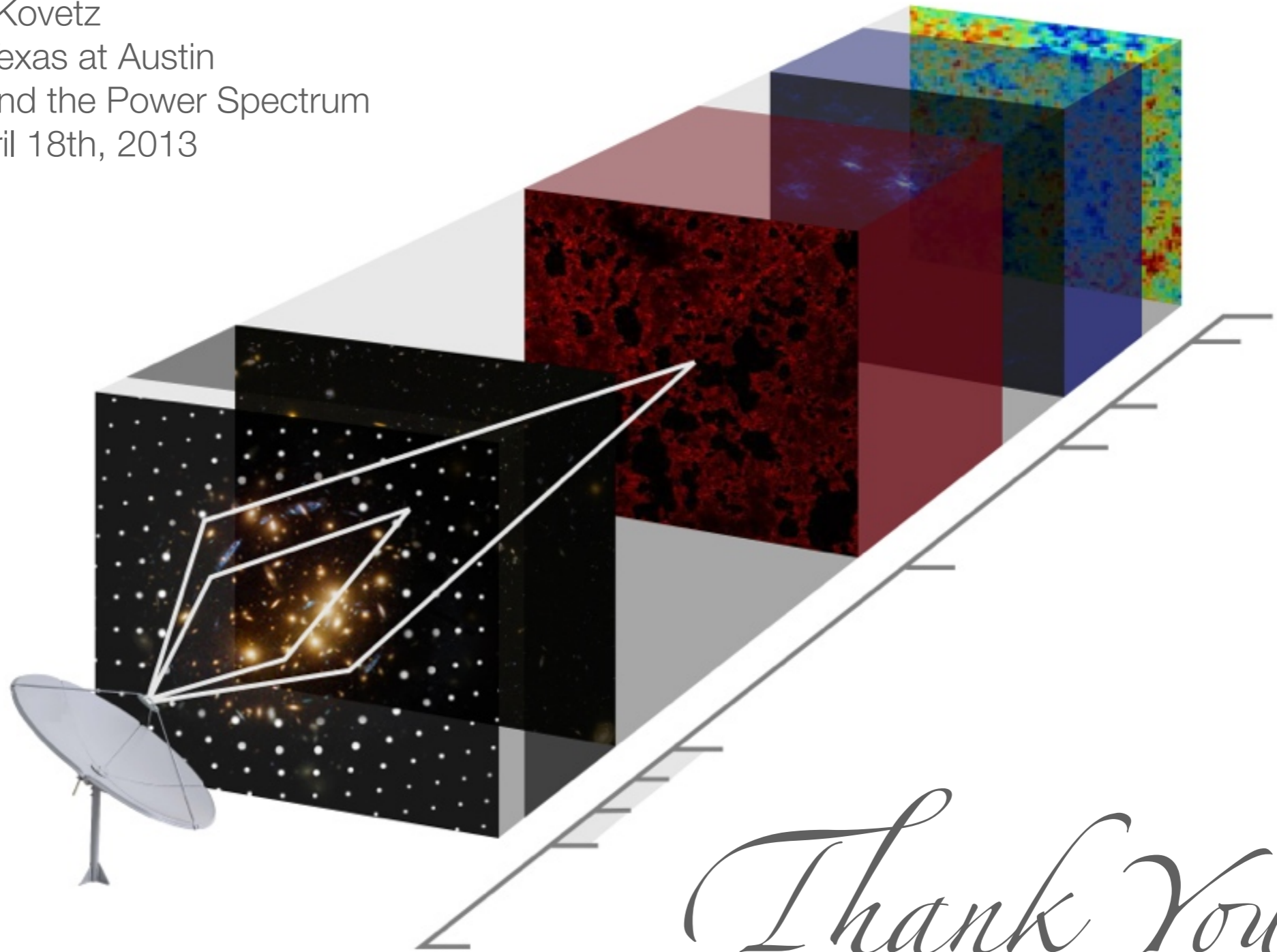
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Redshift Dependence

Tradeoff:

- For high redshift clusters, higher redshift slices have more lensing signal.
- For given baseline, as redshift increases, resolution decreases.

$z = 0.5, 5$

