Title: Features in the CMB

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Abstract: We briefly discuss the potential cosmological implications of our results.

Features in the inflationary power spectrum

Jim Cline, McGill University

with F. Chen, L. Hoi, G. Holder, S. Kanno

PASCOS, 5 June 2008

Examples of nonstandard features

- Bumps in CMB spectrum from tachyonic preheating?

  L. Hoi, JC, G. Holder, arXiv:0706.3887

- Modified Friedmann eq. and inflationary predictions from 6D braneworld

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1. k^3 bumps in CMB spectrum

N. Barnaby, JC (astro-ph/0601481,0611750): tachyonic preheating in hybrid inflation can give k^3 contamination to CMB spectrum if $\lambda, g \ll 1$

J. Lesgourgues (hep-ph/9911447): found similar effect in double D-term inflation model $\Longrightarrow$

J. Traschen, L. Abbott (1984-98): argued that k^3 spectrum is generic for causal processes

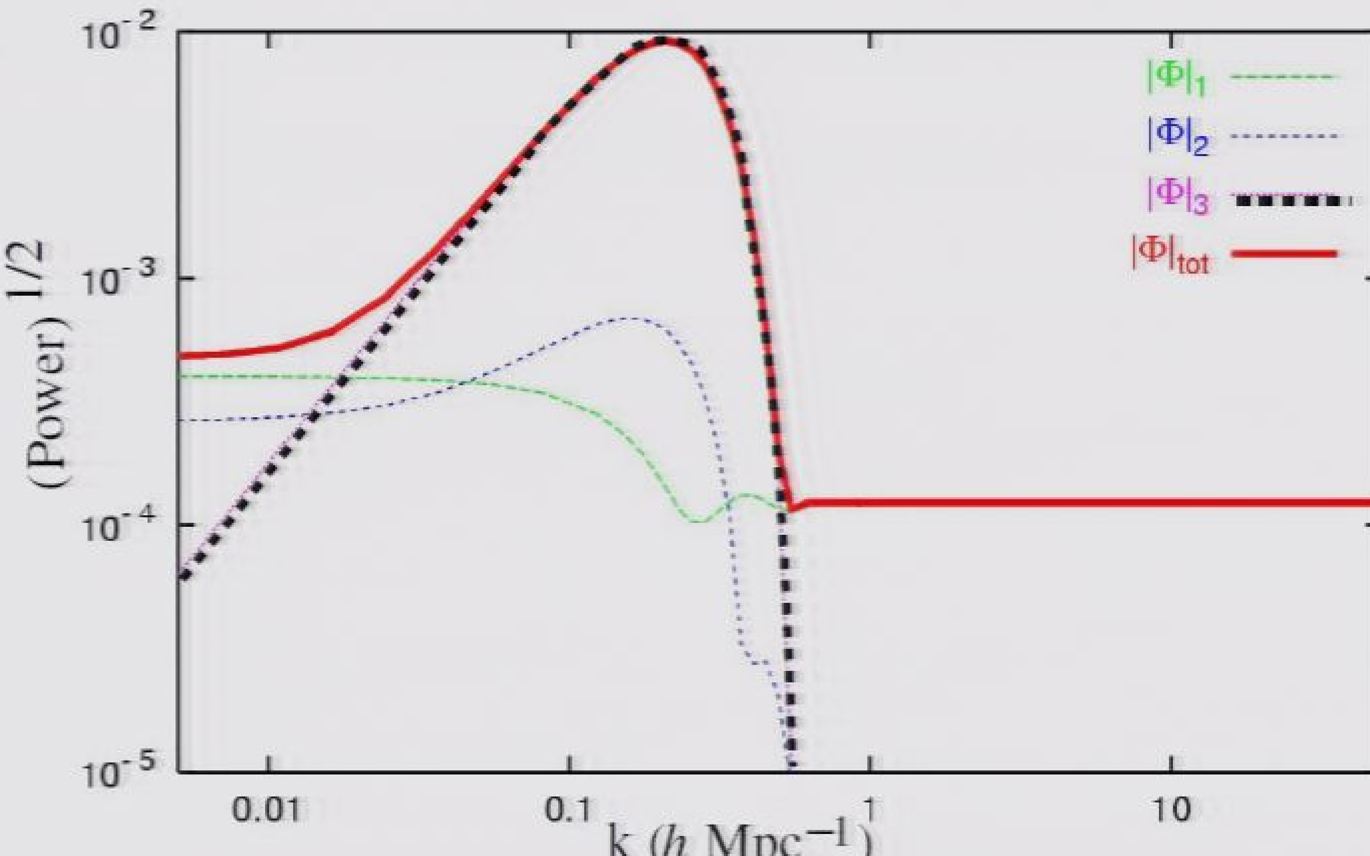
JC, L. Hoi, G. Holder (arXiv:0706.3887): test latest CMB and LSS data for presence of k^3 bump

Example: Double hybrid inflation

J. Lesgourgues, hep-ph/9911447

$$V = \frac{g_A^2}{2}\left(\xi_A - \frac{1}{2}|C|^2\right)^2 + \frac{1}{4}\beta B^2|C|^2 + \frac{g_B^2}{2}\left(\xi_B - \frac{1}{2}|C|^2\right)^2 + \text{1-loop}$$

2 stages of inflation, (B, A) separated by tachyonic instability (C)



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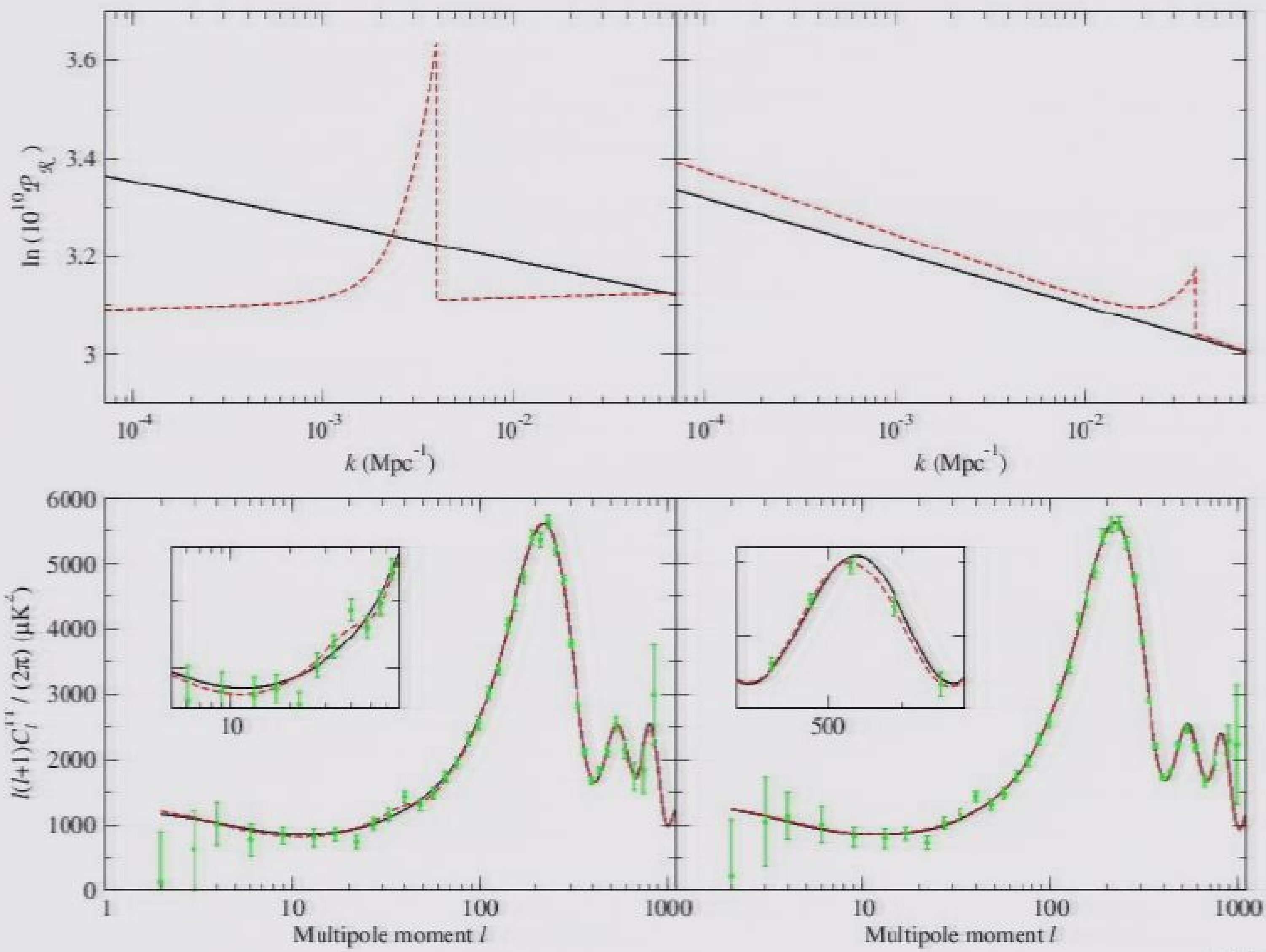
MCMC (CosmoMC) search for bumps

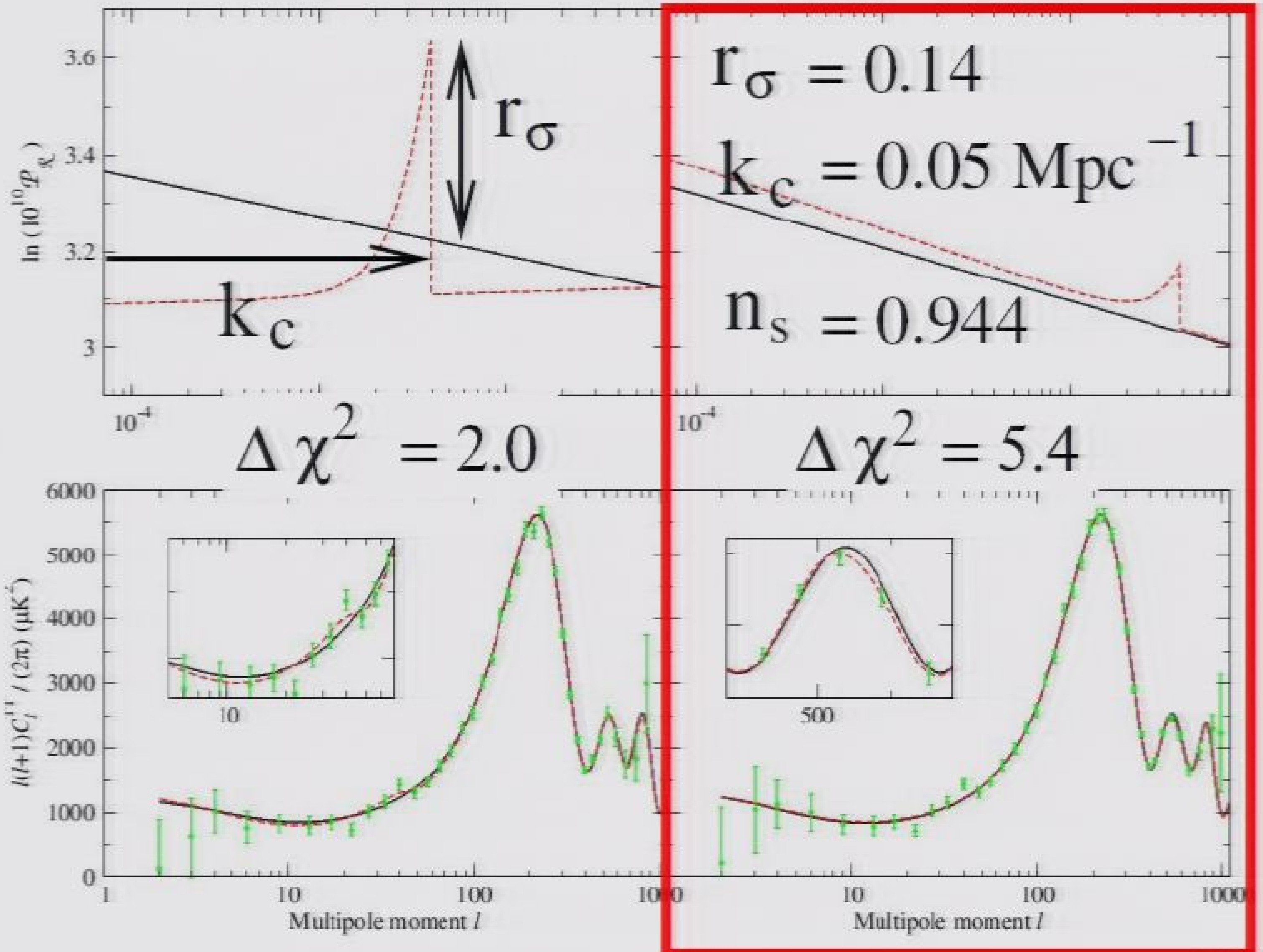
L. Hoi, JC, G. Holder: bumps in primordial spectrum can explain glitches in CMB spectrum



MCMC (CosmoMC) search for bumps

2 new parameters: $r_\sigma =$ ratio of k^3 to k^0 components;

$k_c =$ UV cutoff on k^3 component

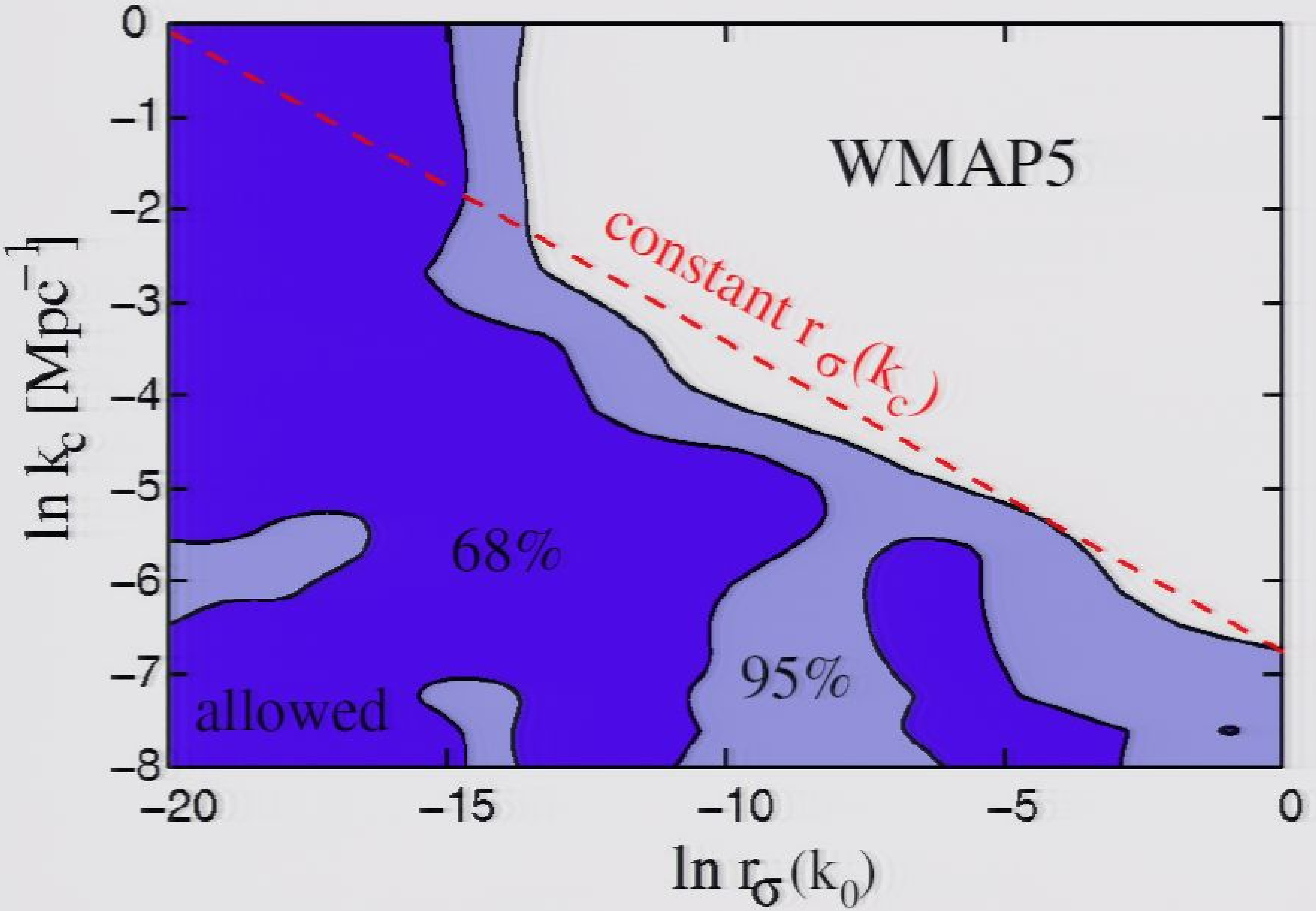


Not greatly sensitive to power of k

k^n	$\Delta\chi^2,\ \ell \sim 50$	$\Delta\chi^2,\ \ell \sim 540$
k^1	-0.1	4.1
k^2	1.2	4.1
k^3	2.0	5.4
k^4	1.5	4.8
k^5	1.9	5.4

- Justifies fixing $n = 3$ and using only 2 extra parameters.
- This is with WMAP3 data.
- Evidence for bumps disappears with WMAP5!
  (WMAP5 punishes lowering n_s at high ℓ.)

Constraints on bumps: WMAP alone



Gives $r_\sigma(k_c) < 0.2$ for $10^{-3} < k_c < 0.1$ Mpc^{-1} @ 95% c.l.

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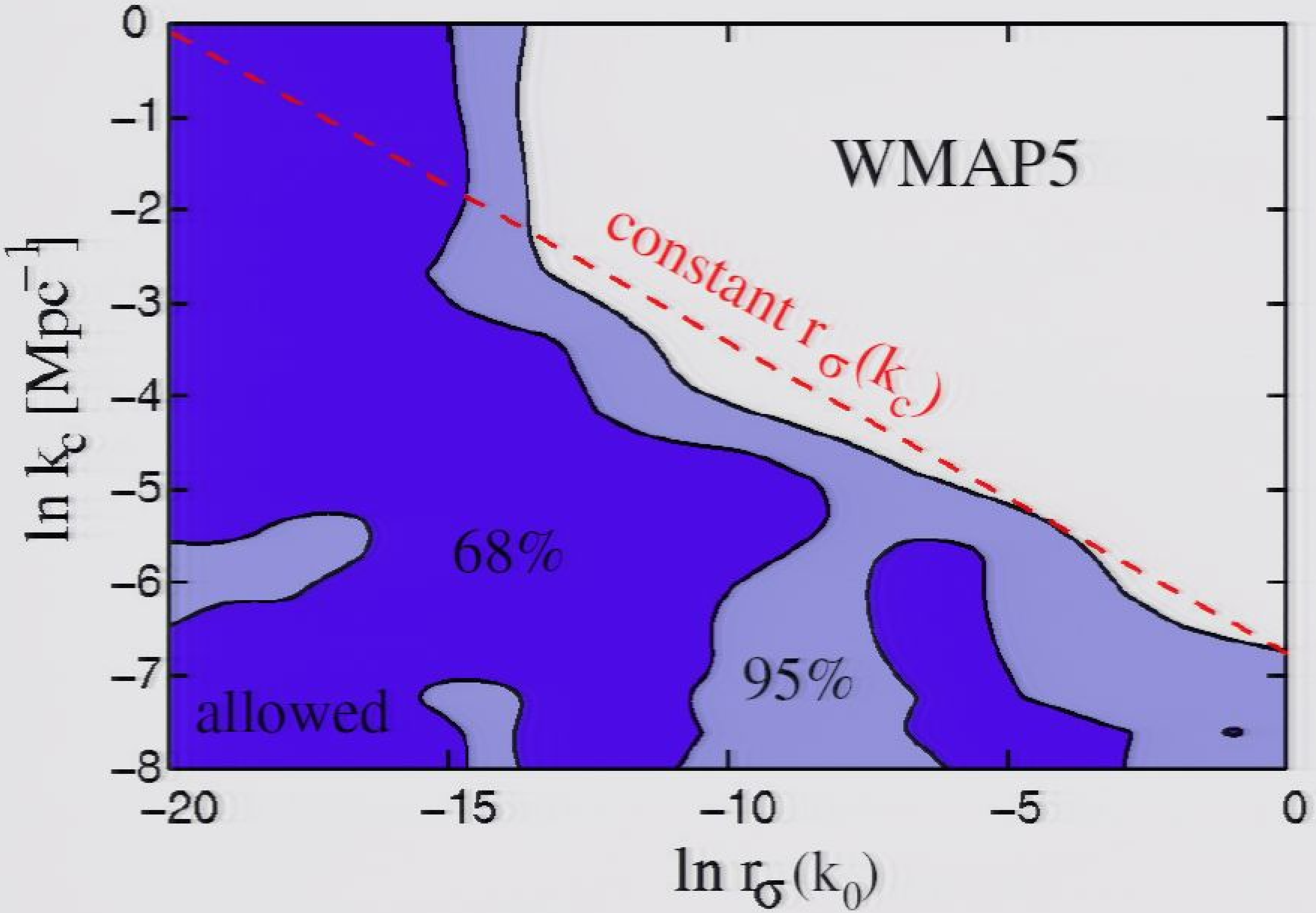

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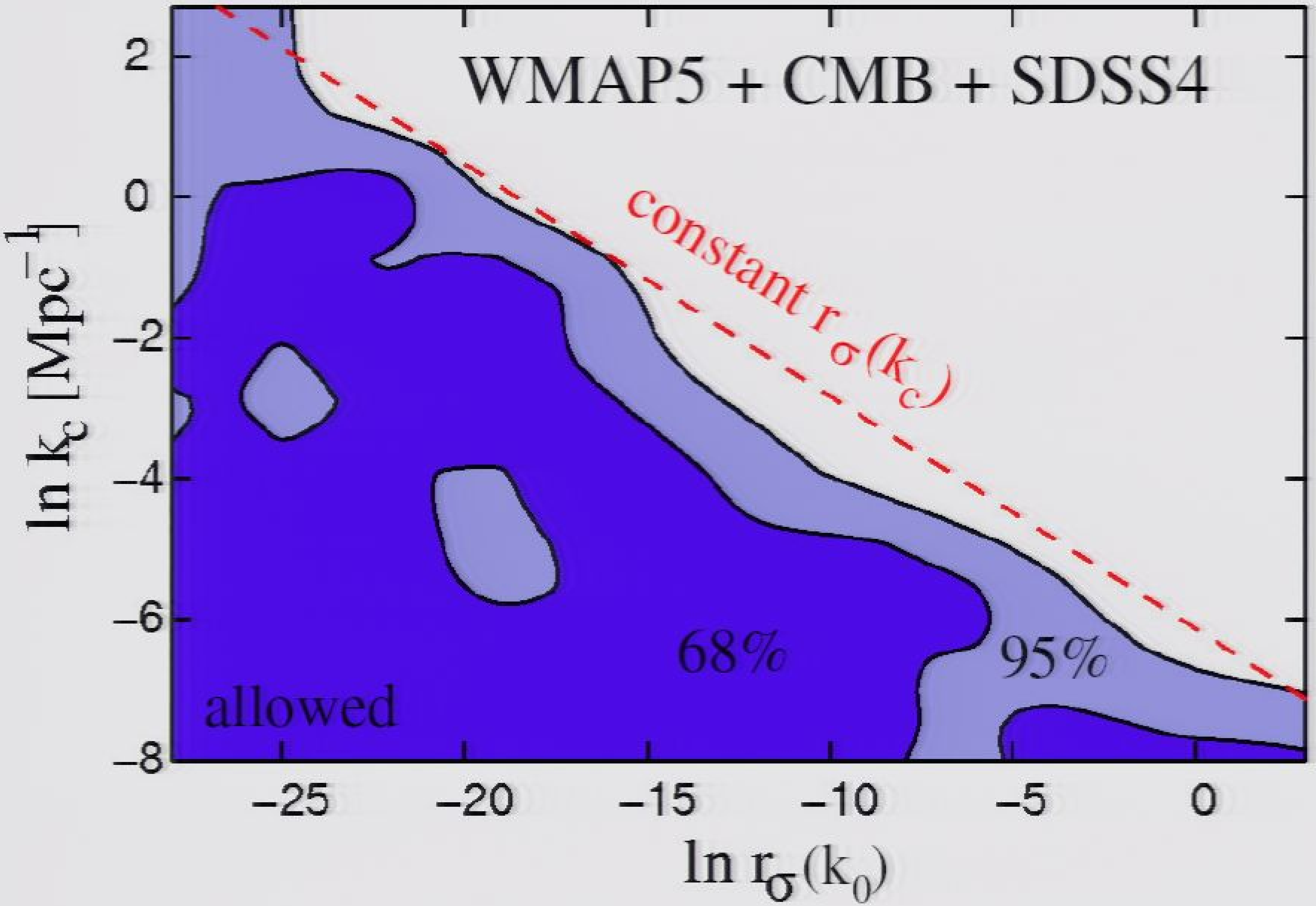
Constraints on bumps: combined data



Gives $r_\sigma(k_c) < 0.09$ for $10^{-3} < k_c < 7.5$ Mpc^{-1} @ 95% c.l.

WMAP3 / WMAP5 comparison

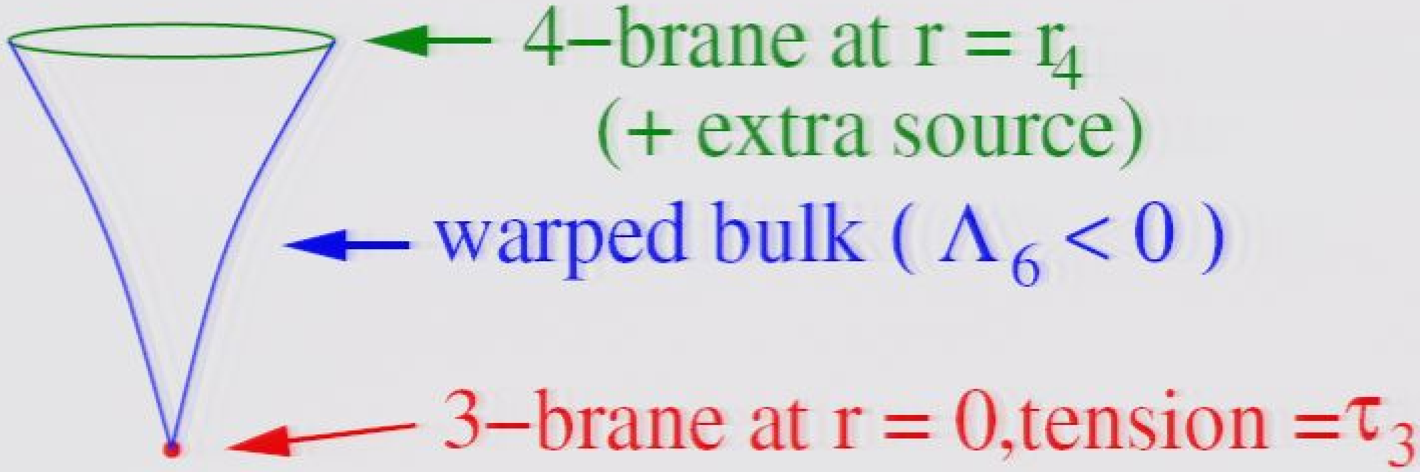
data set	max. r_σ (WMAP3)	max. r_σ (WMAP5)
WMAP only	1.5	0.2
combined	0.7	0.09

Limits improved by factor of 8 from WMAP3 to WMAP5

2. Inflation on 6D Braneworld

F. Chen, JC, S. Kanno (arXiv:0801.0226): closest generalization of Randall-Sundrum model to 6D:

$$ds^2 = a^2(r)(-dt^2 + d\vec{x}^2) + dr^2 + b^2(r)d\theta^2$$



Studied extra-dimensional modifications to Friedmann equation,

$$H^2 = \frac{\rho}{3M_p^2}\mathcal{F}(\rho)$$

with mechanism to stabilize extra dimensions

Details

Can get finite radial size either by:

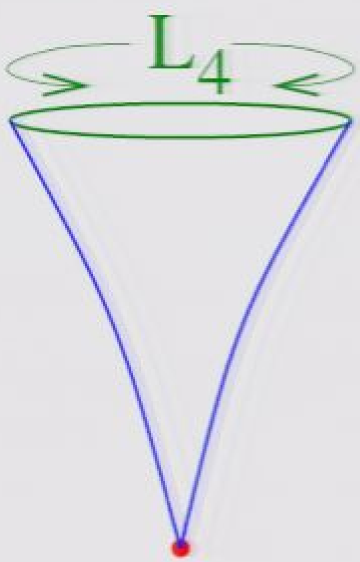
1. Goldberger-Wise mechanism (bulk scalar field)

or

2. Extra matter (τ_4) on 4-brane with $p_\theta = (1-\alpha)\rho$,

$$T_{\mu\nu} = \left(T_4 + \frac{\tau_4}{L_4^\alpha}\right) g_{\mu\nu}$$

$$T_{\theta\theta} = \left(T_4 + (1-\alpha)\frac{\tau_4}{L_4^\alpha}\right) g_{\theta\theta}$$



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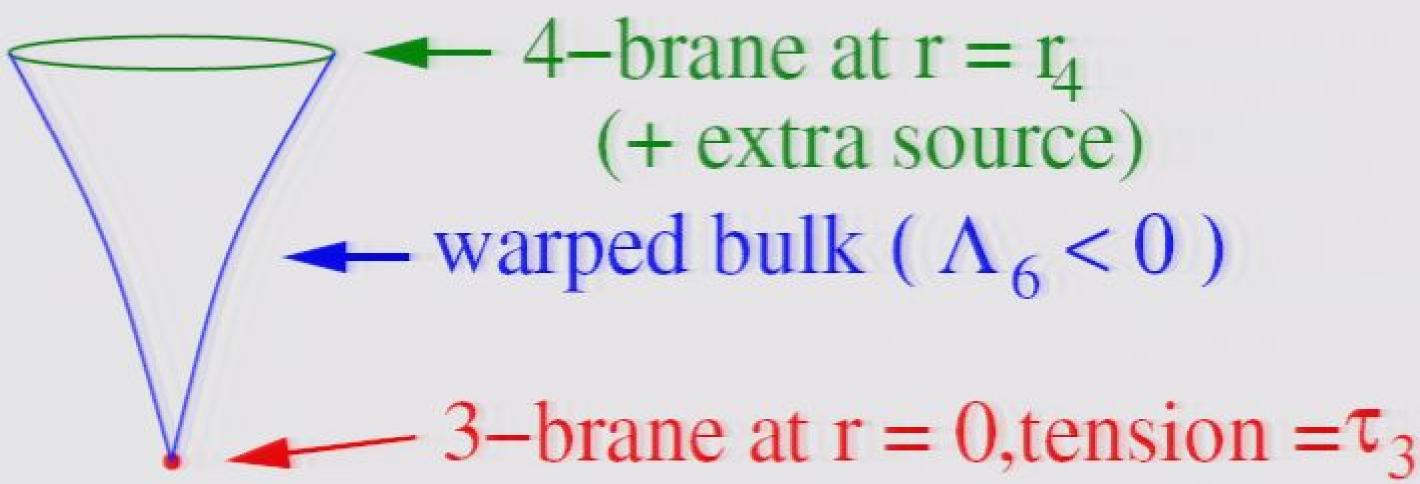

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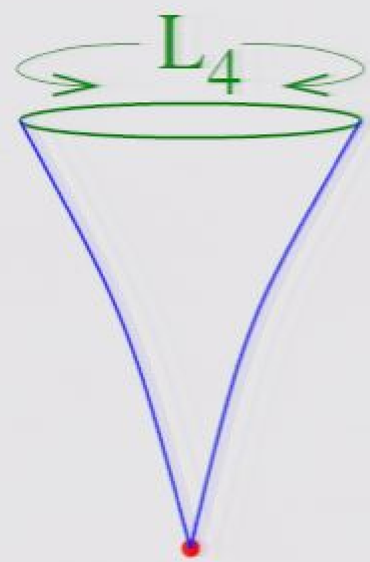

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Exact solution

Let $$ds^2 = a(r)(-dt^2 + e^{2Ht}d\vec{x}^2) + f(r)K d\theta^2 + \frac{dr^2}{f(r)}$$

K parametrizes deficit angle due to conical defect,

$$K \propto 1 - \frac{\tau_3}{2\pi M_6^4}$$

Then

$$a(r) = \frac{r^2}{\ell^2}, \quad f(r) = \frac{r^2}{\ell^2} - \frac{\ell^3}{r^2} + H^2\ell^2$$

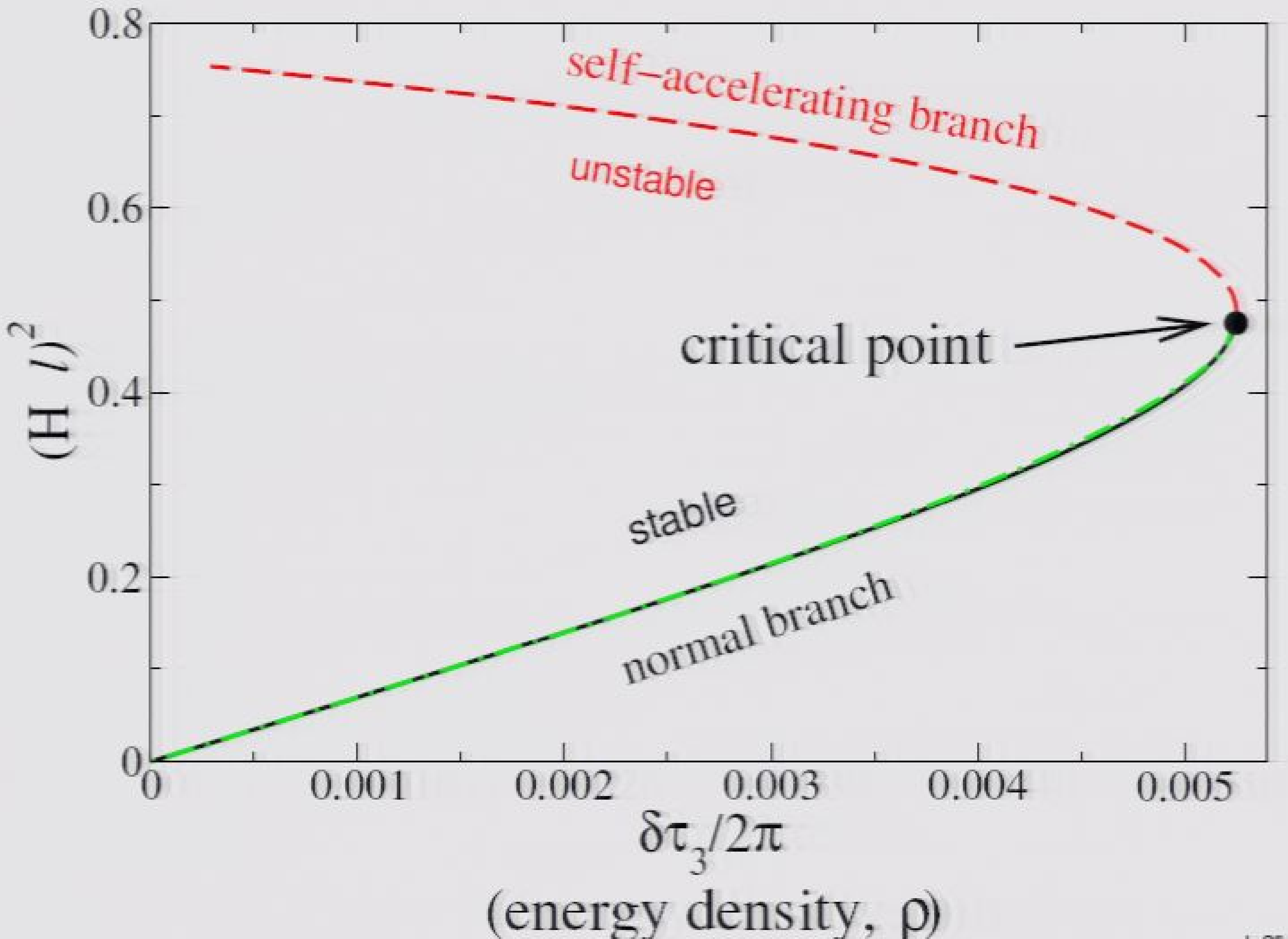
where $\ell =$ AdS curvature length.

2 junction conditions (for a and f) at 4-brane algebraically determine r_4 (size of radial dimension) and H.

Numerically solve the jump conditions for H as a function of τ_3, holding T_4, τ_4 and ℓ fixed $\Longrightarrow$ Friedmann eq.

Modified Friedmann equation

- Hubble parameter is double-valued—self-acceleration!
- But top branch is unstable to decompactification
- $dH/d\rho \to \infty$ at maximum density ρ_m



Modified inflationary predictions

Function $\mathcal{F}(\rho) = \frac{H^2(\rho)}{H_{GR}^2}$ changes spectral indices:

$$n_s - 1 = \frac{1}{\mathcal{F}}\left(2\eta - 6\epsilon\left(1 + \frac{d\ln\mathcal{F}}{d\ln\rho}\right)\right)$$

$$n_t = -\frac{2\epsilon}{\mathcal{F}}\left(1 + \frac{d\ln\mathcal{F}}{d\ln\rho}\right)$$

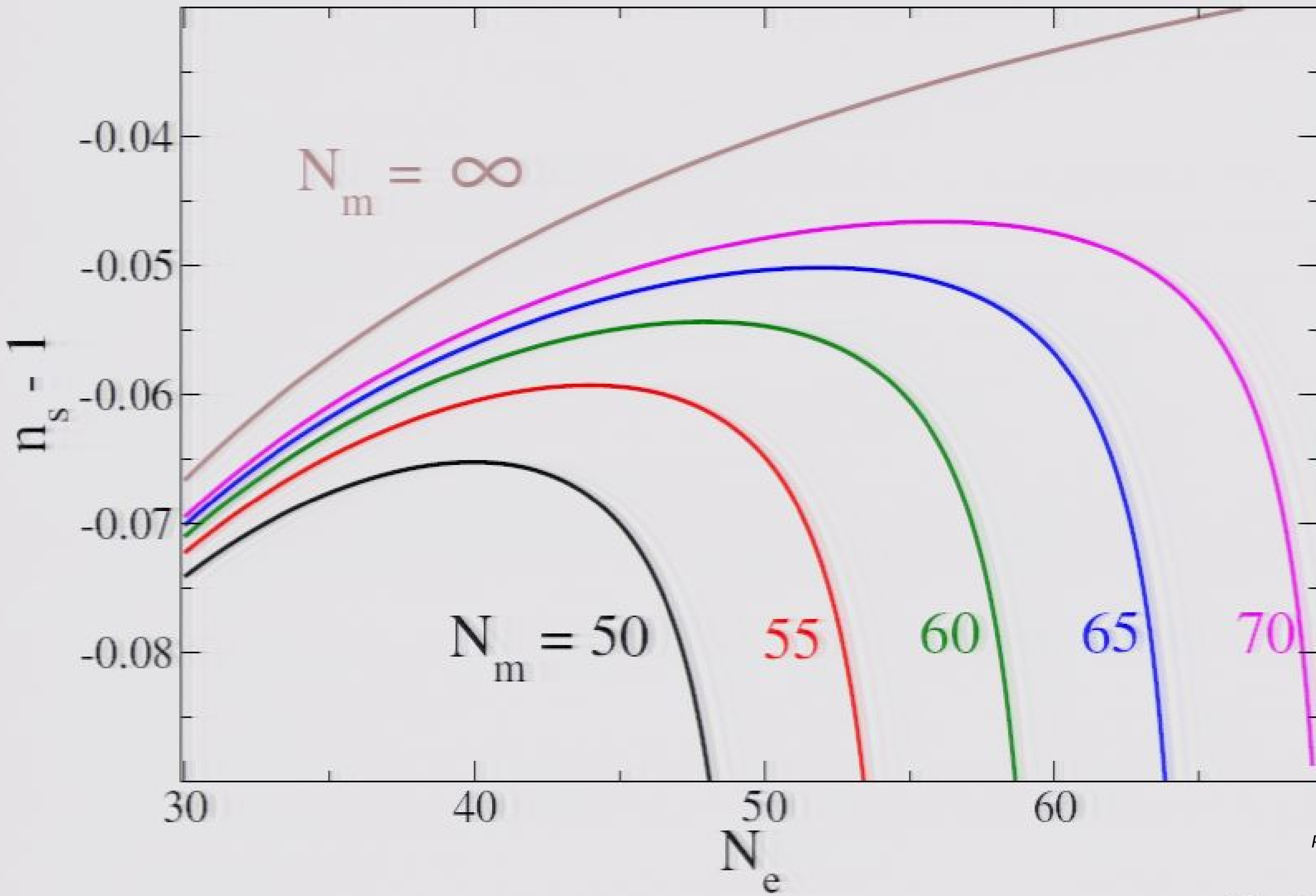
and tensor-to-scalar ratio:

$$r = \frac{16\epsilon}{\mathcal{F}}$$

Standard results recovered when $\mathcal{F} \to 1$.

Chaotic inflation on brane

Maximum density $\rho_m \Longrightarrow$ maximum # e-foldings, N_m.
When $N_e \cong N_m$, relation between n_s and N_e is modified:



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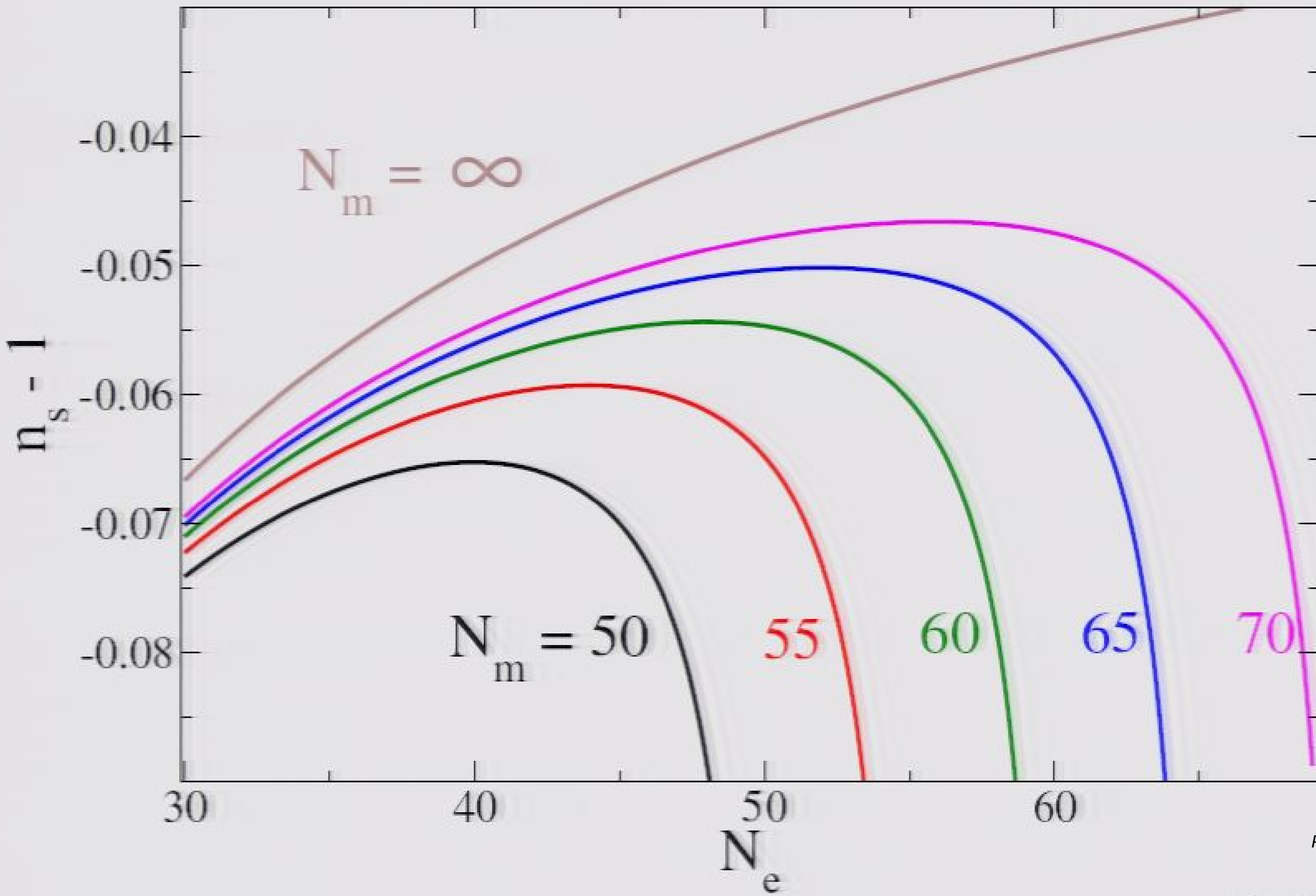

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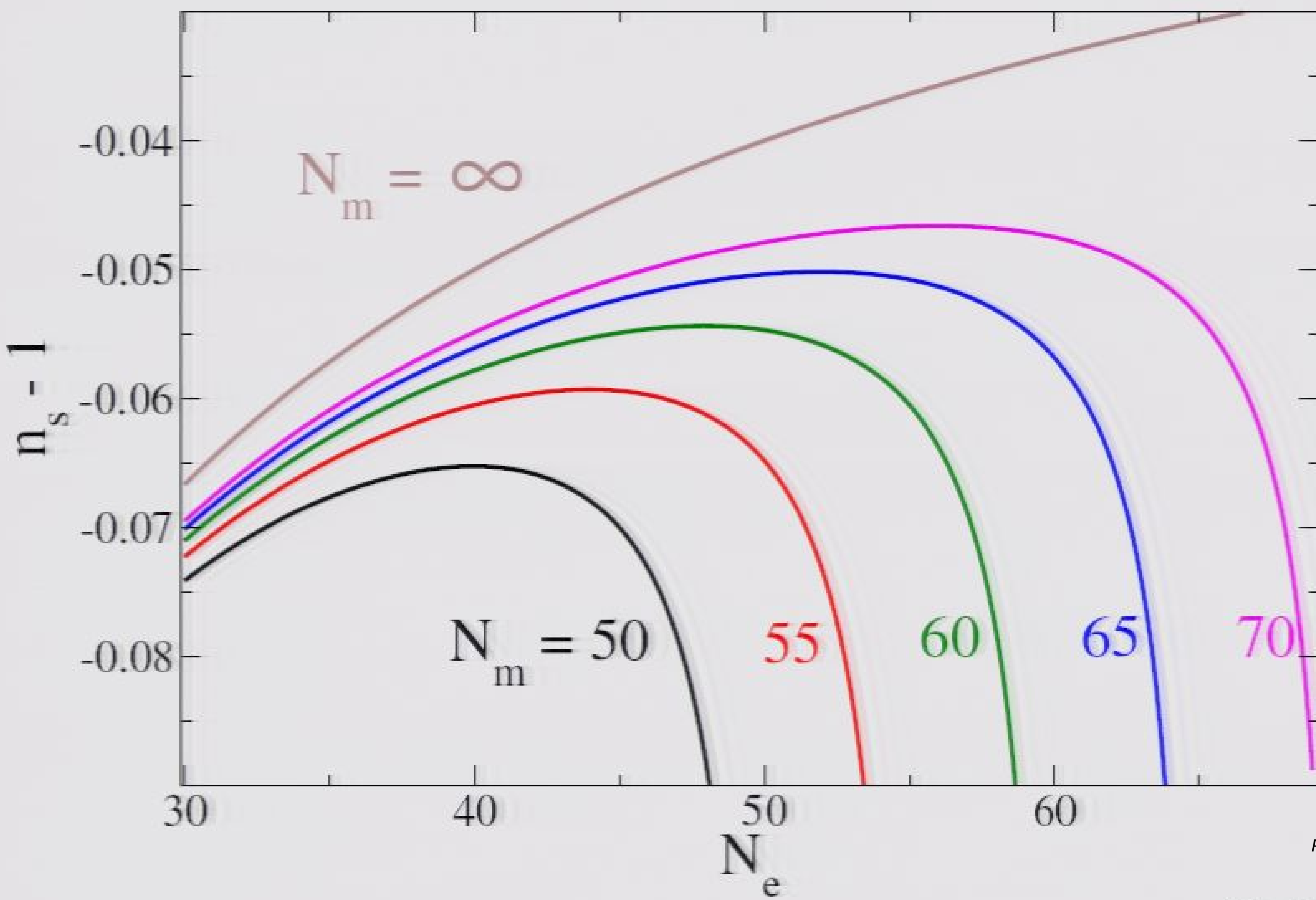
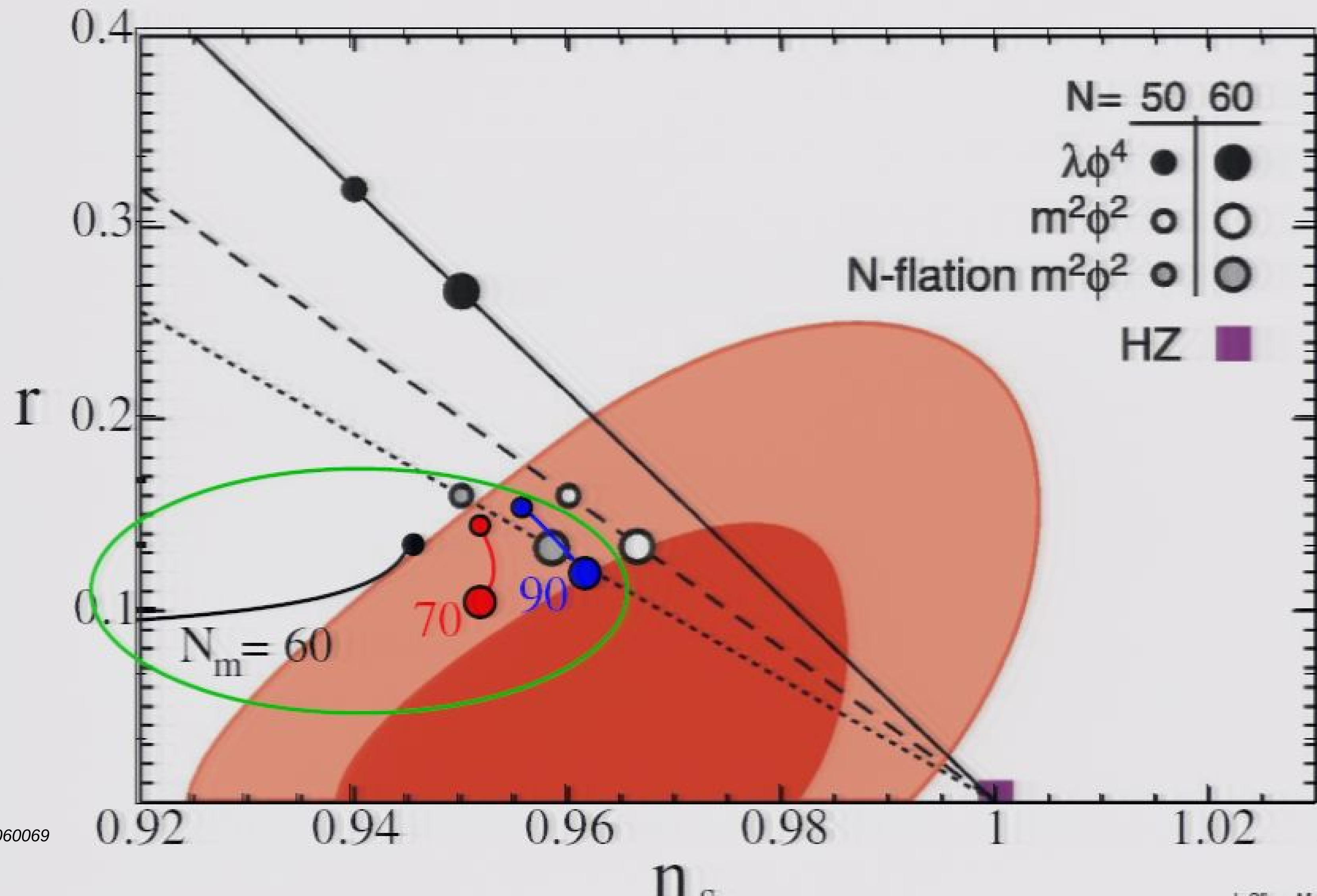


Chaotic inflation on brane

WMAP5 constraints, versus predictions for $m^2\phi^2$ chaotic inflation with $N_m = 60,\ 70,\ 90$

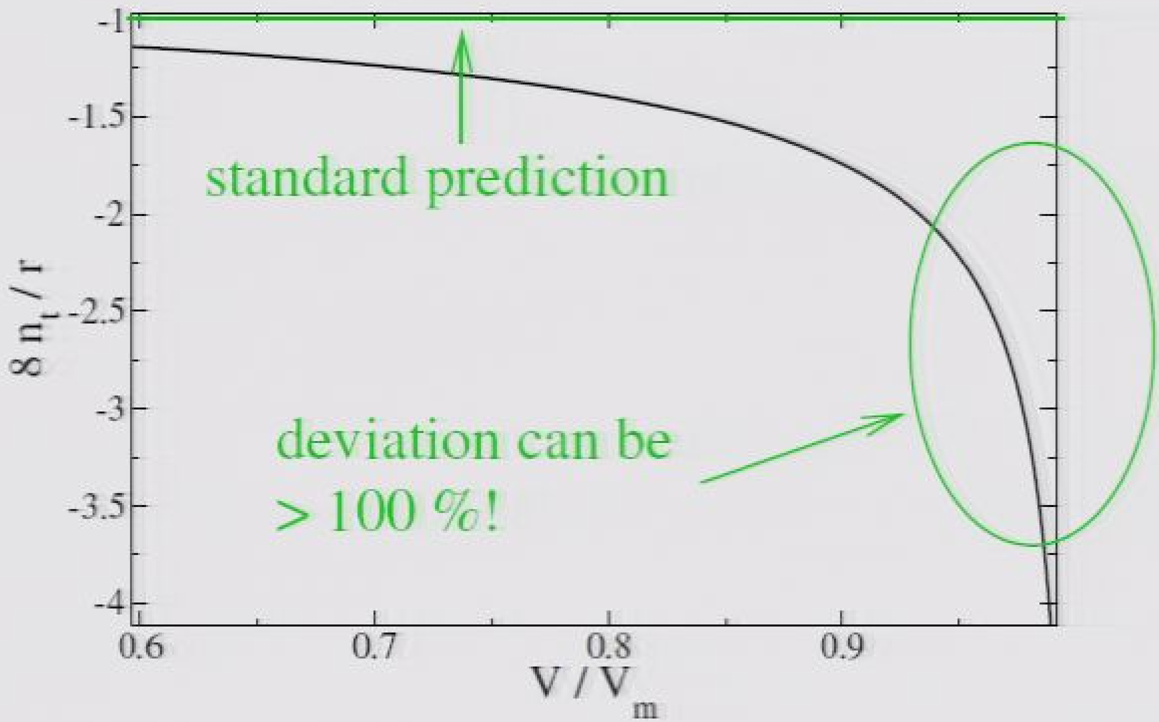


Consistency condition altered

Standard inflation predicts relation between tensor-scalar amplitude ratio r and tensor spectral index n_t:

$$\frac{n_t}{r} = -\frac{1}{8}$$

Modified Friedmann equation alters this prediction:



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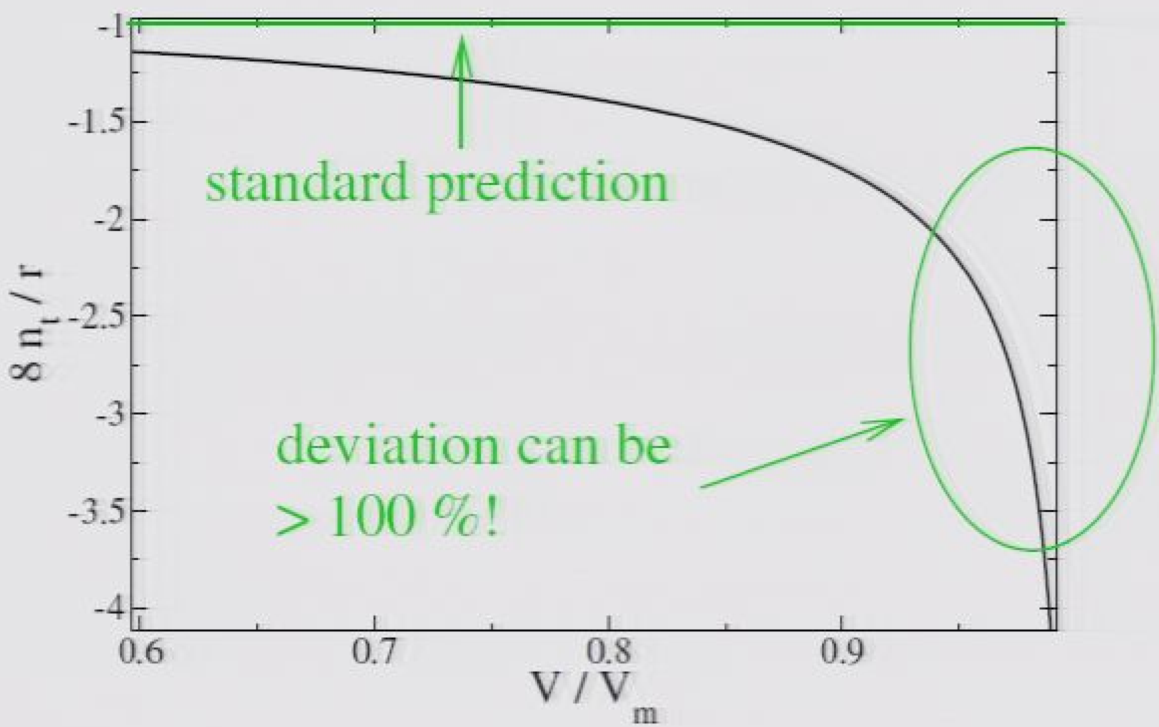

Conclusions

- WMAP5 negates WMAP3 hint of bumps in CMB power spectrum
- New features could emerge with further improvement in data
- Modified Friedmann equation from braneworld can change predictions for inflation: n_s versus N_e, r, and n_t versus r