# Conformal Modulated Reheating

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# Conformal Inflation

inflation driven by a conformally coupled scalar field

Kofman and Mukohyama 2008

$$\mathcal{L} = \sqrt{-g}\left[\frac{M_p^2}{2}R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi) - \frac{1}{2}\xi R\phi^2\right] \quad \text{with} \quad \xi = \frac{1}{6}$$

cosmological fluctuations can be generated by light fields other than the inflaton (e.g. modulated reheating, curvaton)

- How can conformal inflation be distinguished from minimal ( $\xi = 0$ ) models?
- Any special features on cosmological observables?

We focus on the case where conformal inflation and modulated reheating is in work.

# Modulated Reheating

Dvali, Gruzinov, and Zaldarriaga 2003　　Kofman 2003

$\chi$ : light field whose VEV determines the decay rate of $\phi$

fluctuations of $\chi$

$\longrightarrow$ fluctuations in the decay rate of $\phi$

$\longrightarrow$ density perturbations

$$\zeta = -\frac{1}{6}\frac{\delta\Gamma}{\Gamma} \qquad n_s - 1 = \frac{d\,\ln H^2}{d\,\ln k}$$

# Conditions for Conformal Inflation

$$\mathcal{L} = \sqrt{-g}\left[\frac{M_p^2}{2}R - \frac{1}{2}g^{\mu\nu}\partial_\mu\phi\partial_\nu\phi - V(\phi) - \frac{1}{2}\cdot\frac{1}{6}R\phi^2\right]$$

flatness parameters

$$\epsilon \equiv \frac{M_p^2}{2}\left(\frac{V'}{V}\right)^2 \qquad \tilde{\epsilon} \equiv \frac{V'\phi}{2V} \qquad \eta_c \equiv \frac{M_p^2 V''}{V} + \frac{c+2}{3}\left(\frac{V''\phi}{V'} + c\right)$$

$c$ : dimensionless constant

$$\longrightarrow \quad \epsilon,\ |\tilde{\epsilon}|,\ |\eta_c| \ll 1$$

approximations

$$V \simeq 3M_p^2H^2 \qquad -V' \simeq (2+c)H(\dot{\phi} + H\phi)$$

$$\dot{\phi} \simeq -H\phi \quad \text{(rapid roll)}$$

# Cosmological Observables

spectral index

$$n_s - 1 = -2\tilde{\epsilon} - \left\{ \frac{12}{(2+c)^2} + \kappa \right\} \epsilon \; +2\kappa \left( \xi - \frac{1}{6} \right)$$

running

$$\frac{dn_s}{d\ln k} = \kappa\eta + 2\tilde{\epsilon} \; + \left\{ \frac{6(2-3c)}{(2+c)^2} + \kappa \right\} \epsilon \; -4\kappa \left( \xi - \frac{1}{6} \right)$$

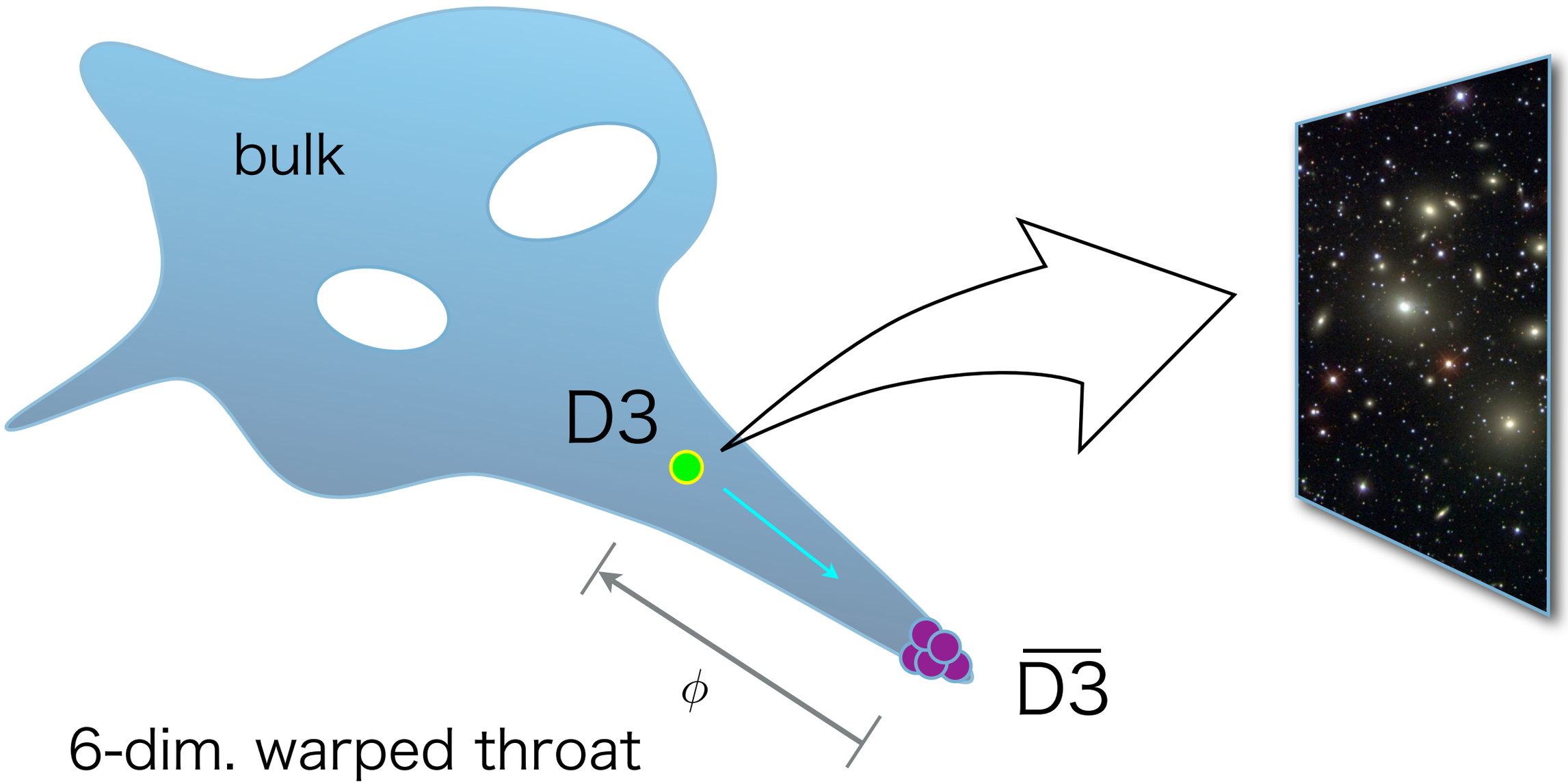
$$\kappa \equiv \left( \frac{\phi}{M_p} \right)^2 \qquad \eta \equiv \frac{M_p^2 V''}{V}$$

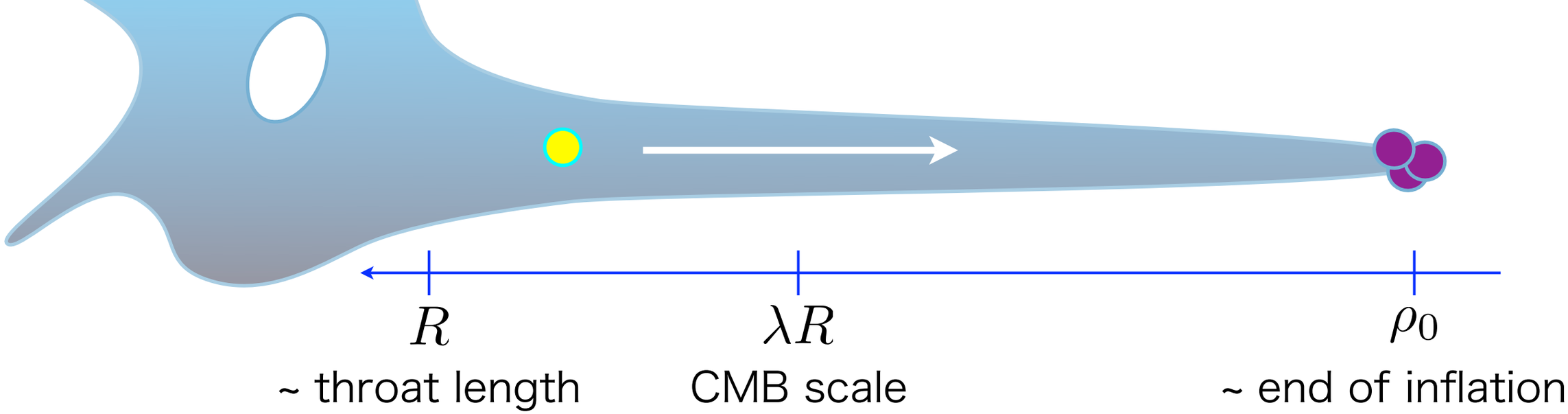
Huge running (comparable to $n_s - 1$ ) are obtained!

# Application to Warped Brane Inflation

Kachru, Kallosh, Linde, Maldacena, McAllister, Trivedi 2003

coformally coupled inflaton : radial position of D3-brane






inflaton potential $$V(\phi) = V_0 \left[ 1 - \frac{M_p^4 \Delta^4}{\phi^4} \right]$$

$\Delta \propto h_0$ : warping of the throat

e-foldings $$\mathcal{N} \simeq -\log\left(\frac{h_0}{\lambda}\right)$$

$$n_s - 1 \simeq -\frac{4}{N}\left\{\frac{h_0^4}{\lambda^4} - 2\lambda^2\left(\xi - \frac{1}{6}\right)\right\}$$

$$\frac{dn_s}{d\ln k} \simeq -\frac{16}{N}\left\{\frac{h_0^4}{\lambda^4} + \lambda^2\left(\xi - \frac{1}{6}\right)\right\}$$

$N$ : background flux number

# Comparison with WMAP5

observational bounds from WMAP5+BAO+SN

(68% CL, negligible $r$ )

$$n_s \;:\; 1.022^{+0.043}_{-0.042} \qquad\qquad \frac{dn_s}{d\ln k} \;:\; -0.032^{+0.021}_{-0.020}$$

$\frac{h_0^4}{\lambda^4}$ terms may well be ignored

$$\begin{cases} n_s - 1 \simeq 8\dfrac{\lambda^2}{N}\left(\xi - \dfrac{1}{6}\right) \\ \dfrac{dn_s}{d\ln k} \simeq -16\dfrac{\lambda^2}{N}\left(\xi - \dfrac{1}{6}\right) \end{cases}$$

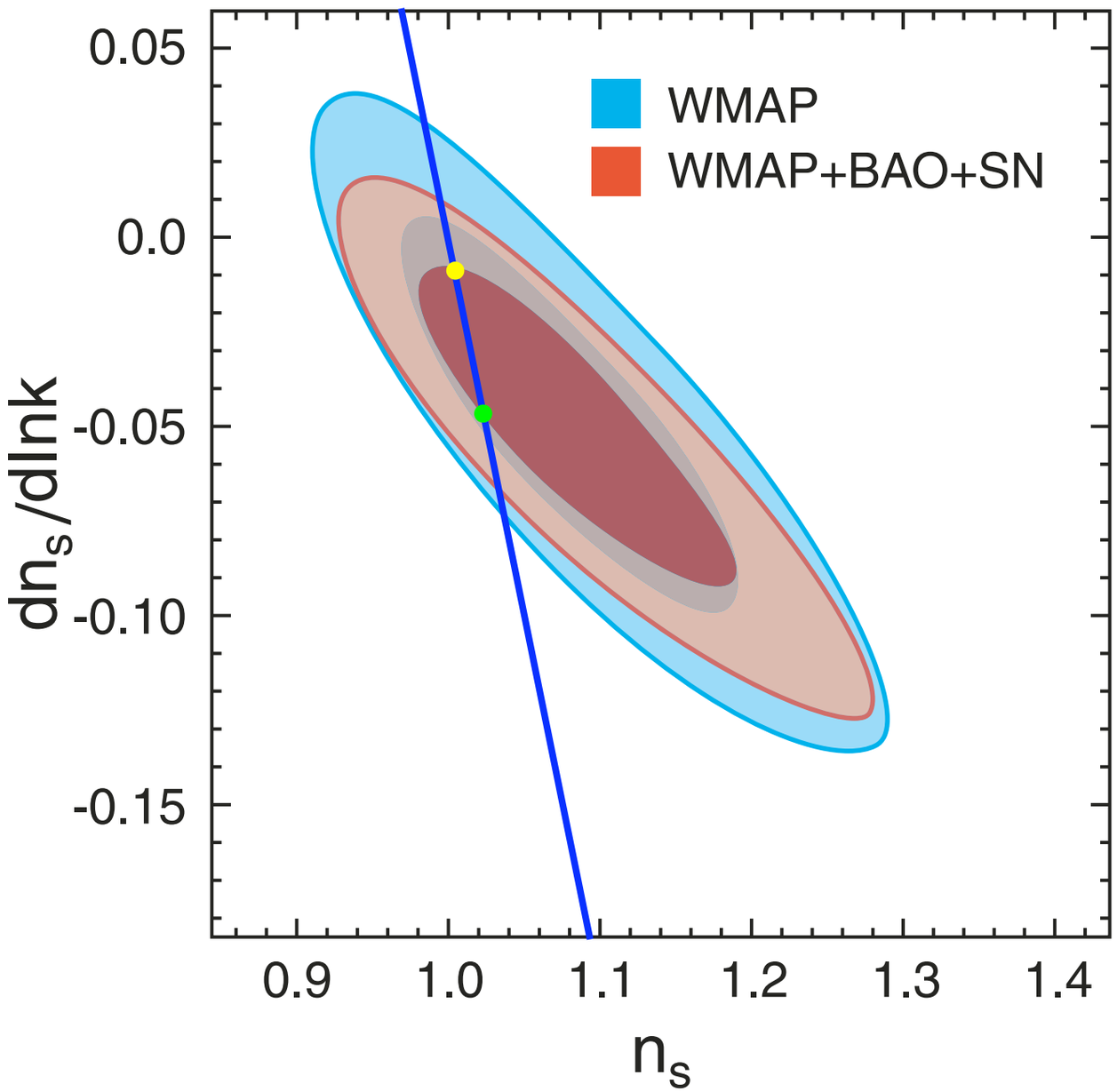
$$\longrightarrow \qquad \frac{dn_s}{d\ln k} \simeq -2(n_s - 1)$$

Bounds on the running impose strict constraints:

$$0.001 < \frac{\lambda^2}{N}\left(\xi - \frac{1}{6}\right) < 0.003$$

# Observational Predictions

Predicts a blue tilt. $0.006 < n_s - 1 < 0.026$




- : $\frac{\lambda^2}{N}\left(\xi - \frac{1}{6}\right) \sim 0.001$
- : $\frac{\lambda^2}{N}\left(\xi - \frac{1}{6}\right) \sim 0.003$

# Summary

- We derived formulae for the spectral index and its running of the cosmological perturbation generated through modulated reheating, when inflation is driven by an almost conformally coupled scalar field.

- The running turns out to be large (comparable to $\mathrm{n}_s - 1$ ).

- When applied to warped brane inflation, the values of the model is dominantly determined by $\left(\xi - \frac{1}{6}\right)$, and predicts a blue tilt.