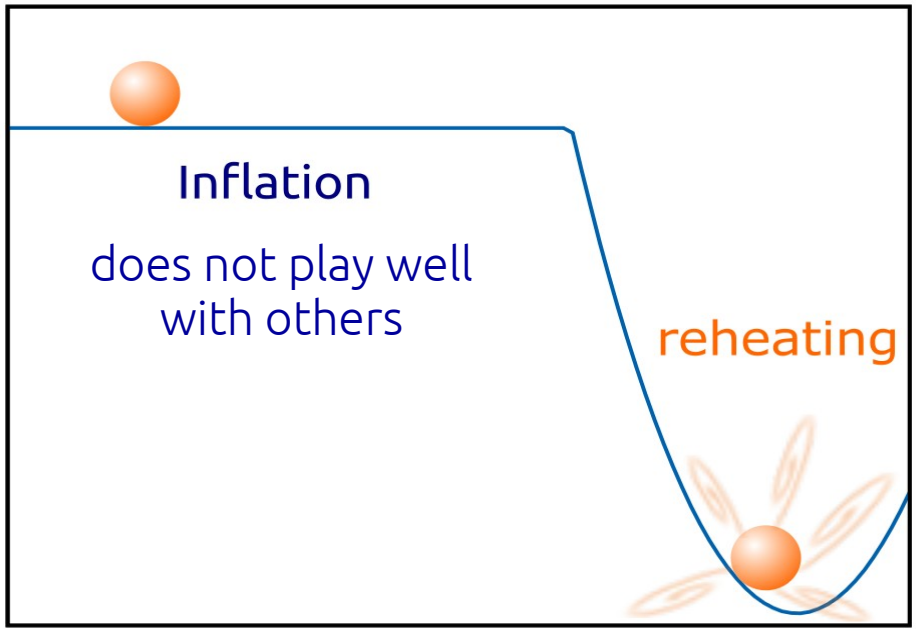
The importance of being warm (during inflation)

Rafael Cerezo
S. Bartrum, M. Bastero-Gil, A. Berera, R.O.Ramos & J. Rosa

2nd Azores School on Observational Cosmology
Angra do Heroismo,
June, 2014

arXiv:1307.5868
Phys. Lett. B 732, 116 (2014)

ugr | Universidad de Granada



interactions required!

Inflaton coupled to other fields during inflation

Warm inflation

- Extra friction
- Smooth graceful exit
- Observational effects

Dissipation!

$$\ddot{\phi} + 3H\dot{\phi} + V_\phi = -\Upsilon(t)\dot{\phi}$$

$$\dot{\rho}_r + 4H\rho_r = +\Upsilon(t)\dot{\phi}^2$$

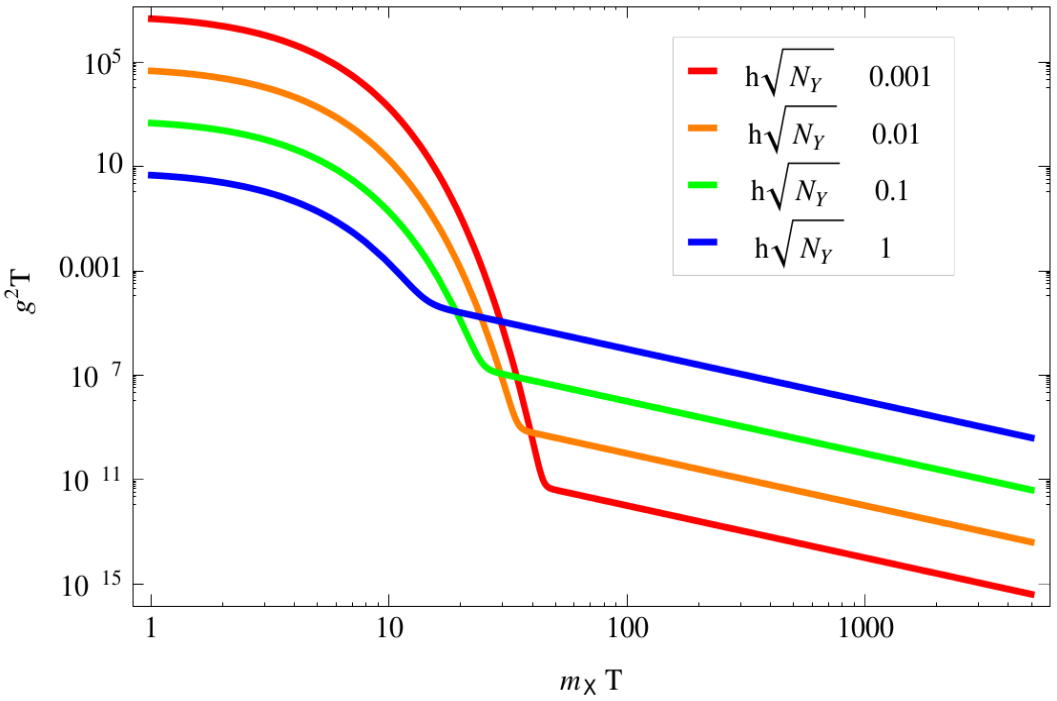
Which interactions?

Pattern of interactions
[Berera&Ramos'02]

$$W = f(\phi) + \frac{g}{2}\Phi X^2 + \frac{h}{2} X Y^2$$

$m_\chi \gg T$ heavy catalyst field

$m_\sigma \ll T$ radiation



small radiative corrections

$$g^2 N_X, h^2 N_Y \lesssim 1$$

- Virtual modes

$$\Upsilon = C_\phi \frac{T^3}{\phi^2}$$

$$C_\phi = 0.02 h^2 N_X N_Y$$

[BasteroGil,Berera,Ramos&Rosa'12]

Predictions

[Berera&Fang'95; Berera'95;Berera'00;Moss&Berera'04]

$$\delta\ddot{\phi}_k + 3H(1+Q)\delta\dot{\phi}_k + \frac{k^2}{a^2}\delta\phi_k \simeq \sqrt{2\Upsilon T}a^{-3/2}\xi_k$$

$$Q = \frac{\Upsilon}{3H}$$

Weak dissipation

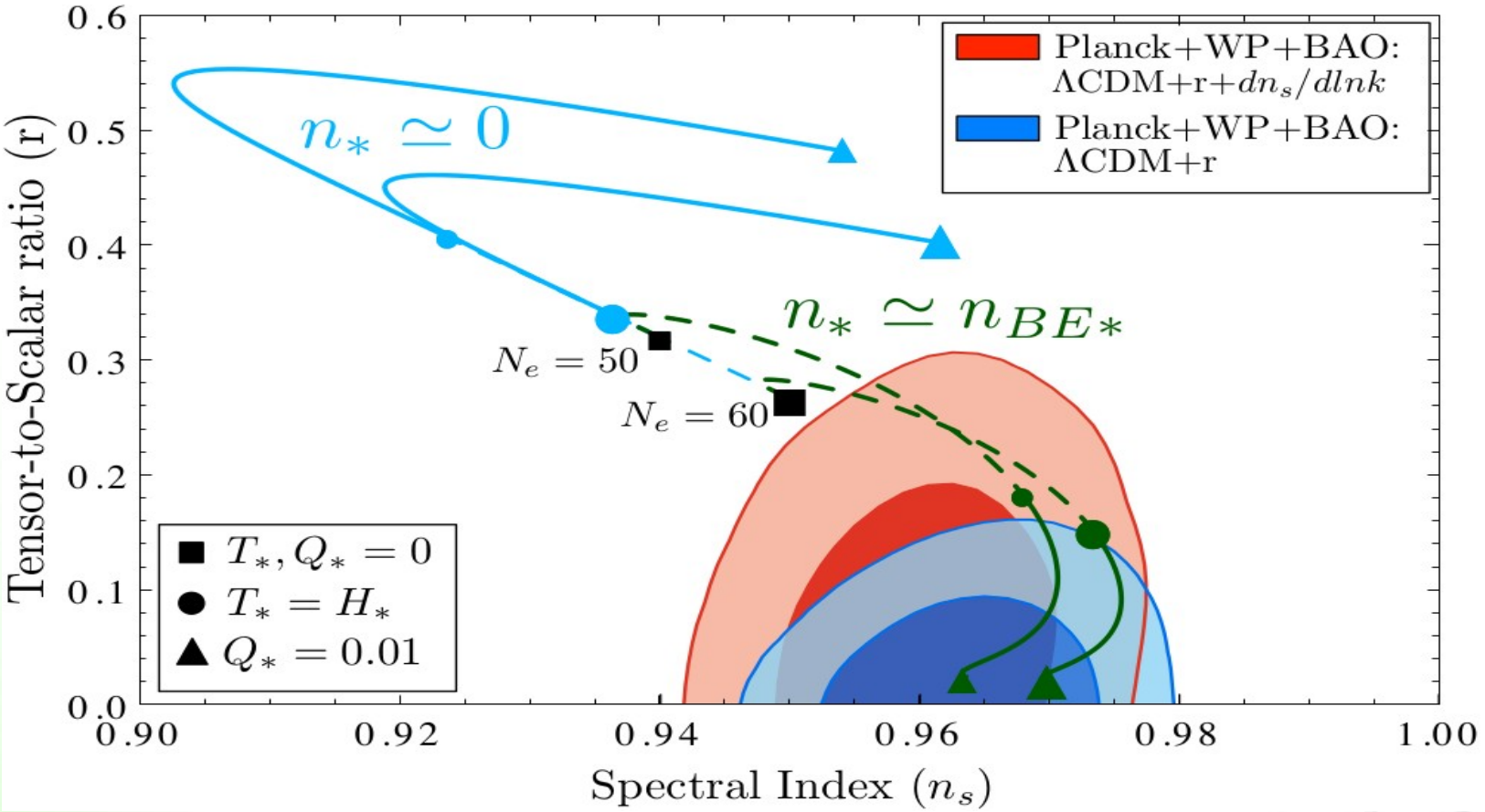
$$\Delta^2_{\mathcal{R}} \simeq \left(\frac{H_*}{\phi_*}\right)^2 \left(\frac{H}{2\pi}\right)^2 [1 + 2n_* + \kappa_*]$$

$$r \simeq \frac{16\epsilon_\phi}{1 + 2n_* + \kappa_*}$$

dissipation $\kappa = 2\pi Q \frac{T}{H}$

inflaton state $n_* \begin{cases} \ll 1 & \text{vacuum} \\ (e^{k/aT} - 1)^{-1} & \text{thermal} \end{cases}$

Example: quartic potential



$$V = \frac{\lambda}{4}\phi^4$$

$$g_* = 228,75$$

- $T \ll H$ ill-defined thermal equilibrium
- $n_*, \kappa_* \ll 1$ larger field values than CI
- $n_* \simeq n_{BE}$ strong suppression

Thermalization

$$\chi \to \sigma\sigma\phi$$

Thermalization
- decays
- inverse decays
- thermal scatterings

[Anisimov,Buchmuller,Drewes,Mendizabal'09]

$$\frac{\Gamma_{\phi *}}{H_*} \simeq 9(\alpha_h \alpha_g)^{3/2} \left(\frac{1-n_s}{0.04}\right) \left(\frac{0.01}{r}\right)^{3/2} \left(\frac{0.005}{Q_*}\right)^{1/2}$$

$$\alpha_h = \frac{h^2 N_Y}{4\pi} \qquad \alpha_g = \frac{g^2 N_X}{4\pi}$$

not too small