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Weak lensing of CMB from cosmic (super-)strings

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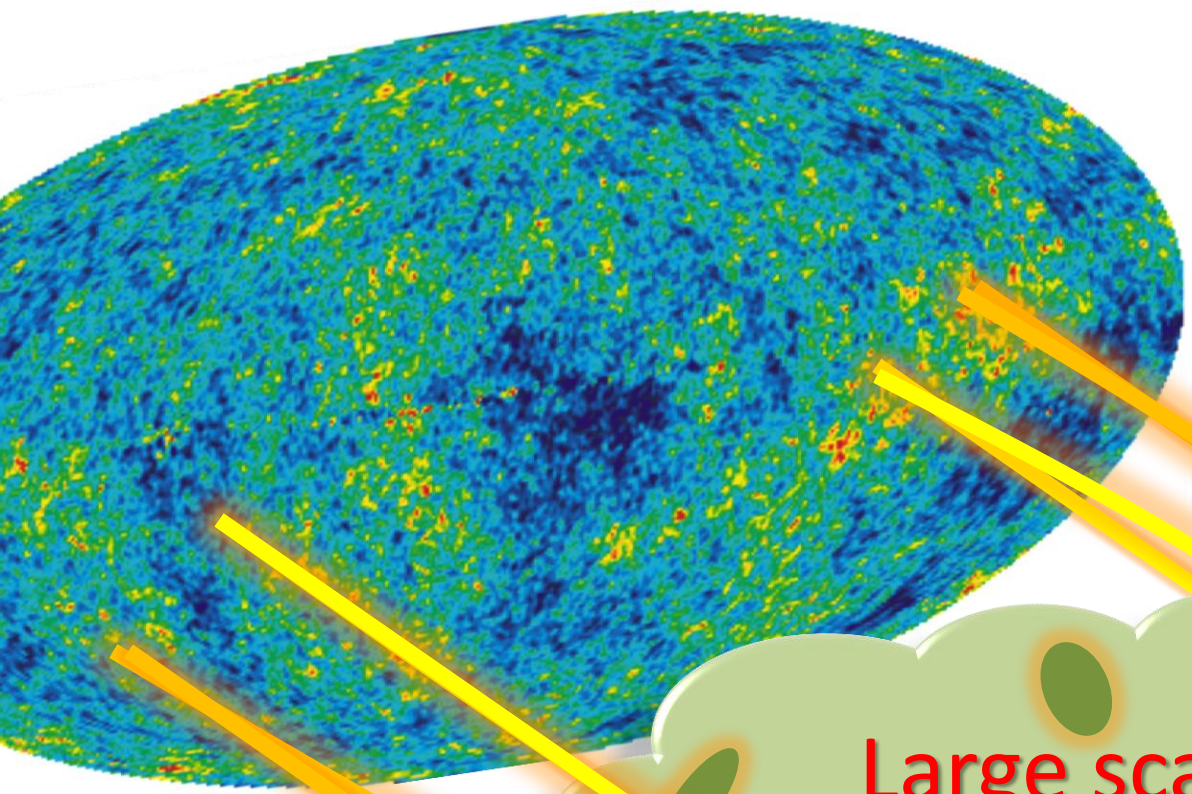
INTRODUCTION

CMB lensing

If no foreground sources, light ray goes straight along unperturbed path.
If LSS exists, light ray will be bent!



Large scale structure

Lensing effect on the CMB can be treated as a mapping of the intrinsic temperature/polarization fields.

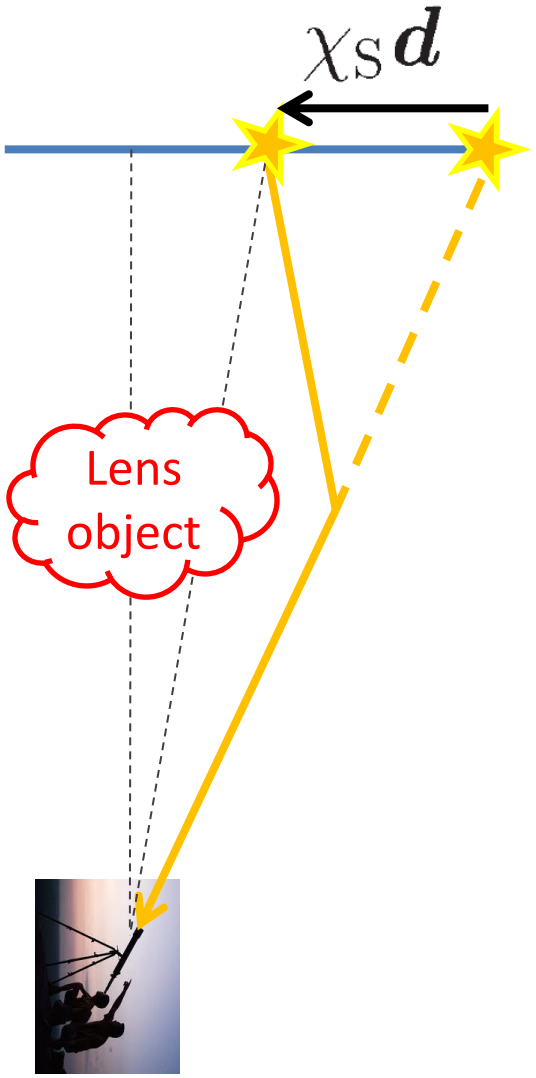
Scalar lensing potential

- Scalar perturbations such as foreground density perturbations produce only the gradient mode of the deflection:

ϕ : scalar lensing potential

$$\boldsymbol{d} = \nabla \cdot \int_0^{\chi_s} \mathrm{d}\chi \frac{\chi_s - \chi}{\chi_s \chi} \Phi(\chi, \boldsymbol{\theta})$$

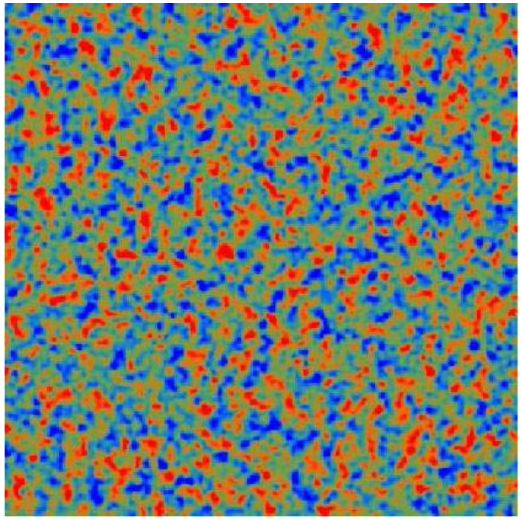
Lensing strength = Geometry of the universe × Matter potential



[Hu+Okamoto (2002)]

Lensing induces CMB B-mode

Only E-mode (unlensed)



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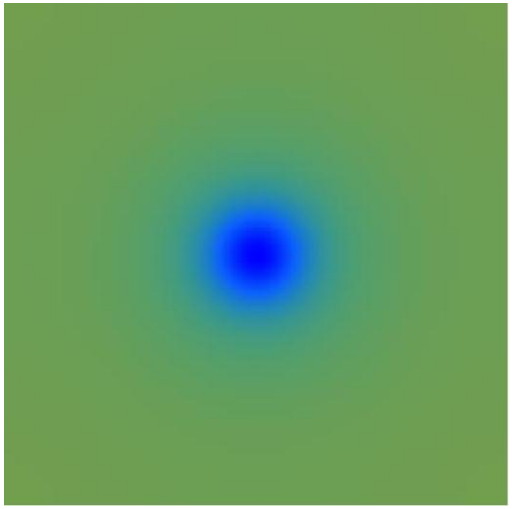
Foreground matter distribution



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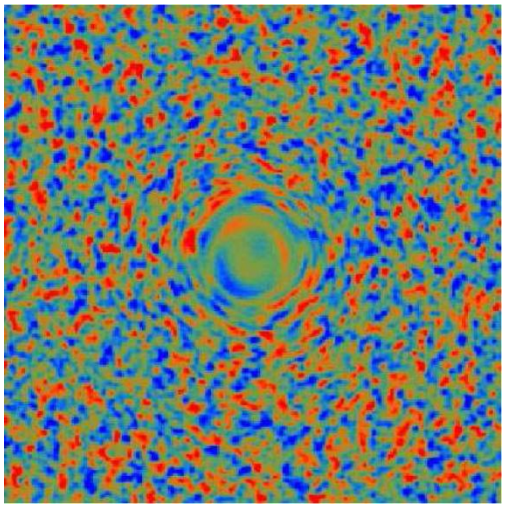
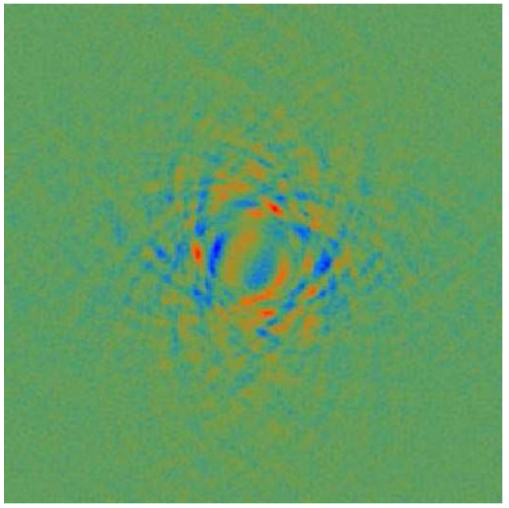
Lensed E-mode

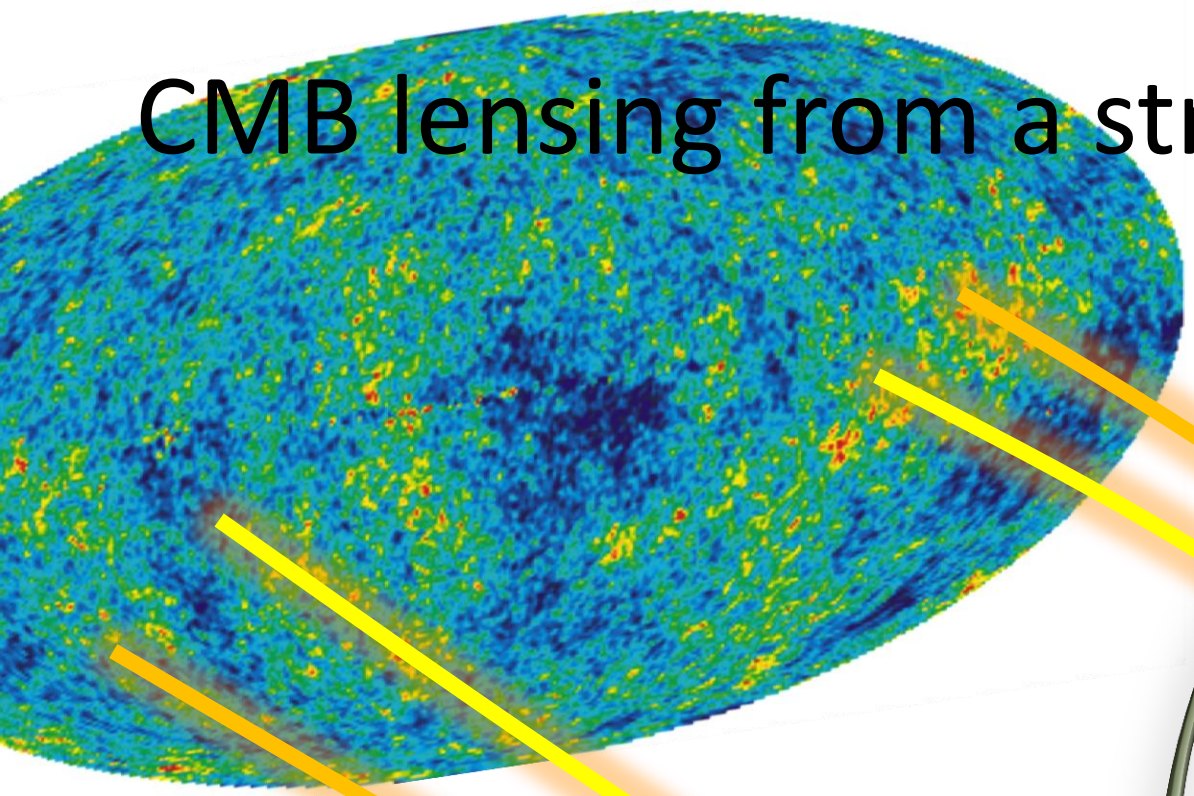


Nonzero lensed B-mode !!!



- Foreground density perturbations contribute to B-mode through the partial conversion of E-mode to B-mode !

CMB lensing from a string network



Key: Cosmic strings can produce not only scalar, but also vector and tensor perturbations !

Gradient and curl part of deflection

- ``Curl mode'' can be induced by scalar and/or tensor perturbations:

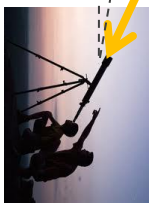
$$\boldsymbol{d} = \nabla\phi + (*\nabla)\varpi$$

Scalar/Vector/Tensor perturbations

~~Scalar~~/Vector/Tensor perturbations

subdominant, but may be helpful for very high energy physics !

Lens object



We should investigate cosmic strings as the possible source of the B-mode though weak lensing.
The curl mode is a new smoking gun of cosmic strings.

Cosmic (super-)strings

- ✓ It is natural to expect that conventional cosmic strings have formed during phase transitions in the early universe.
- ✓ Vari
  may

Intercommutation process provides a mechanism for a string network to lose its energy and approach to an attractor sol.

→ P is strongly related to the string number density !

Intercommuting probability P (clue to detect superstrings !)

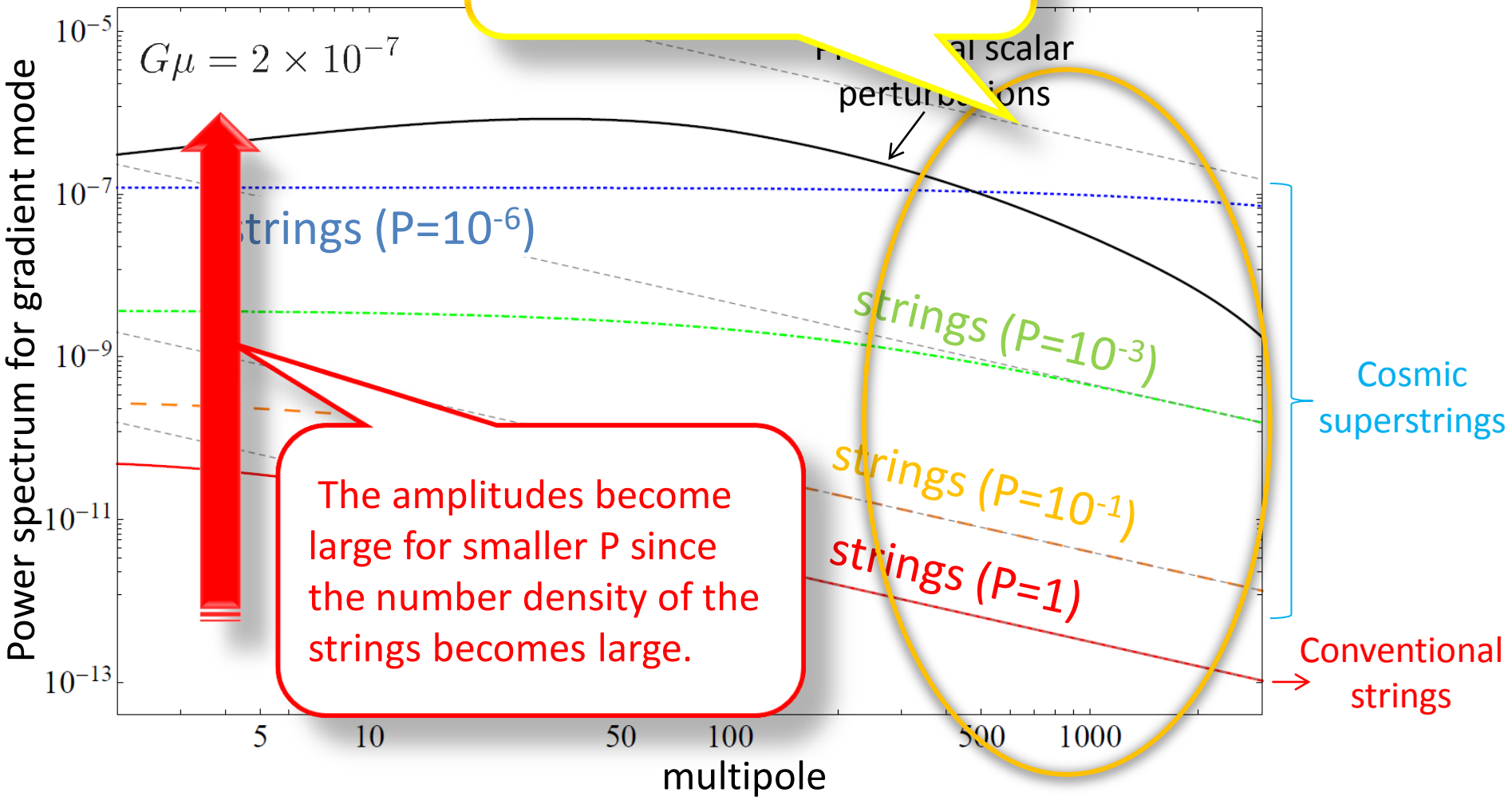
- ➢ Conventional cosmic strings : P=1
- ➢ Cosmic superstrings : $P \sim 10^{-3} \ll 1$

CMB LENSING FROM STRINGS

[**DY**, Takahashi, Sendouda, Yoo, in prep.]

Sca tial from trings

The spectra decay more slowly compared with primordial scalar lensing.

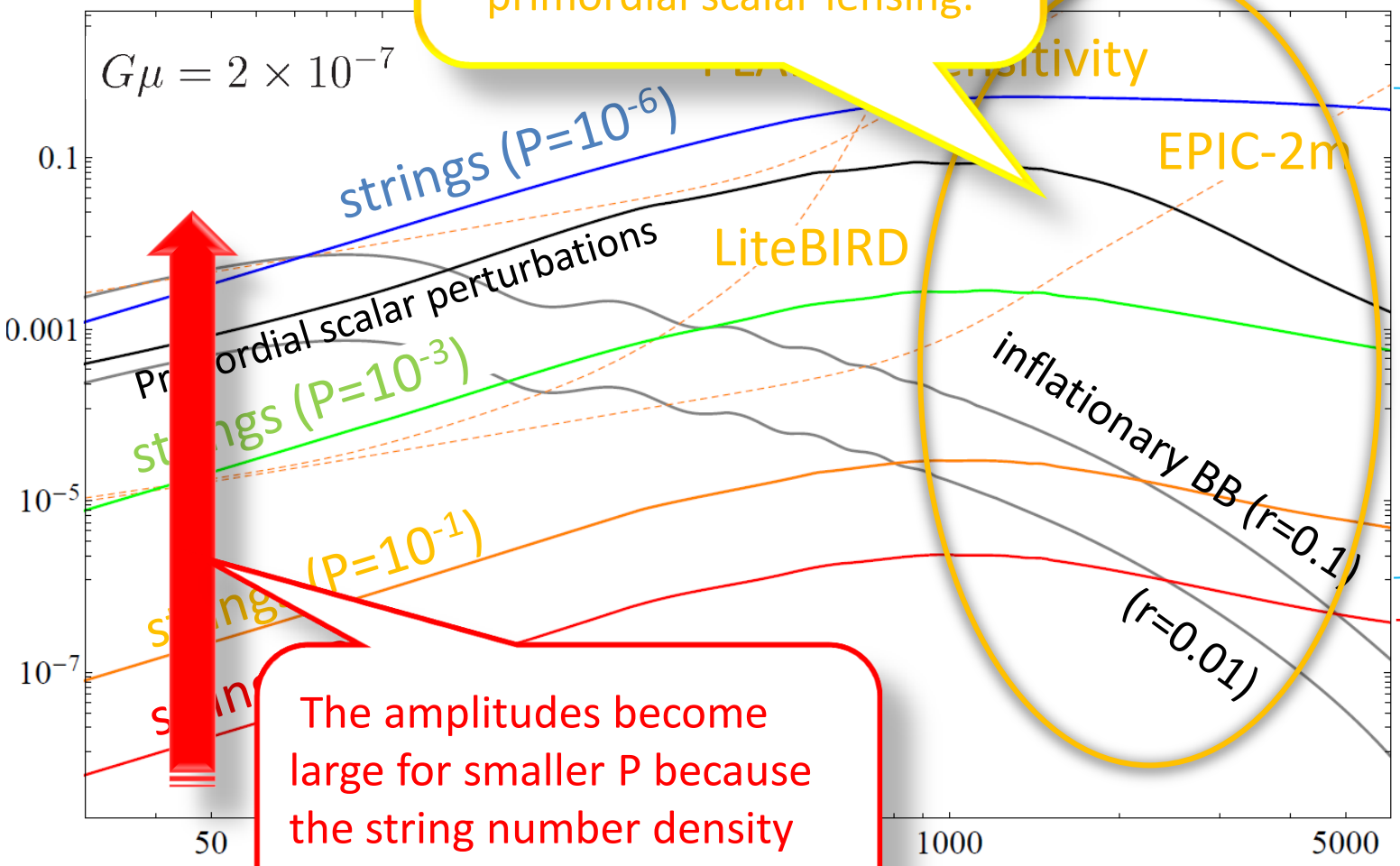


The amplitudes become large for smaller P since the number density of the strings becomes large.

[...ashi, Sendouda, Yoo, in prep.]

B-mode ...nsing by CS

In the small scale limit: the lensed BB spectra decay more slowly compared with primordial scalar lensing.

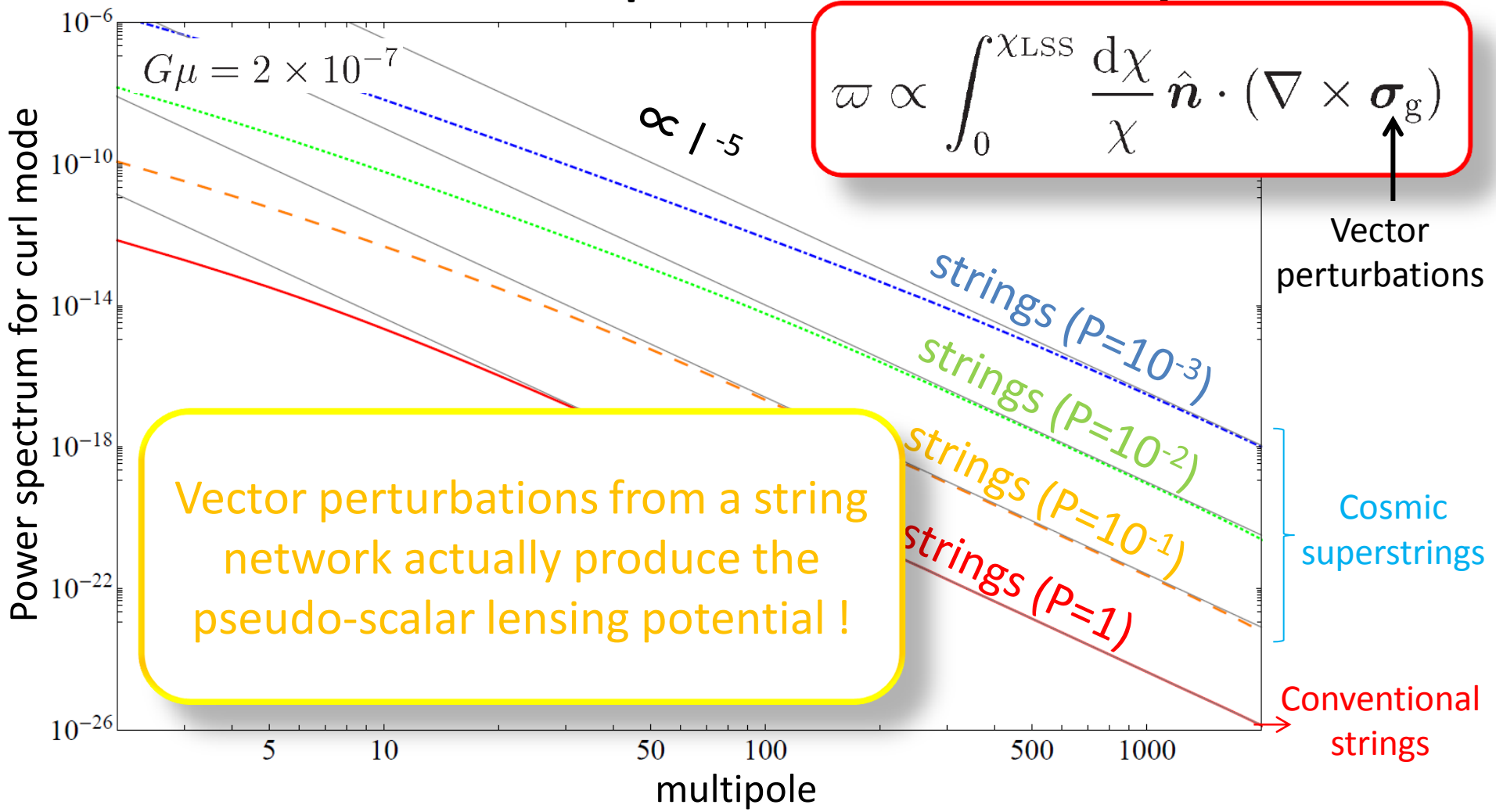


Power spectrum for B-mode

The amplitudes become large for smaller P because the string number density becomes large.

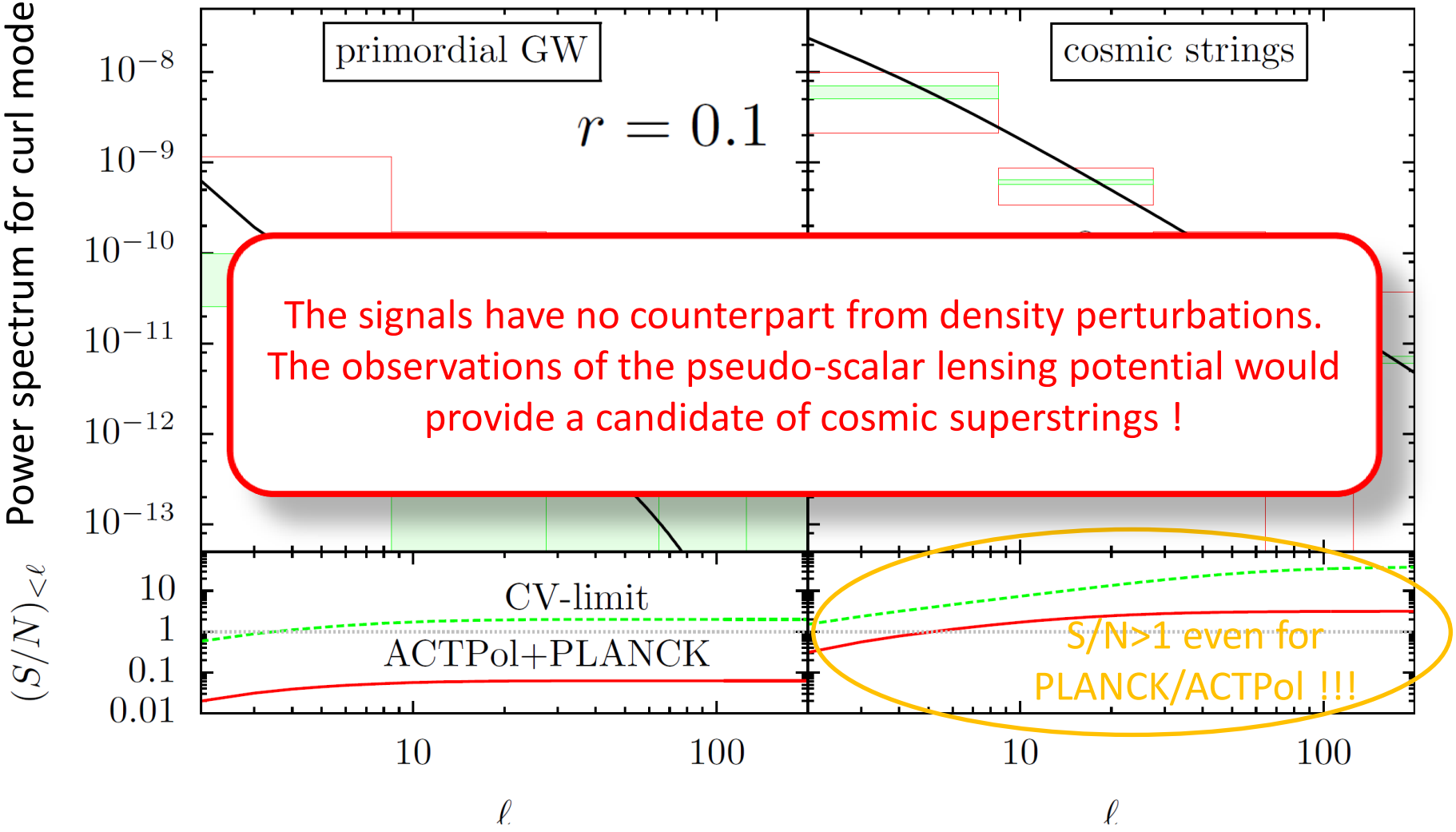
[Namikawa, **DY**, Taruya, in prep.]

Pseudo-scalar lensing potential from vector perturbations by CS



[Namikawa, **DY**, Taruya, in prep.]

Detectability for pseudo-scalar lensing potential



Summary

- ✓ Topological defects can produce not only scalar-, but also vector-/tensor-perturbations, which lead to the unusual deflection:

$$\boldsymbol{d} = \nabla\phi + (*\nabla)\varpi$$

Scalar/Vector/Tensor perturbations

~~Scalar~~/Vector/Tensor perturbations

- ✓ In small scale limit, the BB spectrum decays more slowly compared with the primordial matter perturbations.
- ✓ The pseudo-scalar lensing potential can be induced by a string network and it would provide a new smoking gun of cosmic superstrings!

Thank you !