Detecting effects of transplanckian physics with cosmological precision measurements

based on

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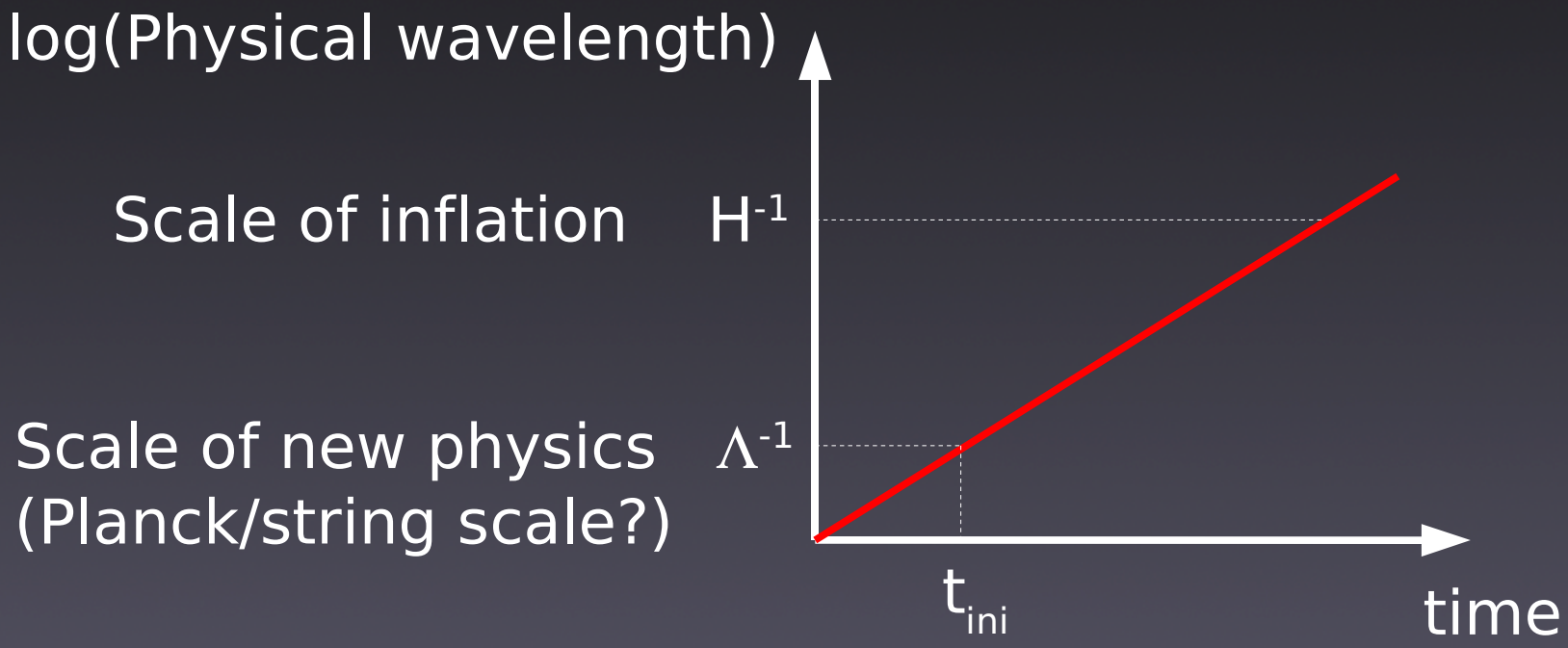
Inflation and initial conditions

- Inflation sets initial conditions for structure formation
- What about the initial conditions of inflation itself?
  - Classical level: attractor solution exists
  - Quantum level: no unique choice

  Typically impose Bunch-Davies vacuum of de Sitter space at sub-Hubble scales

Transplanckian origin of fluctuations



- At early times, wavelength is shorter than Planck scale (or other new physics scale)
- Impose initial conditions at scale Λ^{-1} (not necessarily Bunch-Davies)

Signatures of non-BD initial conditions

- Depends on new physics...
- Many suggestions:

[Danielsson; Easther, Greene, Kinney, Shiu; Martin, Brandenberger; Bozza, Giovannini, Veneziano; Kaloper, Kleban, Lawrence, Shenker; ...]

- Generic prediction:
  - Oscillatory modulation of perturbation spectra
  - Amplitude suppressed by some power of

$$\xi = H/\Lambda$$

Transplanckian ripples

(Danielsson model + slow roll inflation)

$$\mathcal{P}(k) \simeq \mathcal{P}^{\mathrm{BD}}(k) \left\{ 1 + \xi \left(\frac{k}{k_0} \right)^{-\epsilon} \sin \left[\frac{2\epsilon}{\xi} \ln \left(\frac{k}{k_0} \right) + \varphi \right] \right\}$$

- ξ = H/Λ: amplitude, frequency
- ϵ (first slow-roll parameter): frequency

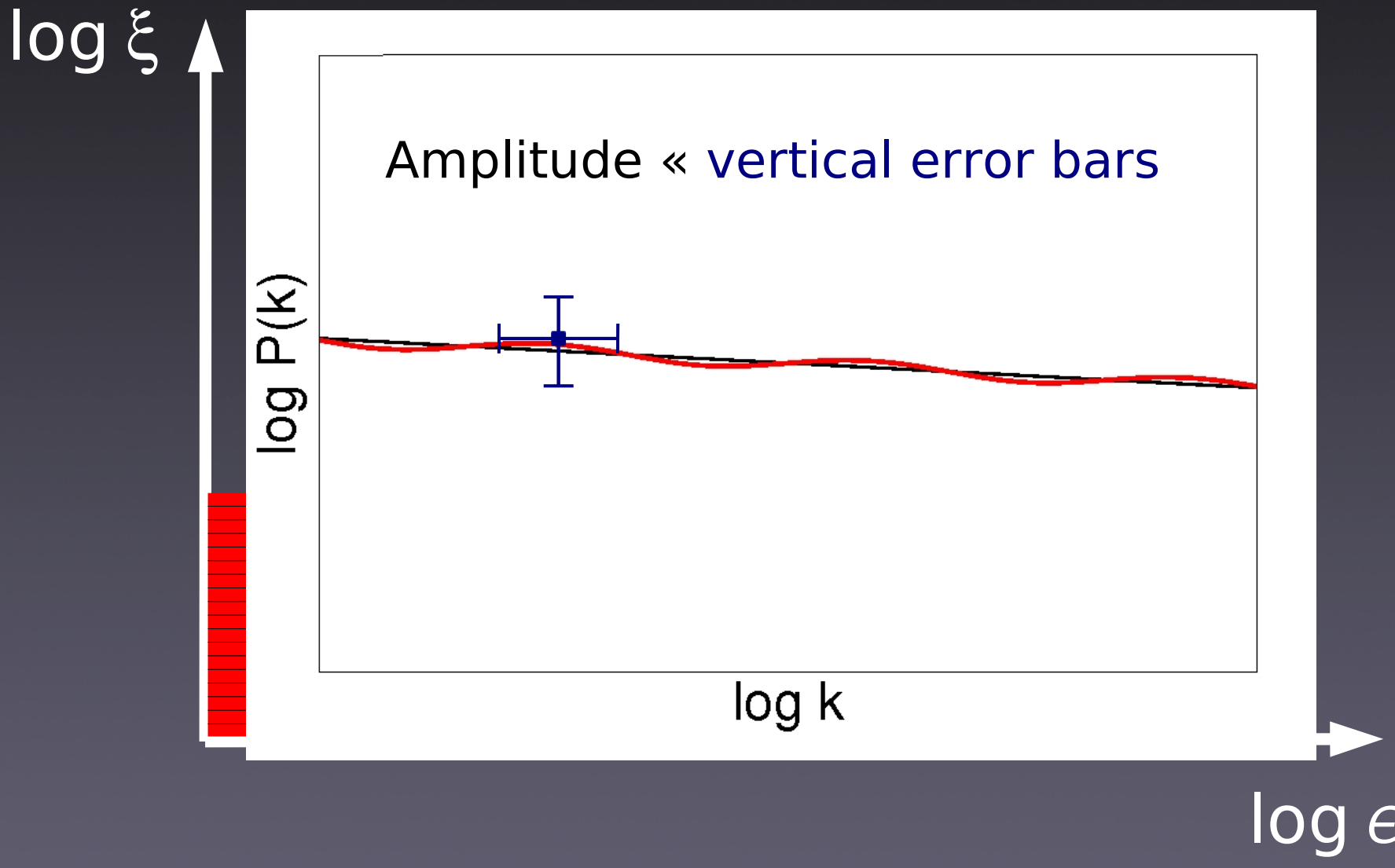
  (NB: tensor-to scalar ratio r = 16 ϵ)
- φ: phase

No evidence at present [Peiris et al. 2006]

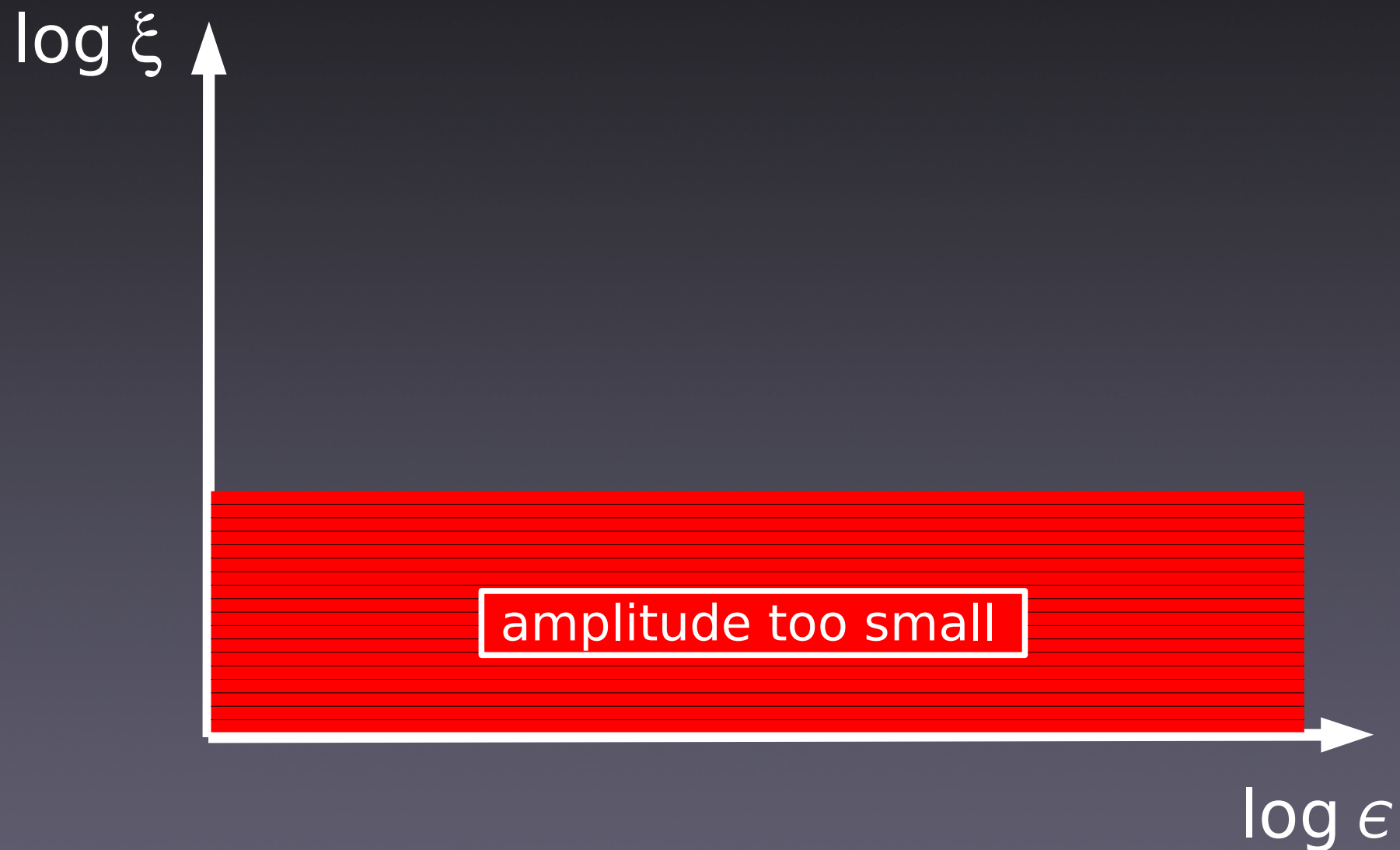
Can we distinguish ripples from smooth spectra in the future?

Parameter space

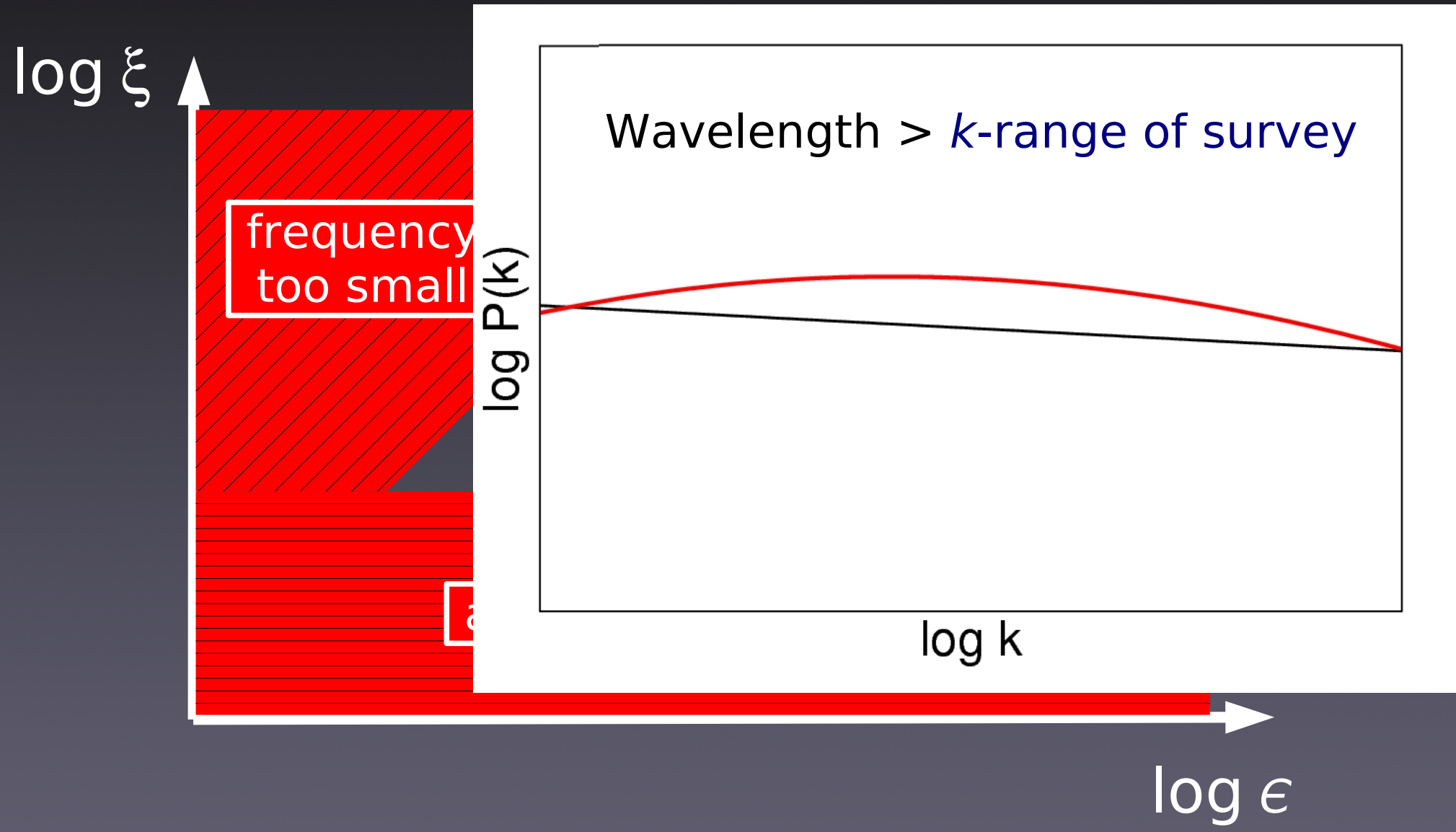
Parameter space



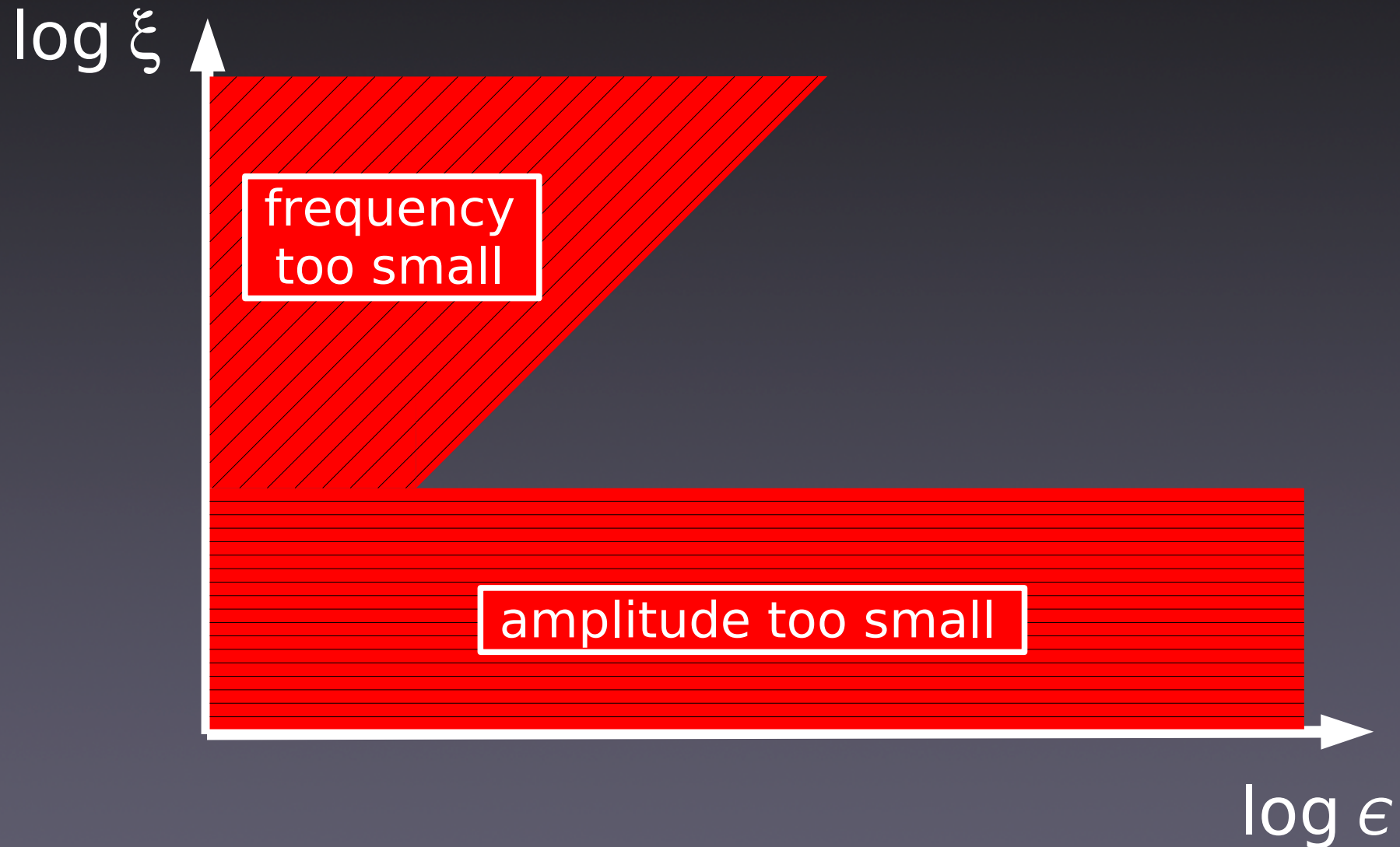
Parameter space



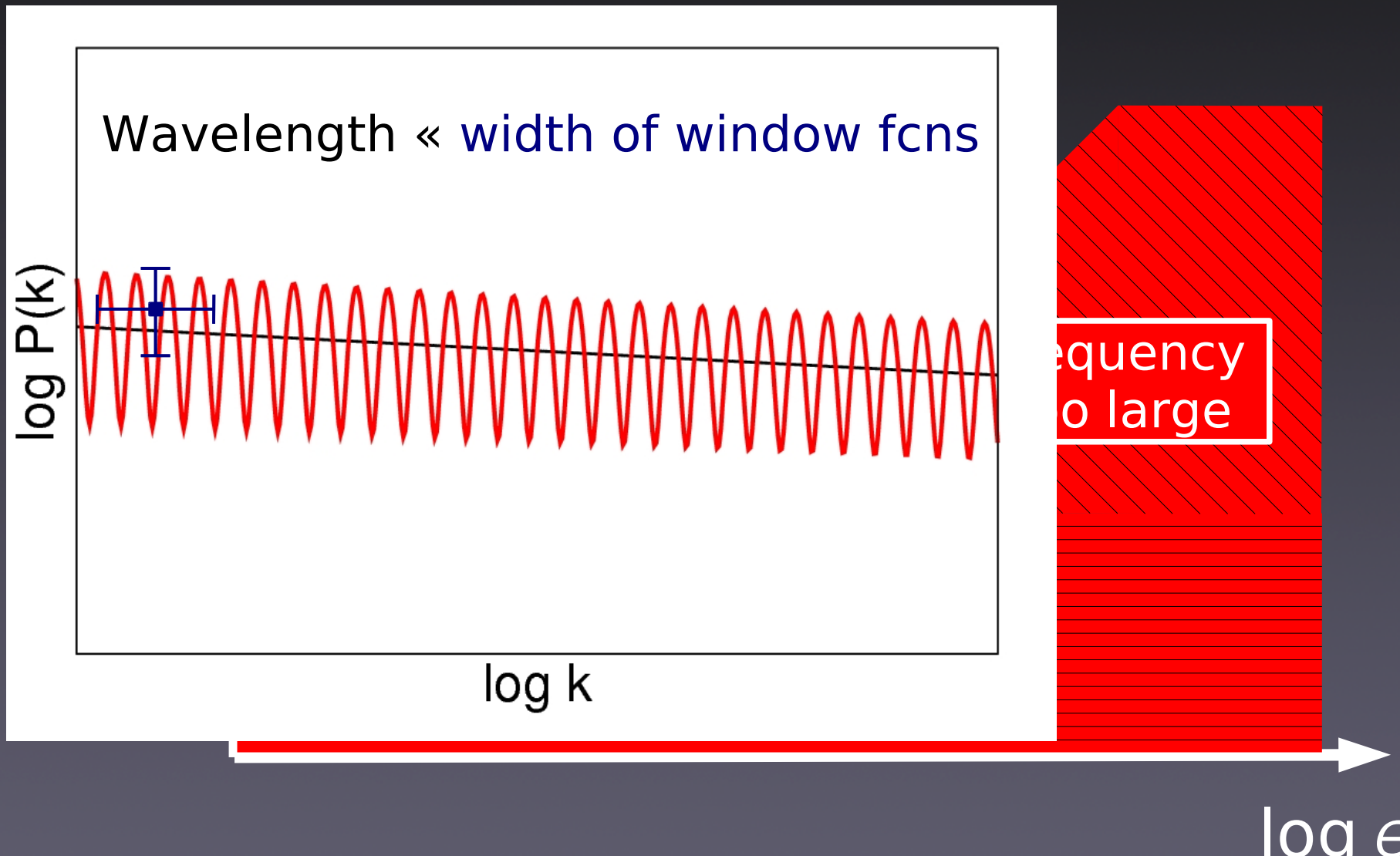
Parameter space



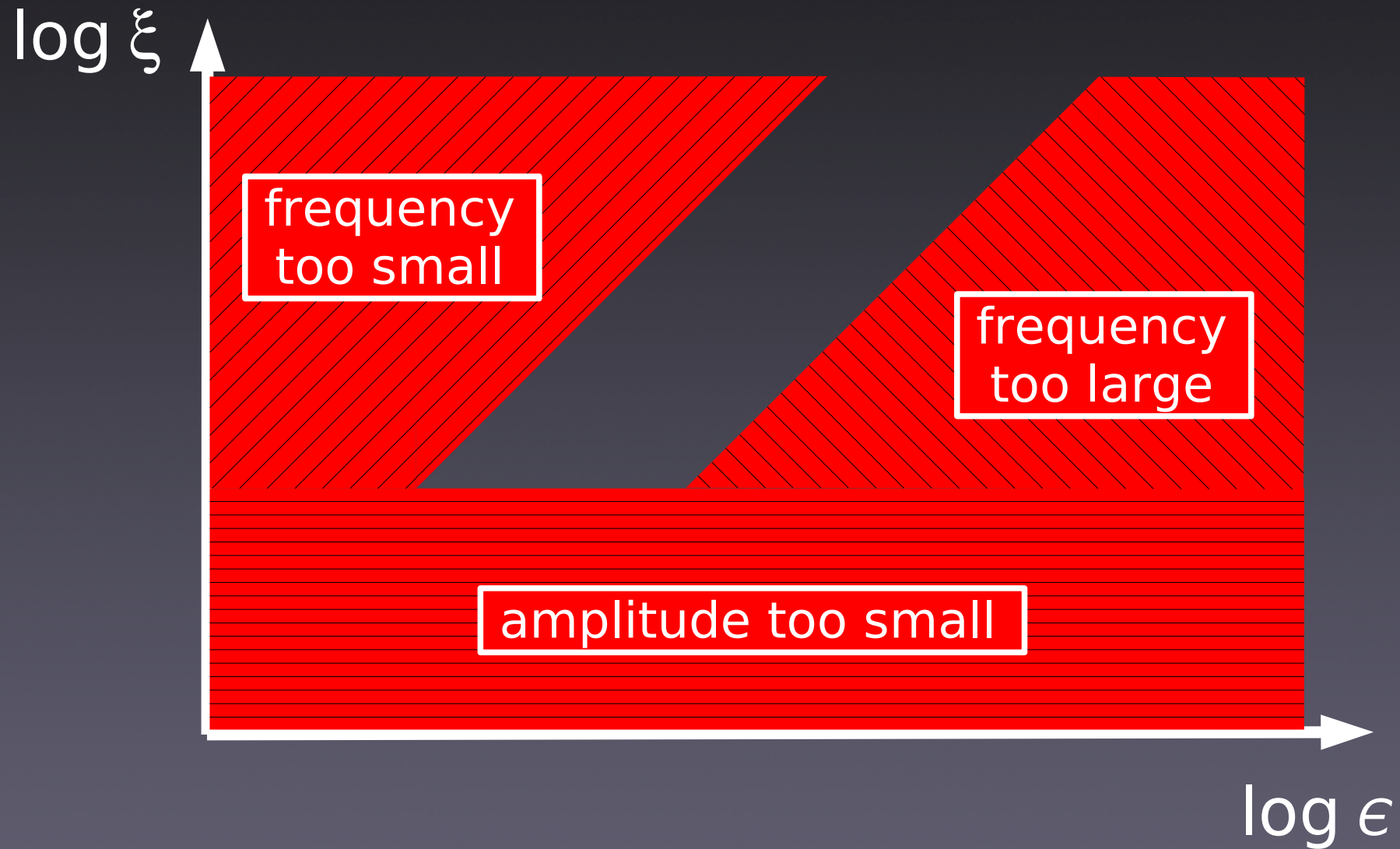
Parameter space



Parameter space



Parameter space



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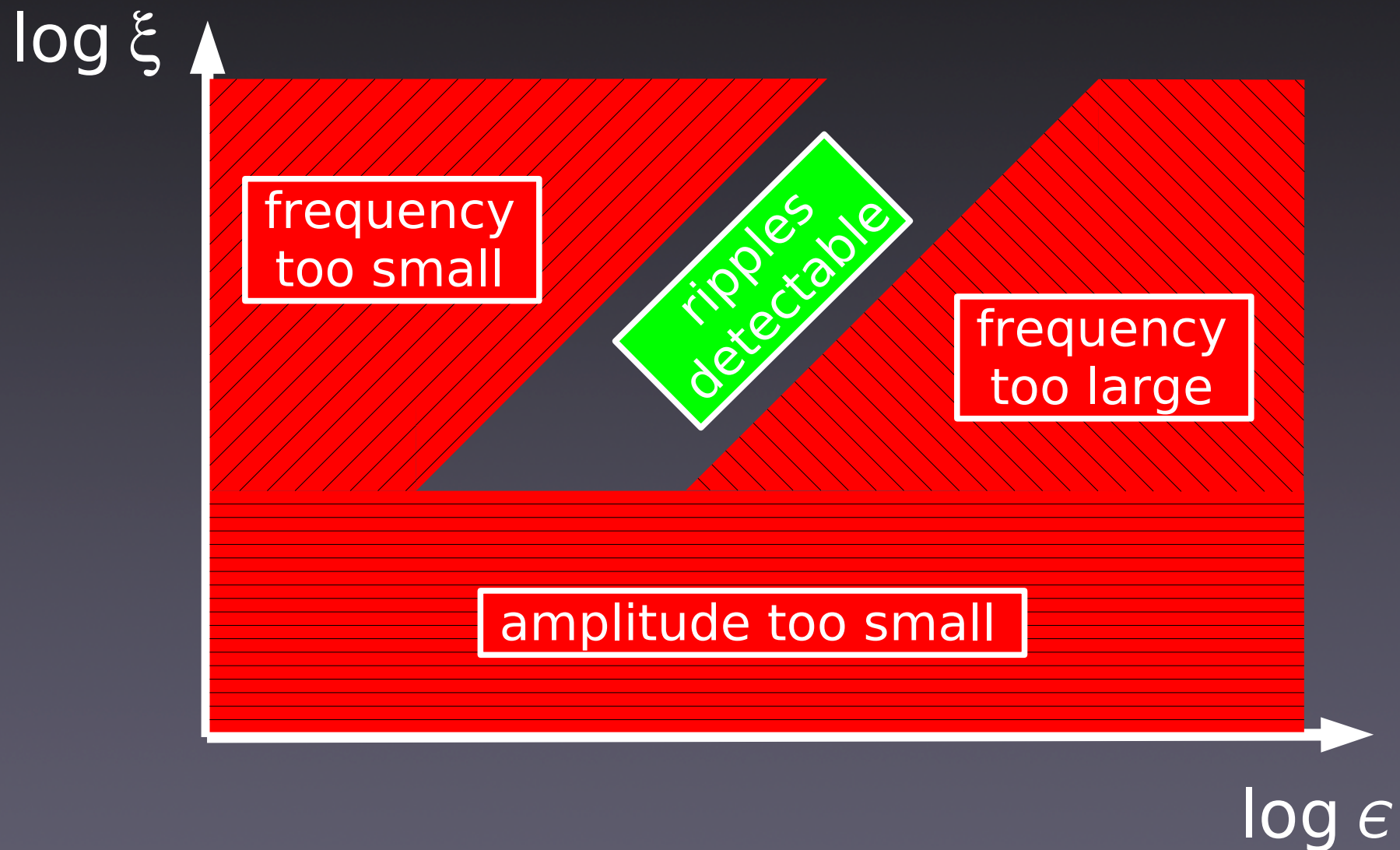
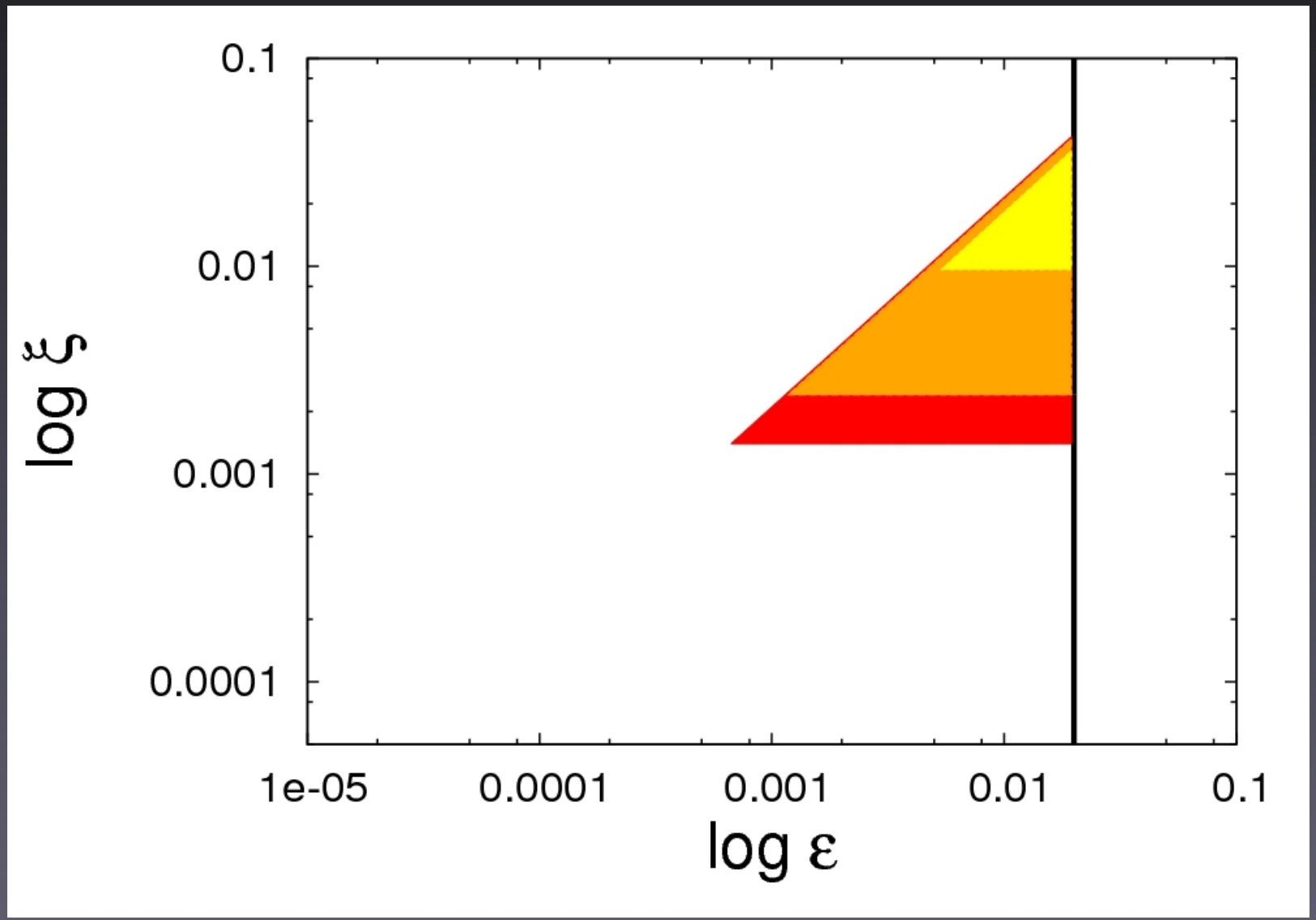


What can be detected?

- Assume real spectrum is wiggly
- Analytically estimate $\Delta\chi^2(\xi,\epsilon,\text{data})$ between fit with wiggly spectrum and fit with smooth spectrum *(backed up with rigorous simulation for selected parameter values)*
- ''Detectable @ 2σ'': $\Delta\chi^2 > 4$

Cosmic Microwave Background



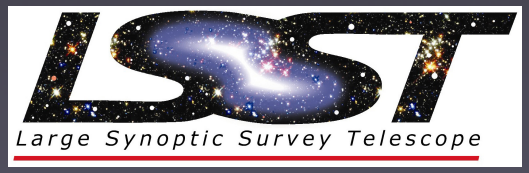
"WMAP"

"Planck"

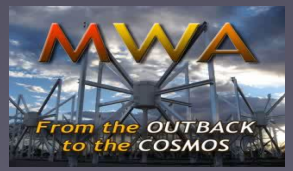
CVL_{2000}

Can we do better?

- CMB limited by sampling error
  Last scattering surface is only 2d!
- For any improvements, need tracers of 3d matter perturbations + large volume
  - Galaxies:



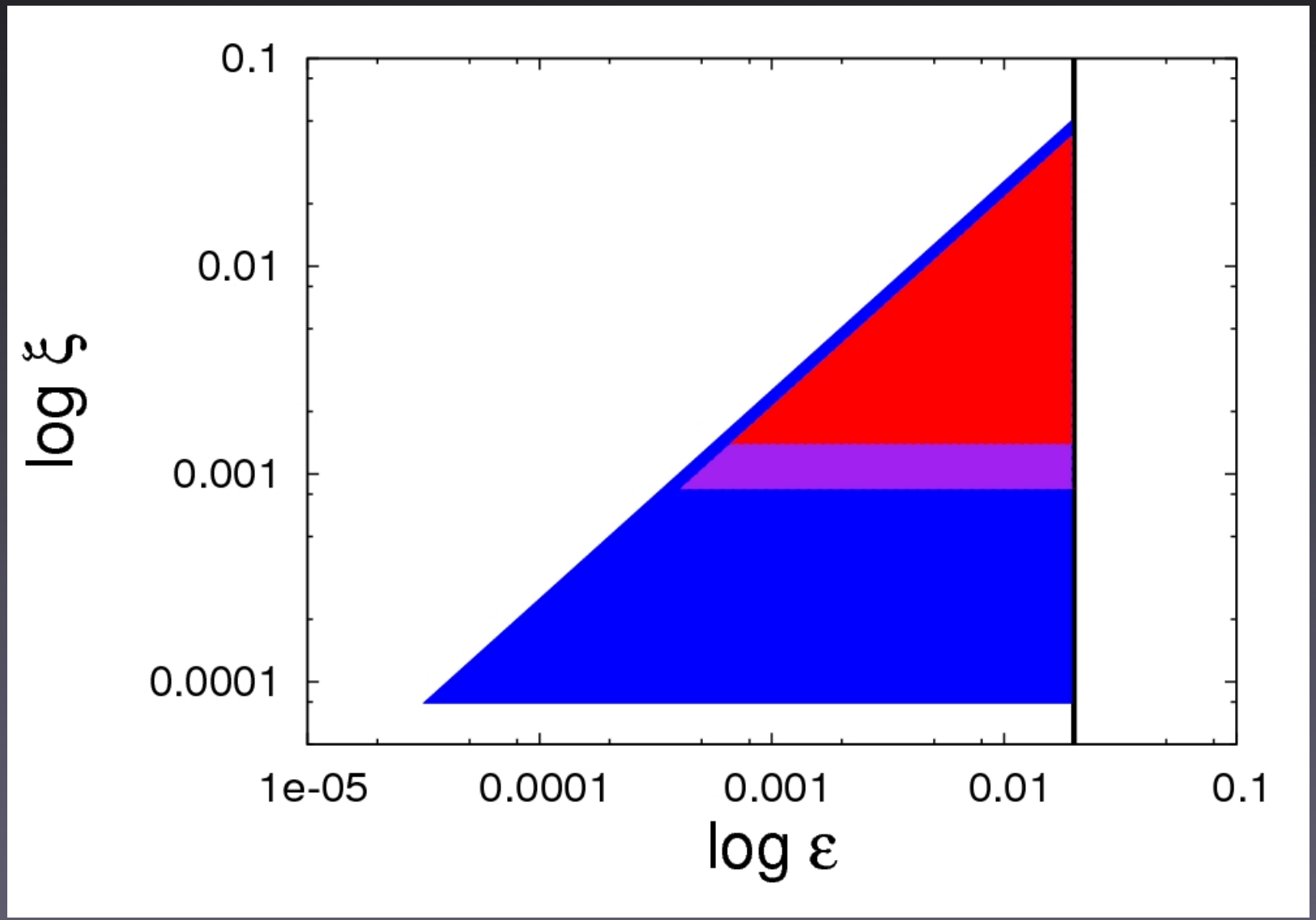
  - Neutral hydrogen (21 cm spin-flip line):



FFTT

[Tegmark, Zaldarriaga]

Future LSS probes



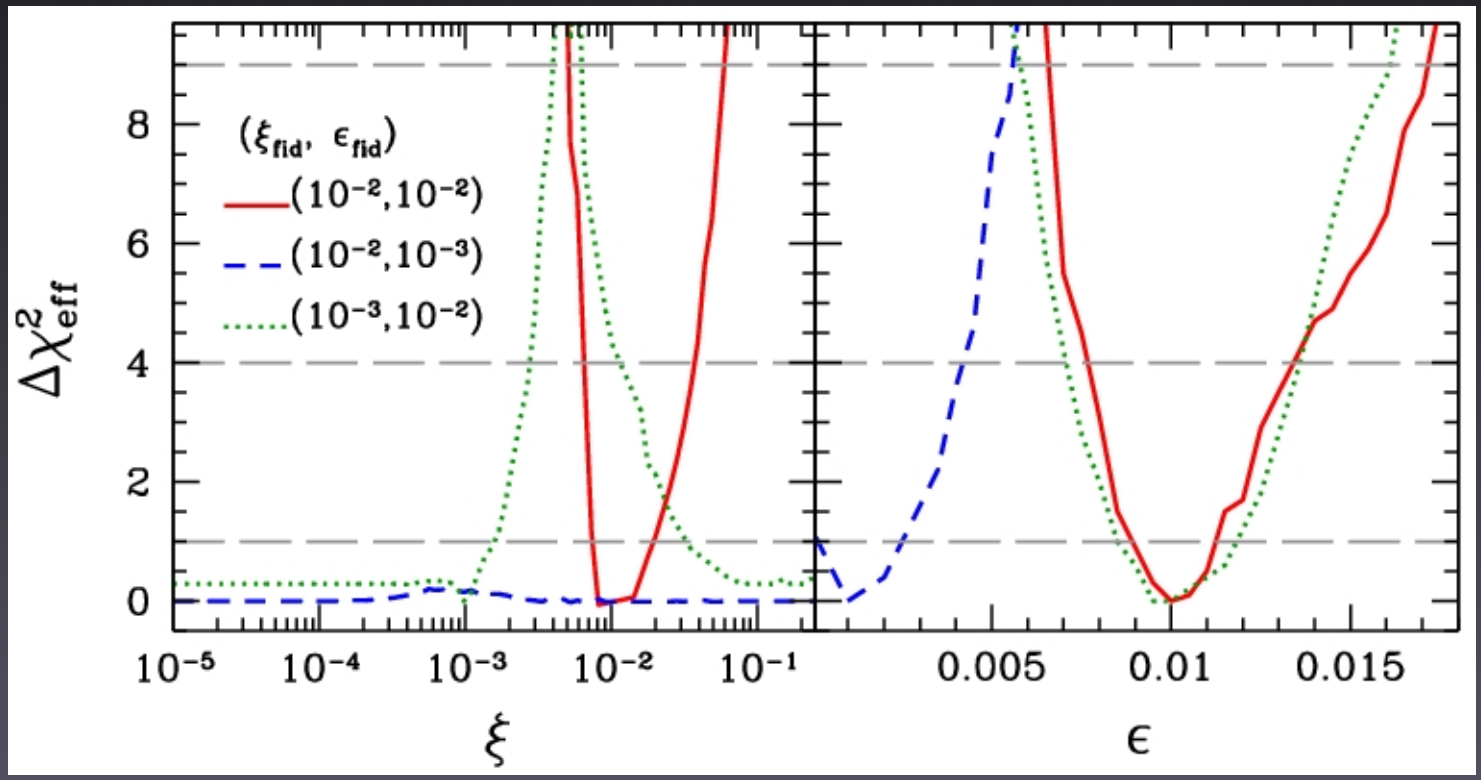
CVL_{2000}

CVL_{2000} + LSST

CVL_{2000} + FFTT

Conclusions

- Possibility of detection requires large tensor-to-scalar ratio [Easther Kinney Peiris]
- Under optimistic conditions, ξ as small as 10^{-4} may be detectable
- Present bound on H (see W. Valkenburg's talk) means $\Lambda > 0.1\ M_p$ will not be seen
- We probably (?!) do not need to worry about ''Trans-Planckian'' effects, but any detection would be a great thing


$(\xi_{fid}, \epsilon_{fid})$
$(10^{-2},10^{-2})$
$(10^{-2},10^{-3})$
$(10^{-3},10^{-2})$
$\Delta\chi^2_{eff}$
0
2
4
6
8
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
ξ
0.005
0.01
0.015
ϵ