Overview of Complementarity & Synergy with Other Wavelengths in Cosmology

Keitaro Takahashi
(Kumamoto University)

[on behalf of SKA Cosmology Team]
Ultimate Surveys in SKA Era

- **CMB**
  - B-mode: LiteBird, COrE, B-Pol, EPIC
  - spectrum: PRISM, PIXIE

- **opt/IR**
  - image: Euclid, WFIRST, LSST
  - spectrum: Euclid

- **X-ray**
  - eROSITA

statistical errors dominated
↓

systematic errors & cosmic variance dominated
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We need to think and collaborate!

statistical errors dominated

↓

systematic errors & cosmic variance dominated
Possible Synergies

- ISW with CMB
- weak lensing with opt/IR
- cluster cosmology with CMB and X-ray
- multi-tracer method with opt/IR and X-ray
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cross correlation between gals and CMB → probe gravitational potential
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\[ \tilde{\gamma} = \gamma + \gamma^i + \gamma^s \]

intrinsic shape (Patel+ 2010)    integrated polarization angle (Stil+ 2009)

Beck & Hoernes, 1996
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Possible Synergies

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  multi-tracer method with opt/IR

Seljak (2009)
reduce cosmic variance by taking a ratio of $\delta$ s of two populations with different bias (halo mass)

$$\delta_1 = b_1\delta_{DM} \quad \Rightarrow \quad \frac{b_2}{b_1} = \frac{\delta_2}{\delta_1}$$

obtain ratio of bias without stochasticity!
→ constraint on primordial non-Gaussianity

Carlton Baugh
Tests of Inflation

- density fluctuations
  - almost scale-invariant
  - tiny deviation from scale invariance
- primordial gravitational wave
  - existence (BICEPII?)
  - spectrum → future CMB experiments
- statistics of fluctuations
  - almost Gaussian
  - tiny non-Gaussianity

SKA will do the final test of inflation!
Multi-tracer method

Ferramacho et al. (2014)

SKA continuum survey

- Star forming galaxies (SFR): $M_{halo} = 1 \times 10^{11} h^{-1} M_{\odot}$
- Starbursts (SB): $M_{halo} = 5 \times 10^{13} h^{-1} M_{\odot}$
- Radio Quiet Quasars (RQQ): $M_{halo} = 3 \times 10^{12} h^{-1} M_{\odot}$
- Radio loud AGN (FRI): $M_{halo} = 1 \times 10^{13} h^{-1} M_{\odot}$
- Radio loud AGN (FRII): $M_{halo} = 1 \times 10^{14} h^{-1} M_{\odot}$

5 tracers
$\rightarrow f_{NL} < 1$

SKA cannot distinguish all populations.
$\rightarrow$ need opt/IR & X-ray!
Multi-tracer method

Yamauchi, KT & Oguri, in preparation
combine SKA & Euclid

SKA: continuum survey
  (5 tracers)
Euclid: imaging survey
  (5 tracers & 8 z bins)

\( f_{\text{NL}} \sim O(0.1)! \)
Planck constraint

nonlinear effects

cyclic model

simple inflation

extended inflation

nonGaussianity

$f_{NL}$
nonGaussianity

$ f_{NL} $

Planck constraint

SKA1

nonlinear effects

SKA2

cyclic model

extended inflation

simple inflation
confirm our understanding of nonlinear processes

constrain many of extended models and cyclic model

nonGaussianity

$f_{NL}$

10

1

0.01

Planck constraint

nonlinear effects

SKA1

SKA2

cyclic model

simple inflation

extended inflation
Summary

future ultimate surveys

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synergies

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- multi-tracer method with **opt/IR** and **X-ray**