

DANIEL G. FIGUEROA

(From Jan. 2015 @ CERN)

1st PD (2011-2012)

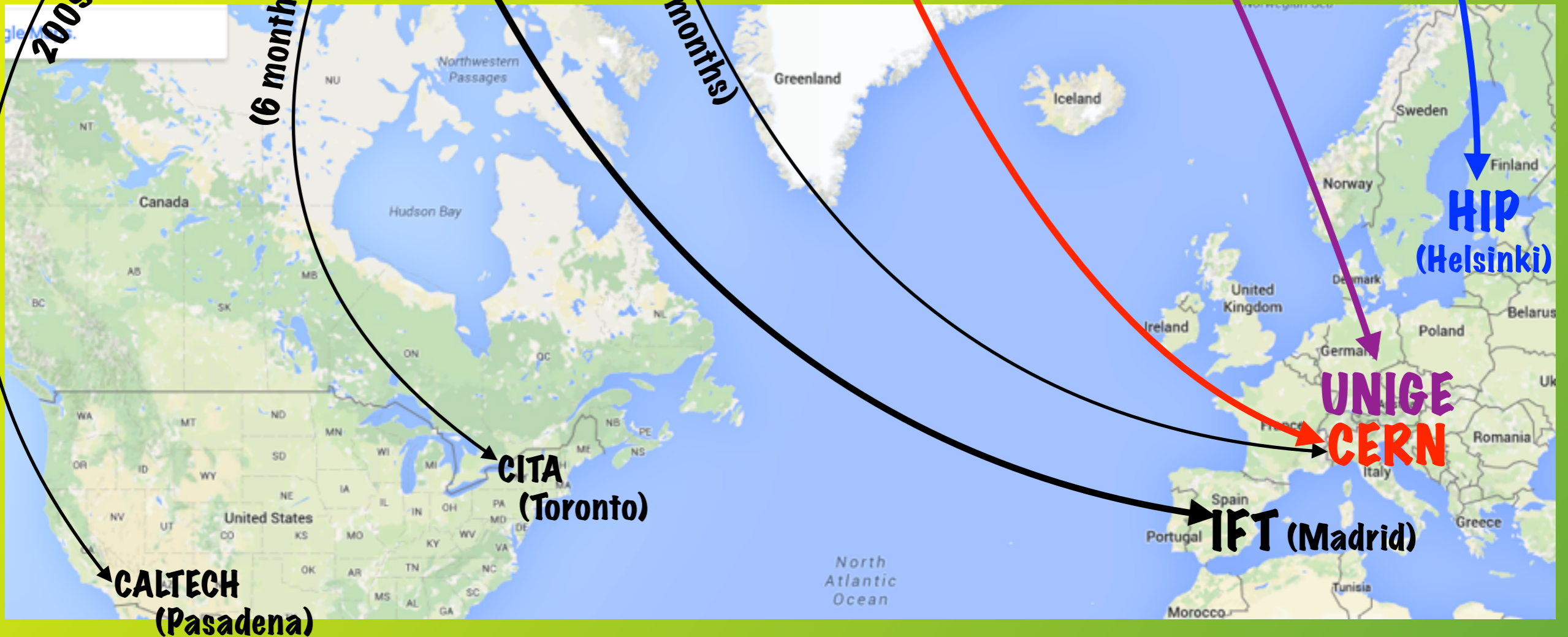
2nd PD (2011-2012)

Ph.D. (2007-2010)

2009 (6 months)

(6 months) 2007

2010 (9 months)

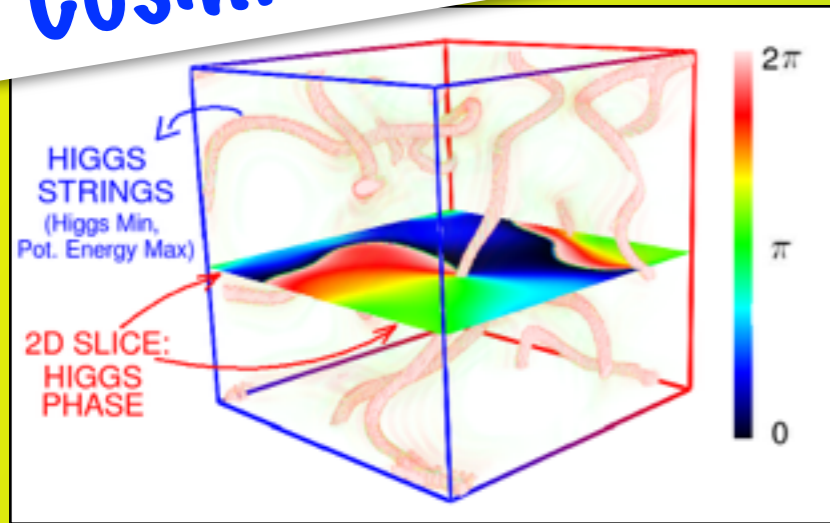


DANIEL G. FIGUEROA
(Since Jan. 2015 @ CERN)

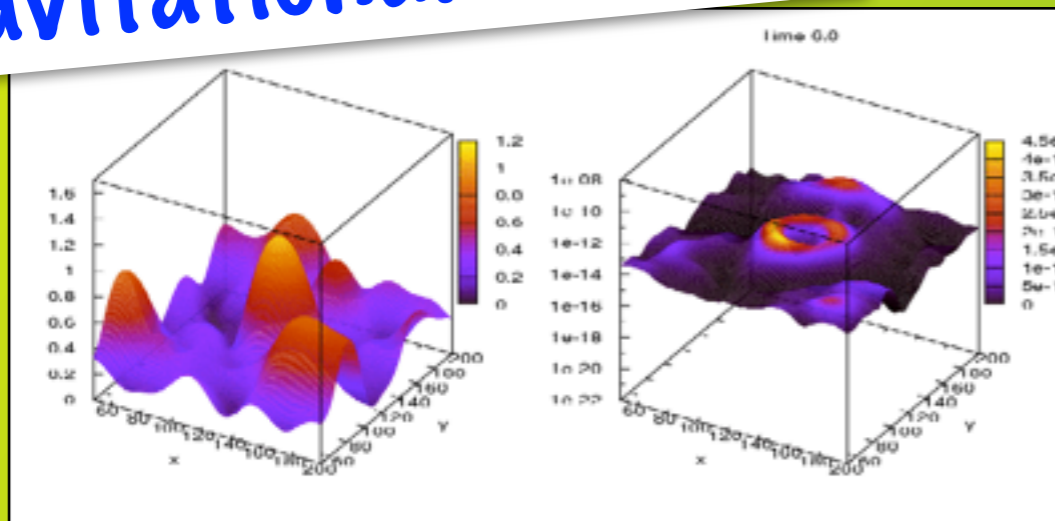
What do I do ?

**Non-Equilibrium
Early Universe
phenomena !!!**

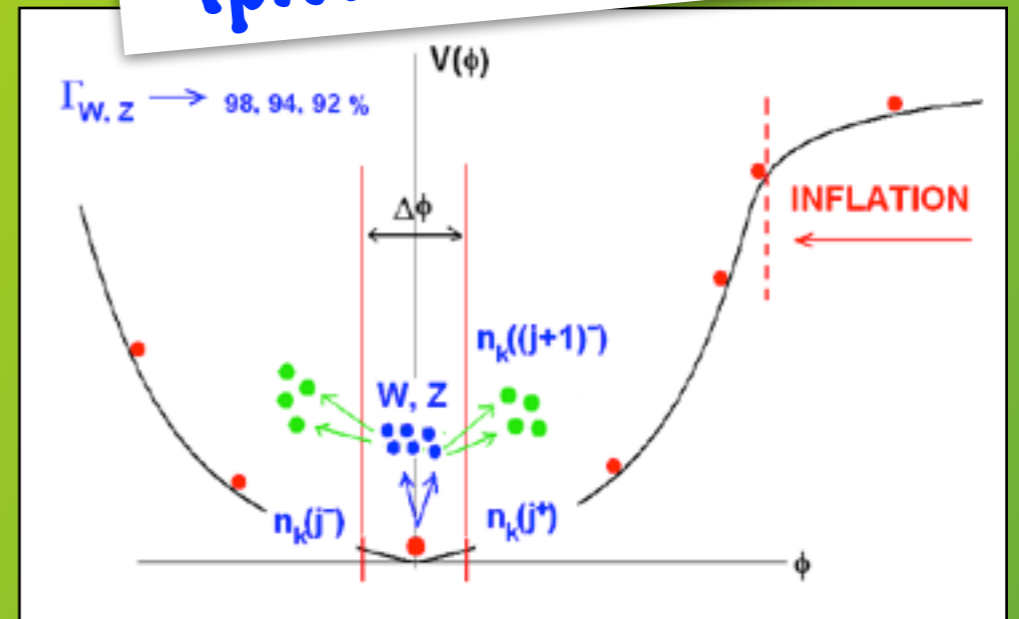
Cosmic Strings !



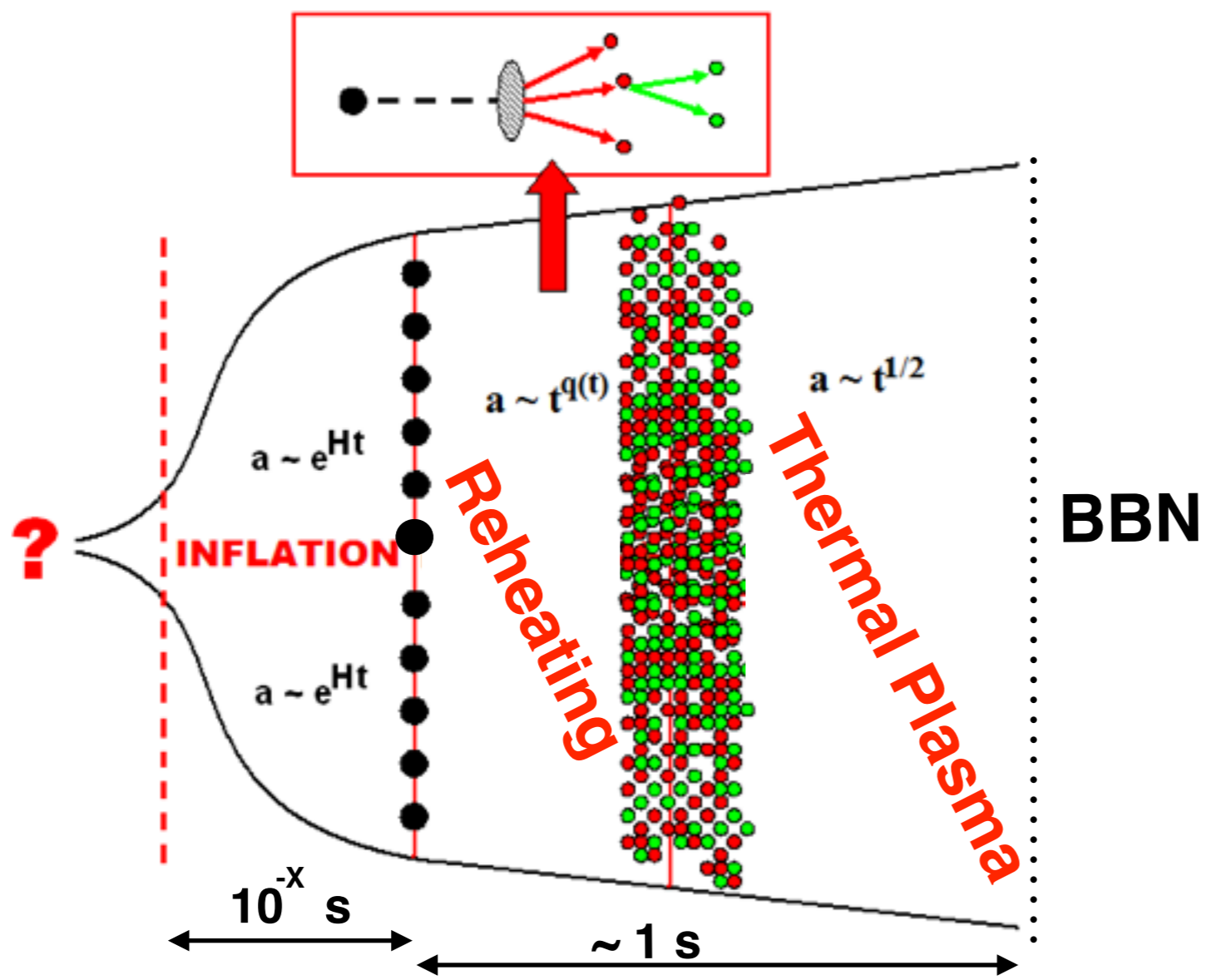
Gravitational Waves !!



(p)Reheating !!!

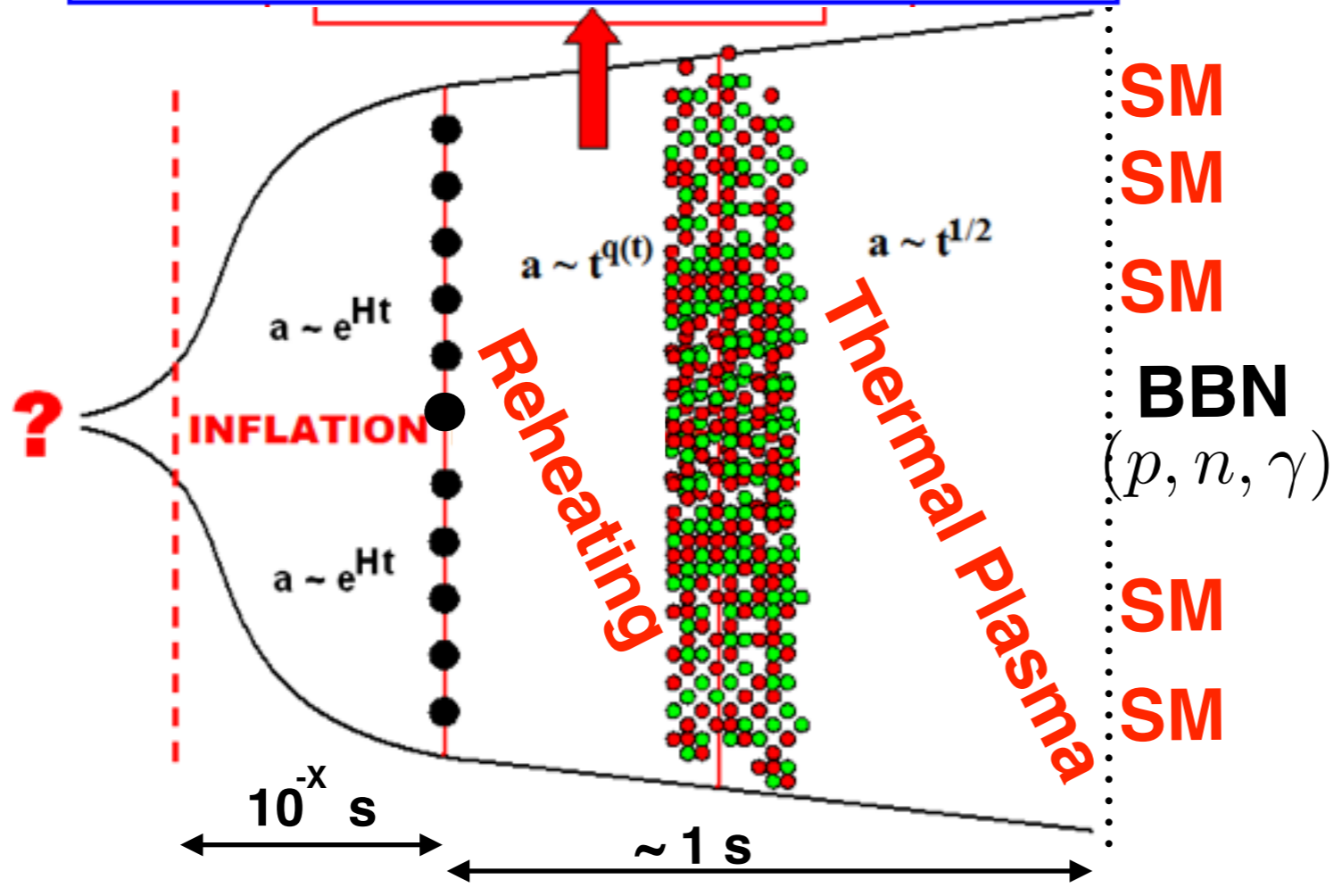


(p)Reheating the Universe



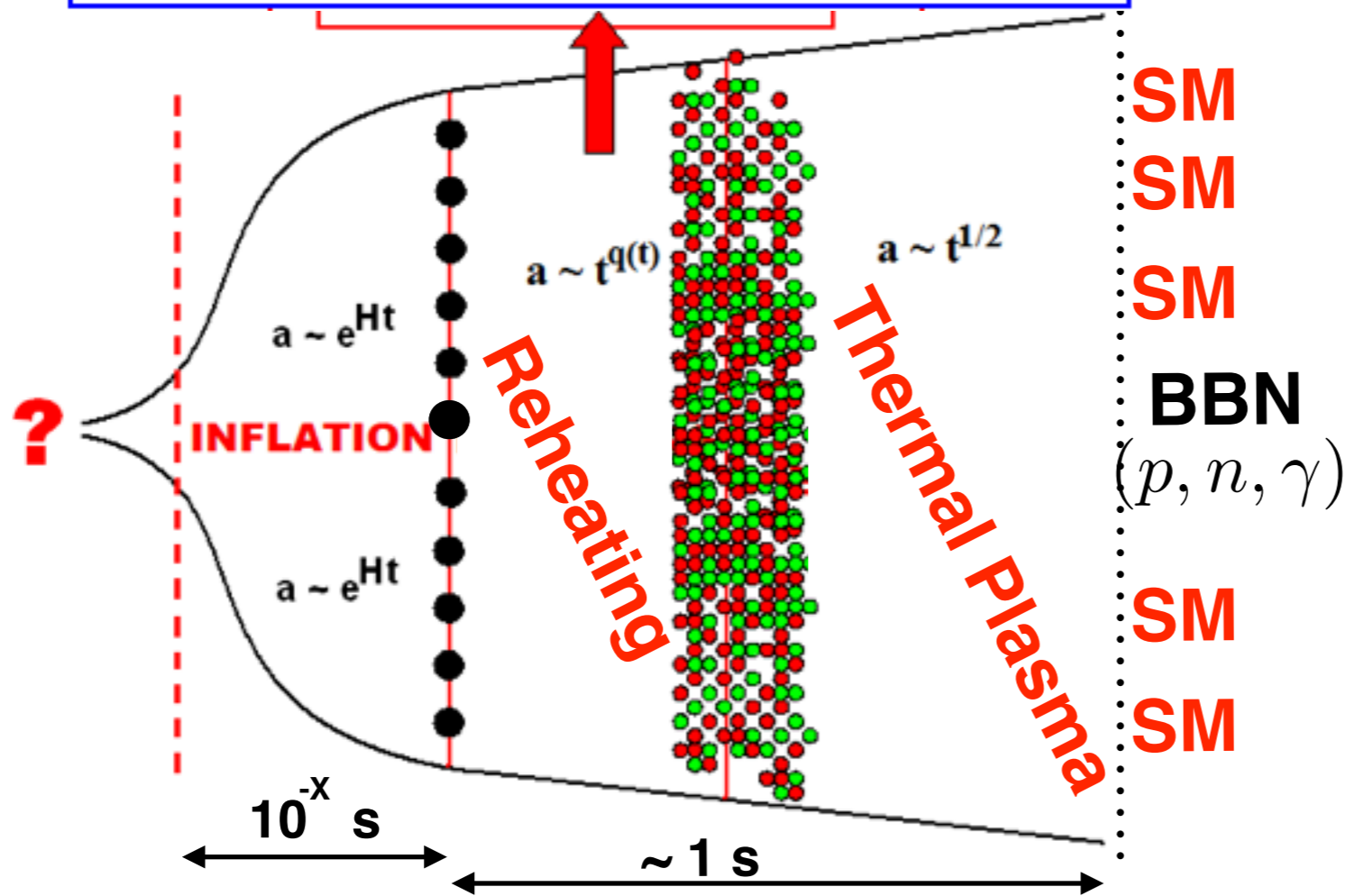
**(p)Reheating into
the Standard Model**

$$\mathcal{L} = \mathcal{L}(\phi, \varphi_i, \psi_j, A_\mu, h_{\mu\nu}, \dots)$$



(p)Reheating into the Standard Model

$$\mathcal{L} = \mathcal{L}(\phi, \varphi_i, \psi_j, A_\mu, h_{\mu\nu}, \dots)$$

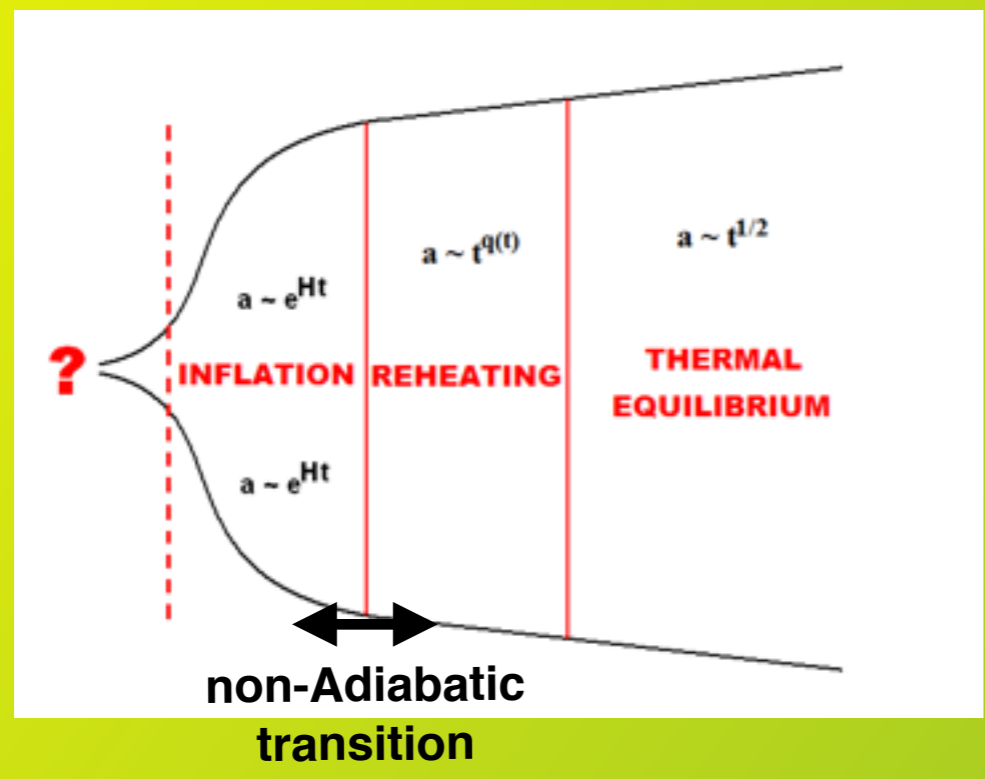


Connection between SM and Inflationary Sector ???

- * Higgs Portals ?
- * Mediator fields ?
- * No coupling ?

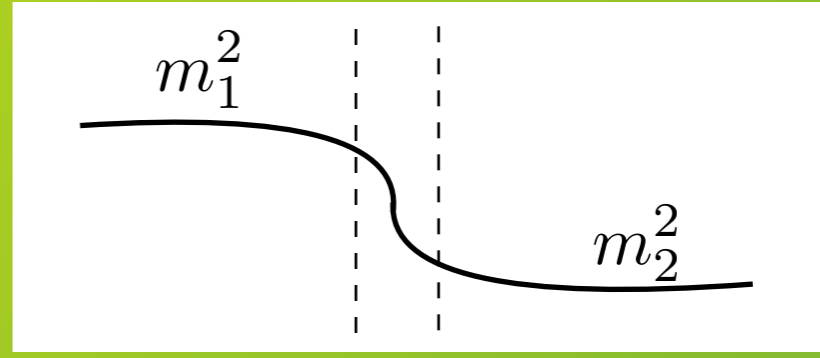
(p)Reheating into the Standard Model
No Coupling to Inflaton

$$\frac{\lambda}{4} (|\varphi|^2 - v^2)^2 + \frac{\xi}{2} R |\varphi|^2$$



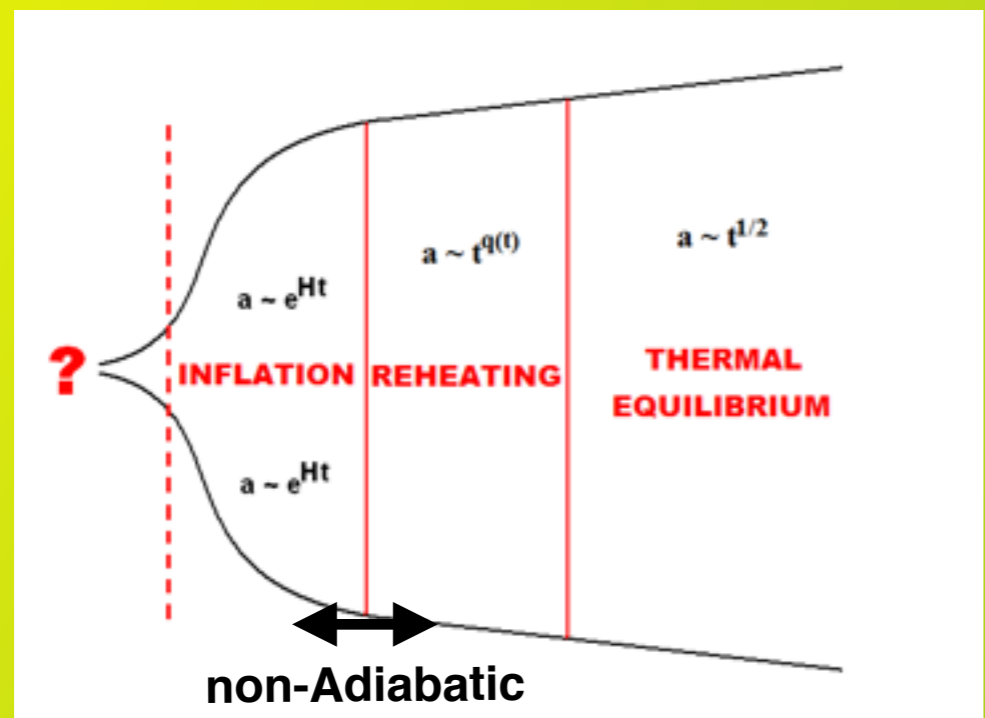
- * Inf: $m_\varphi^2 = \xi R = 12\xi H^2$
- * After: $m_\varphi^2 = \xi R = 3(1 - 3w)\xi H^2$

Equation of State



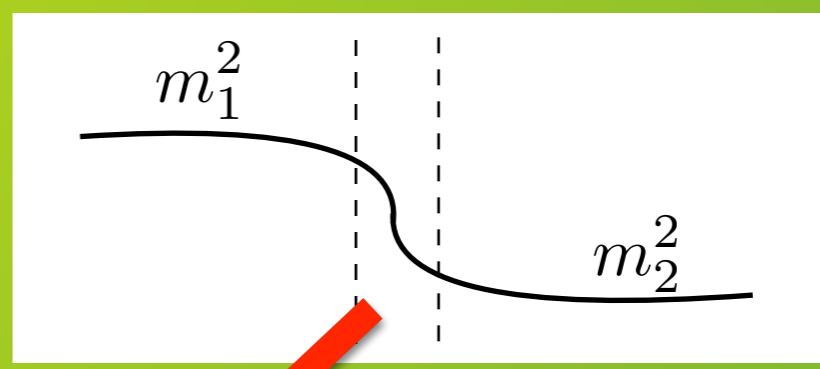
(p)Reheating into the Standard Model
No Coupling to Inflaton

$$\frac{\lambda}{4}(|\varphi|^2 - v^2)^2 + \frac{\xi}{2}R|\varphi|^2$$



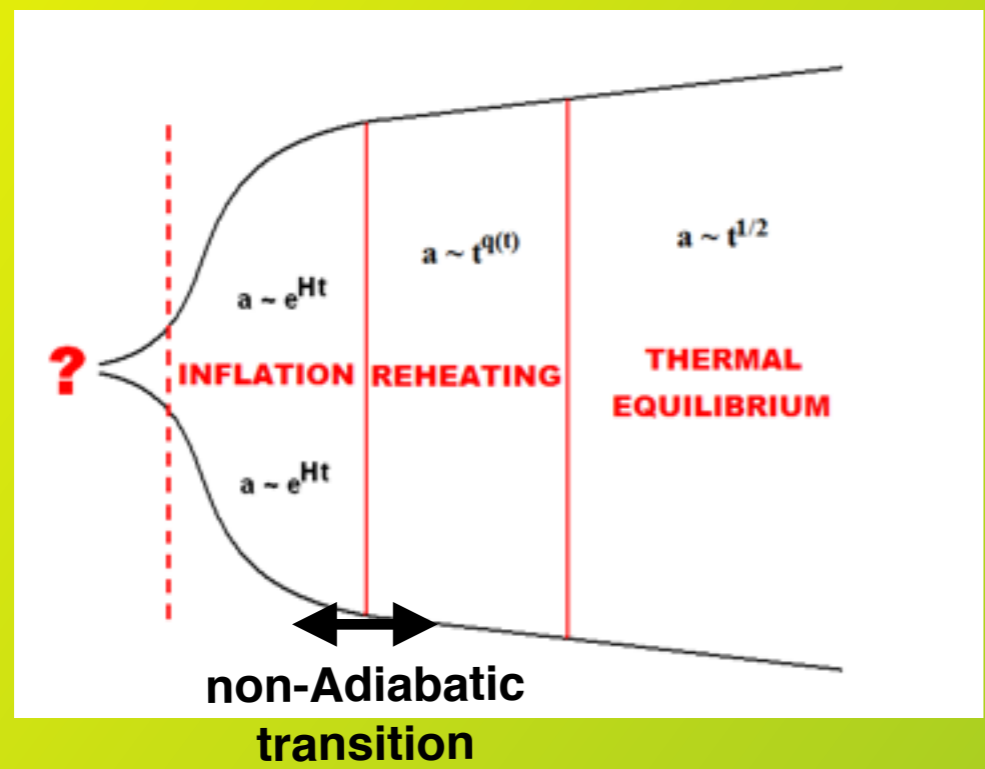
- * Inf: $m_\varphi^2 = \xi R = 12\xi H^2$
- * After: $m_\varphi^2 = \xi R = 3(1 - 3w)\xi H^2$

Equation of State



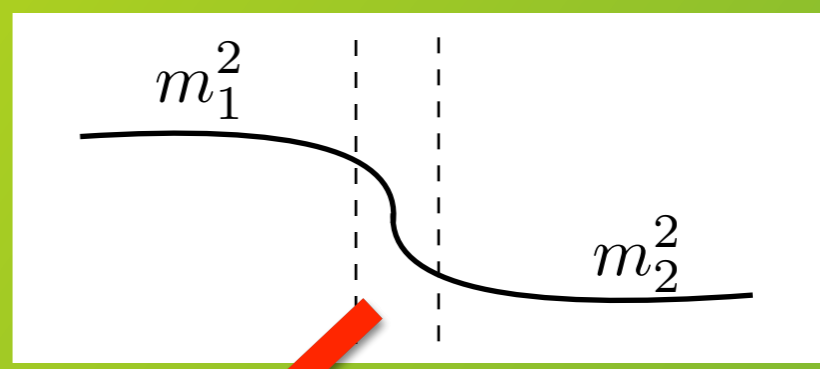
(p)Reheating into the Standard Model
No Coupling to Inflaton

$$\frac{\lambda}{4} (|\varphi|^2 - v^2)^2 + \frac{\xi}{2} R |\varphi|^2$$



- * Inf: $m_\varphi^2 = \xi R = 12\xi H^2$
- * After: $m_\varphi^2 = \xi R = 3(1 - 3w)\xi H^2$

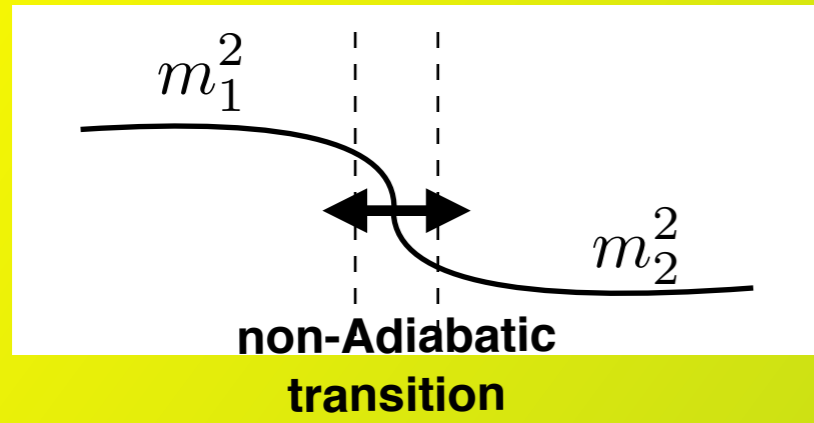
Equation of State



Higgs-Excited !!!

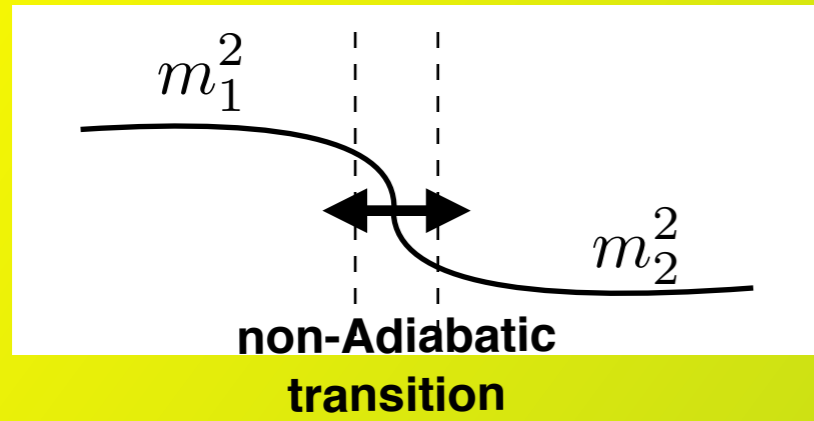


Higgs-Excited !!!



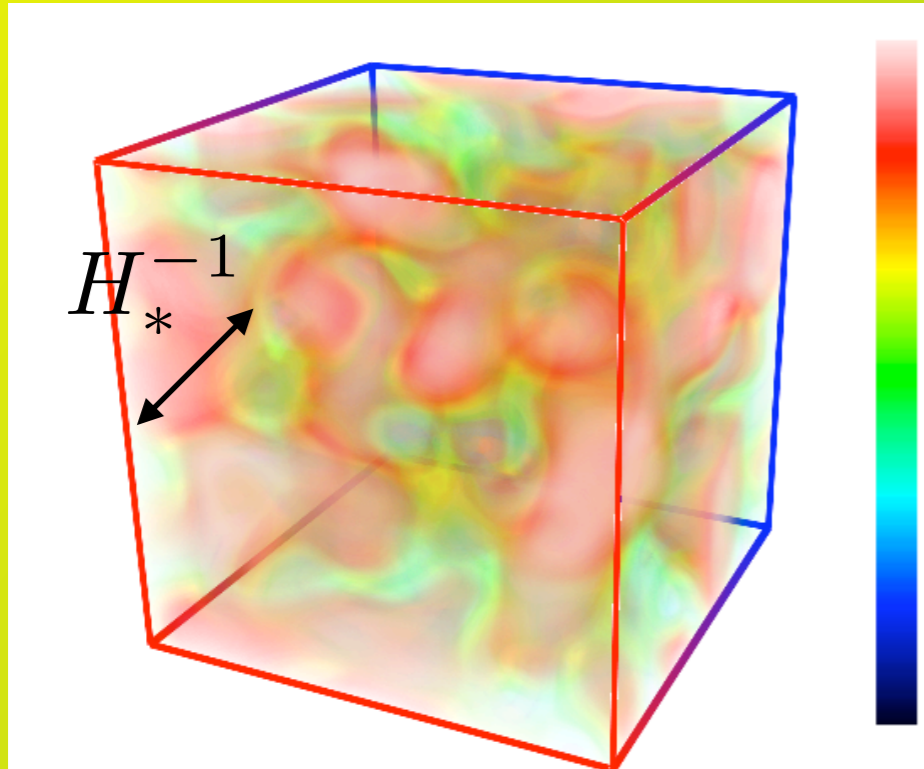
Higgs-Excitation !!!

$$\langle \varphi^2 \rangle = \mathcal{O}(10^{-3}) \left(1 - \frac{m_1}{m_2} \right)^2 \frac{H_*^2}{\sqrt{\xi}}$$

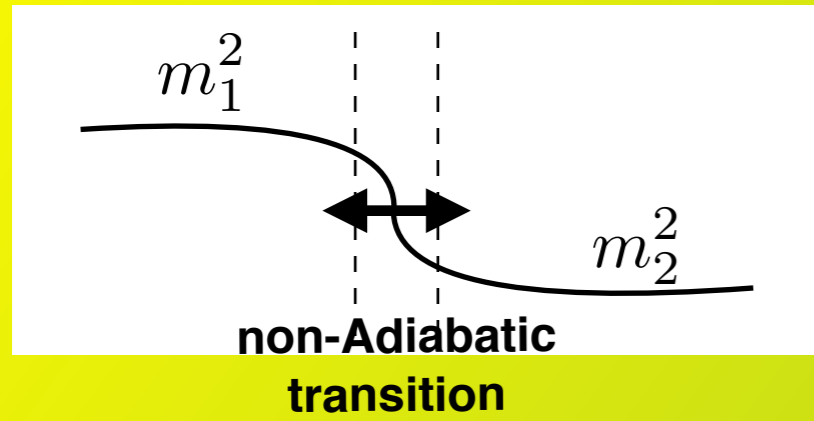


Higgs-Excitation !!!

$$\langle \varphi^2 \rangle = \mathcal{O}(10^{-3}) \left(1 - \frac{m_1}{m_2} \right)^2 \frac{H_*^2}{\sqrt{\xi}}$$

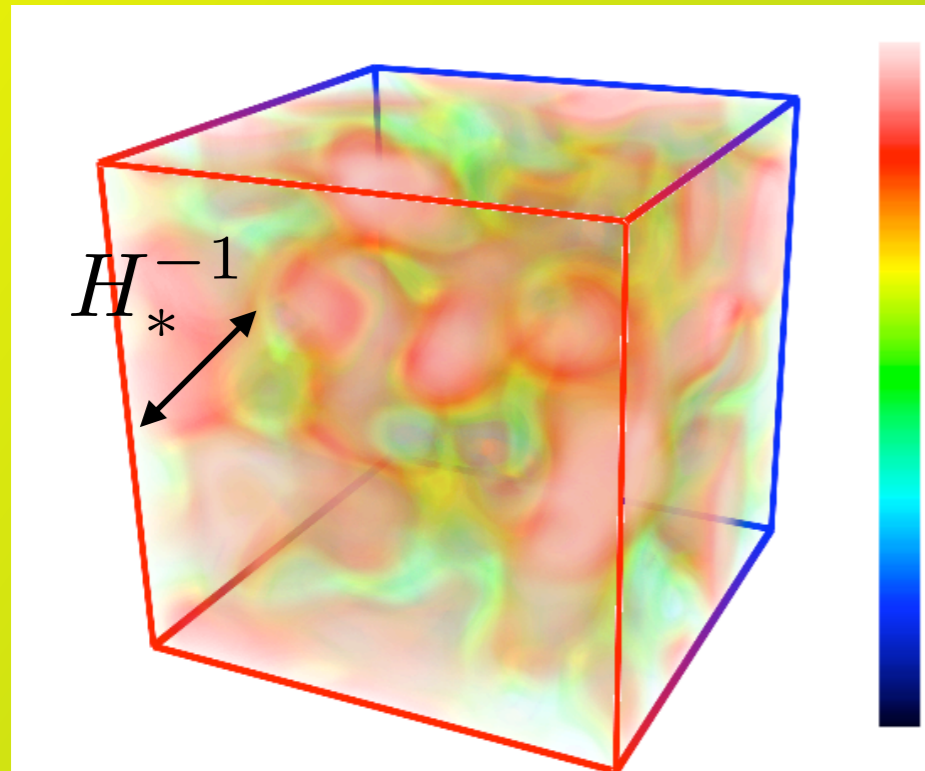


$$\frac{\lambda}{4} (|\varphi|^2 - v^2)^2 + \frac{\xi}{2} R |\varphi|^2$$



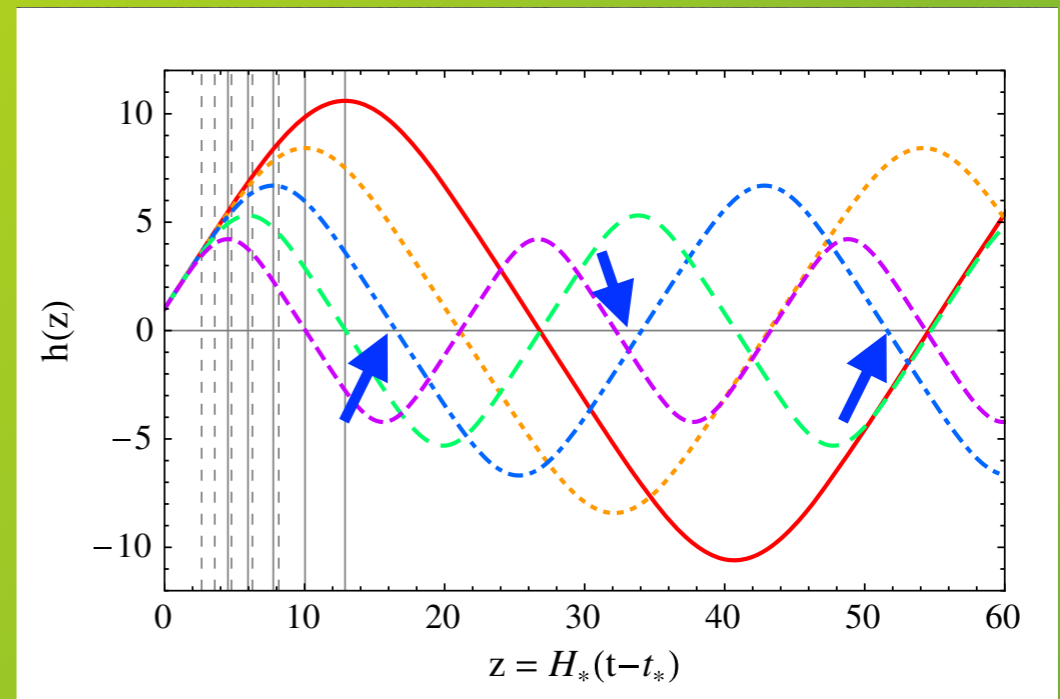
Higgs-Excitation !!!

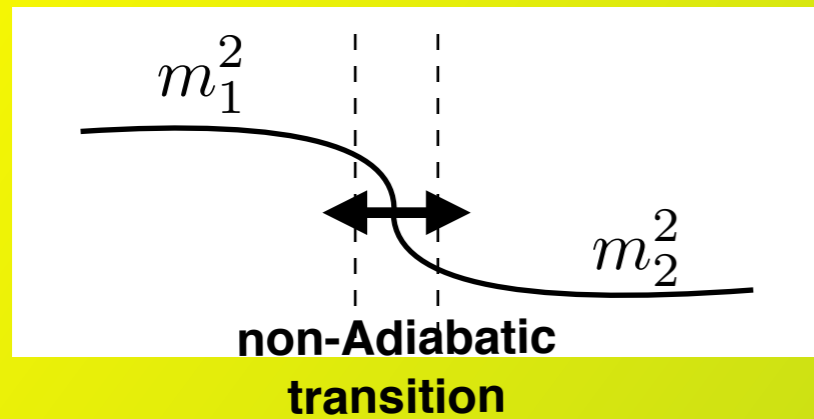
$$\langle \varphi^2 \rangle = \mathcal{O}(10^{-3}) \left(1 - \frac{m_1}{m_2} \right)^2 \frac{H_*^2}{\sqrt{\xi}}$$



$$\frac{\lambda}{4} (|\varphi|^2 - v^2)^2 + \frac{\xi}{2} R |\varphi|^2$$

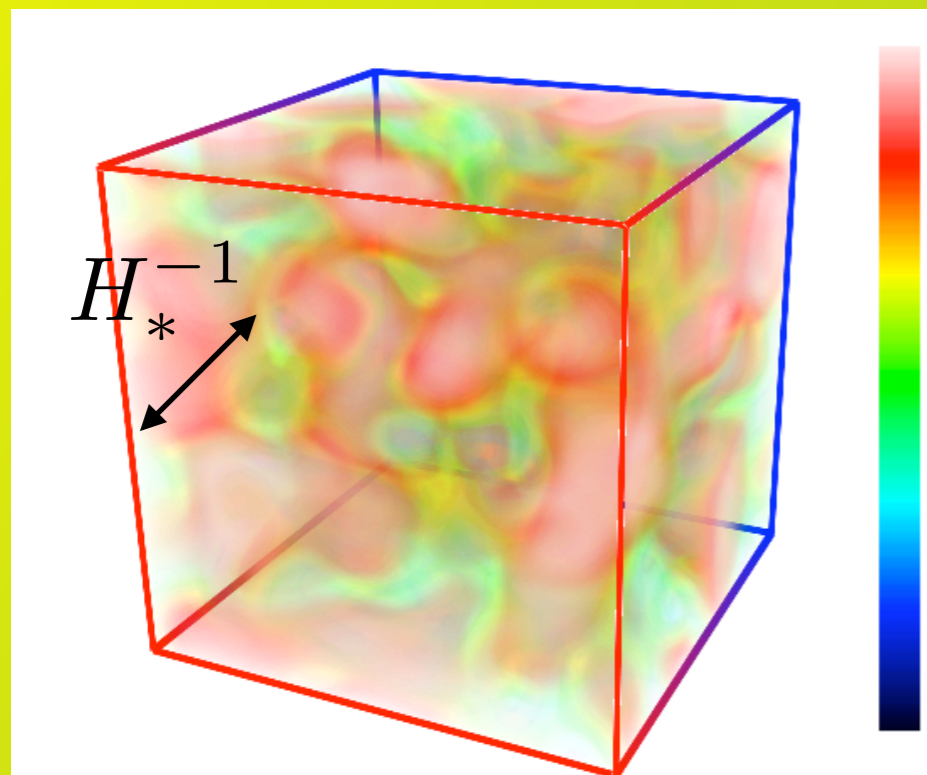
Higgs Condensate Oscillates!





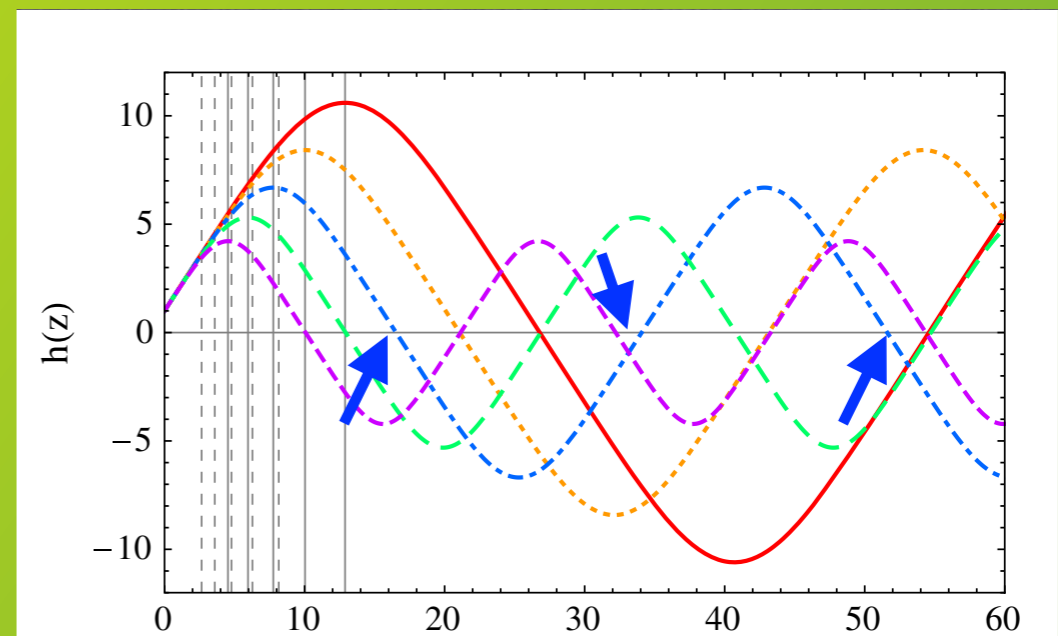
Higgs-Excitation !!!

$$\langle \varphi^2 \rangle = \mathcal{O}(10^{-3}) \left(1 - \frac{m_1}{m_2} \right)^2 \frac{H_*^2}{\sqrt{\xi}}$$



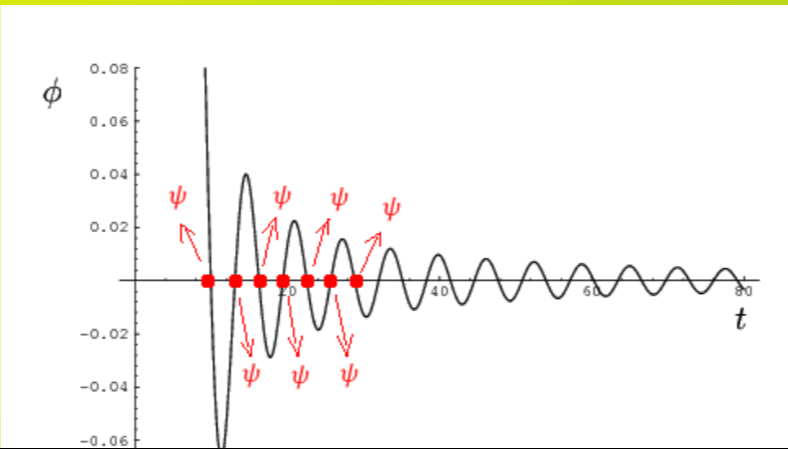
$$\frac{\lambda}{4} (|\varphi|^2 - v^2)^2 + \frac{\xi}{2} R |\varphi|^2$$

Higgs Condensate Oscillates!



SM species produced due to non-Perturbative Effects !!!

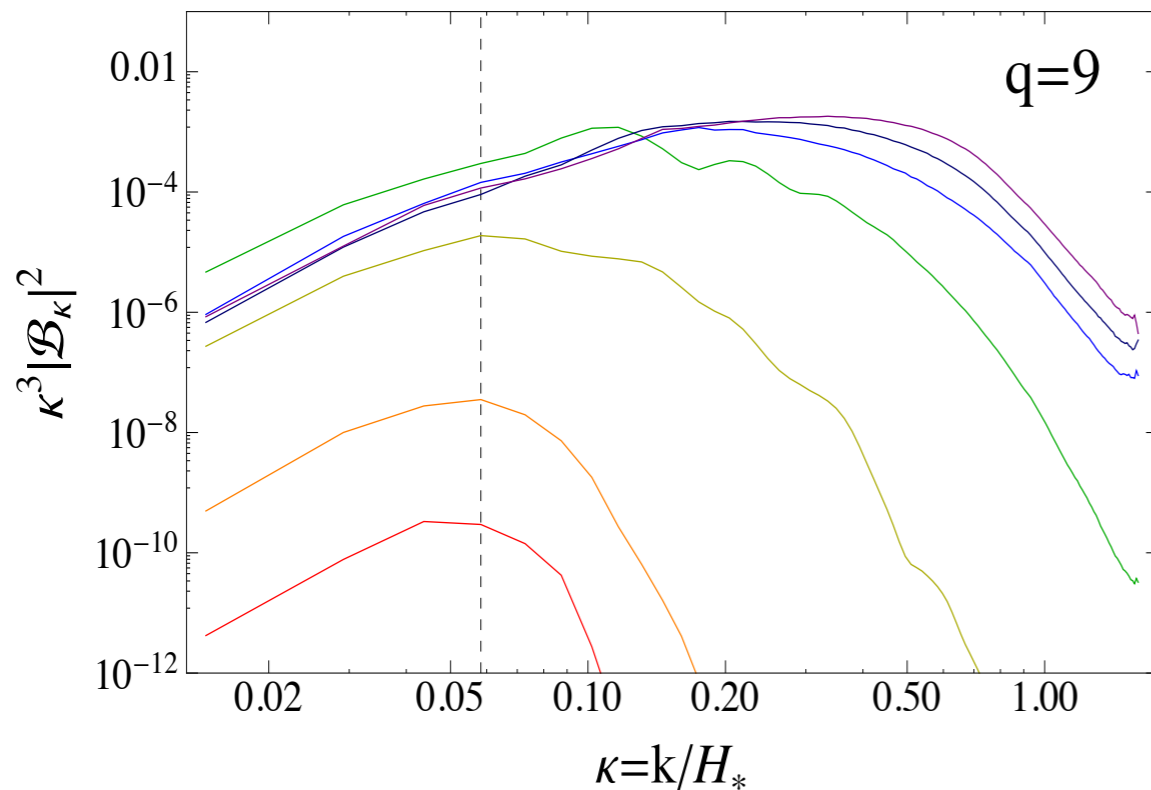
Higgs Condensate Oscillations:



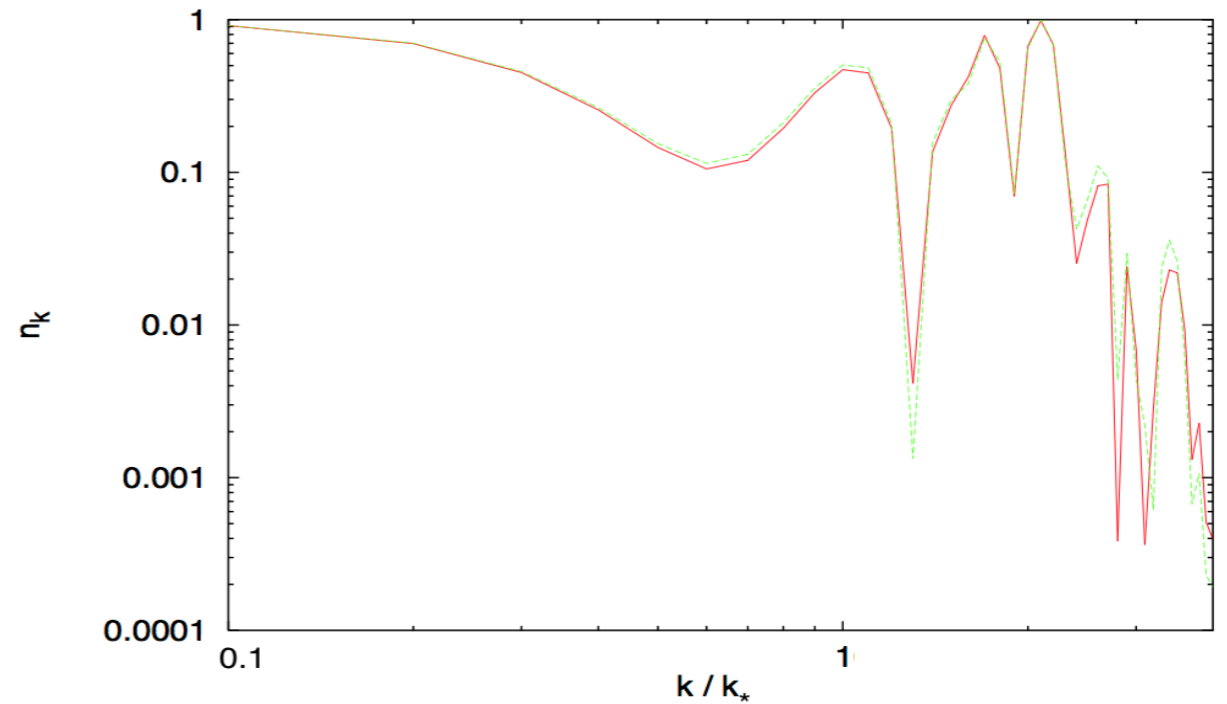
All SM species are produced!!!

Post-Inflationary production of SM species

Gauge Bosons



Fermions



(Enqvist, Nurmi, Meriniemi 2013
 + Rusak 2014, + Weir 2015
 DGF, Torrenti, Garcia-Bellido 2015)

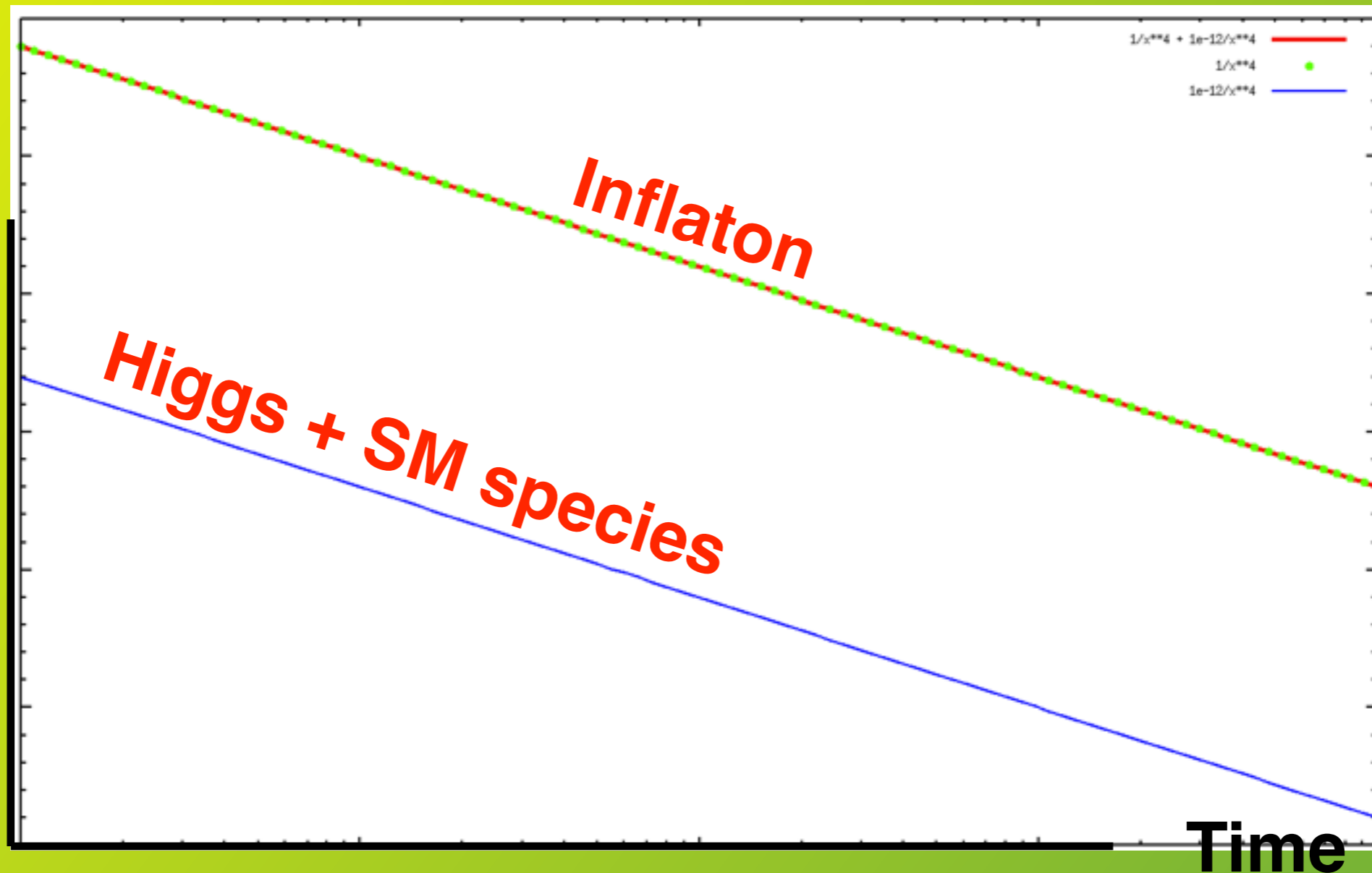
DGF 2014

$$\text{Initially : } \langle \lambda \varphi_*^4 \rangle \ll H_*^2 m_p^2$$

**SM produced!
but subdominant**



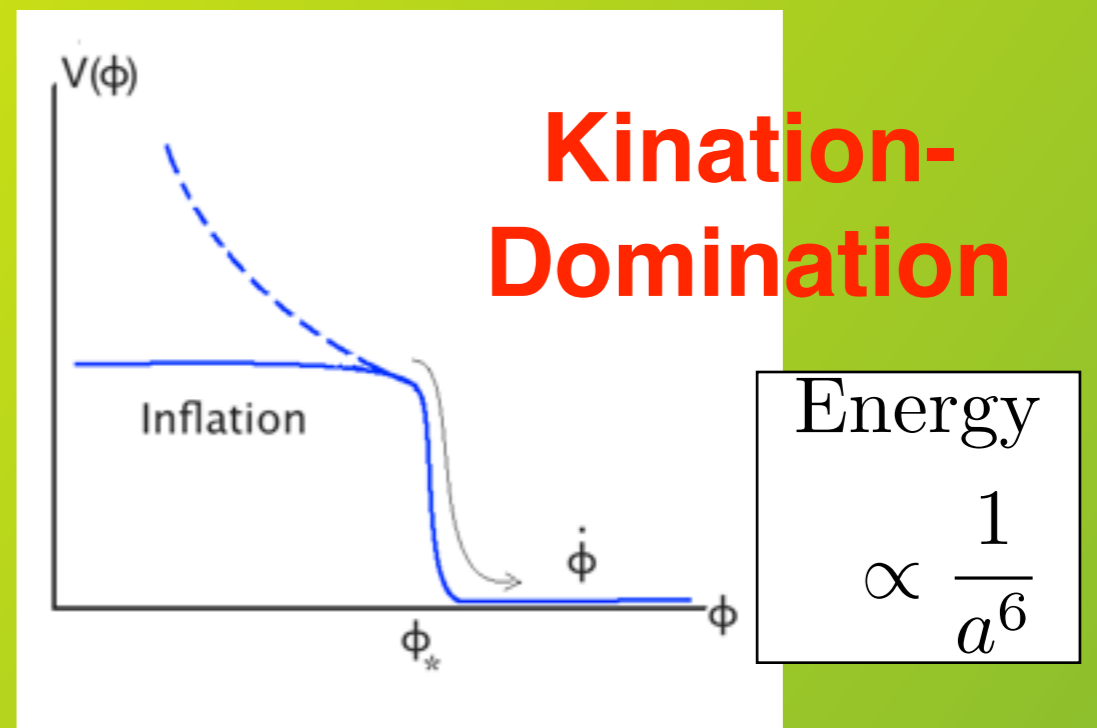
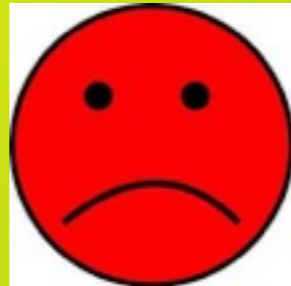
Energy



Time

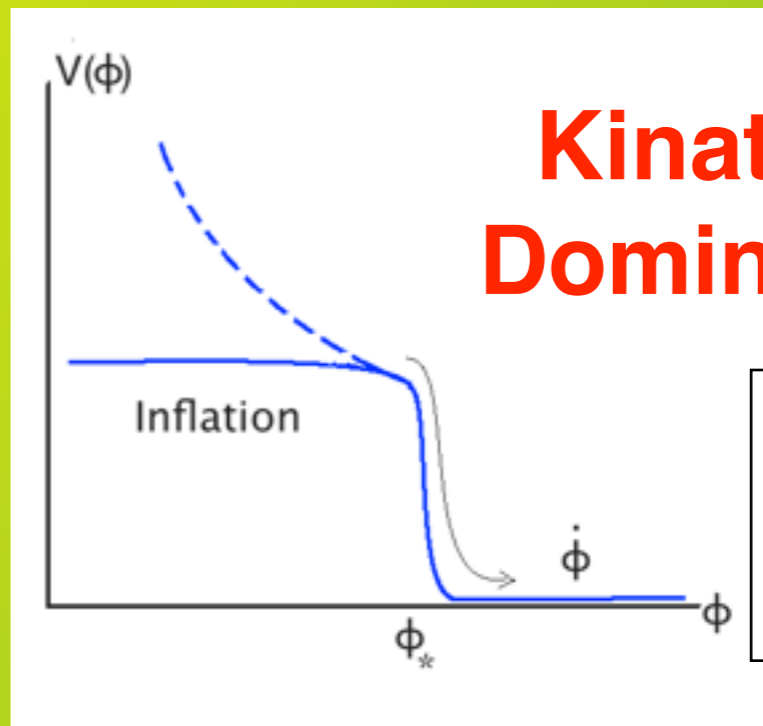
$$\text{Initially : } \langle \lambda \varphi_*^4 \rangle \ll H_*^2 m_p^2$$

**SM produced!
but subdominant**

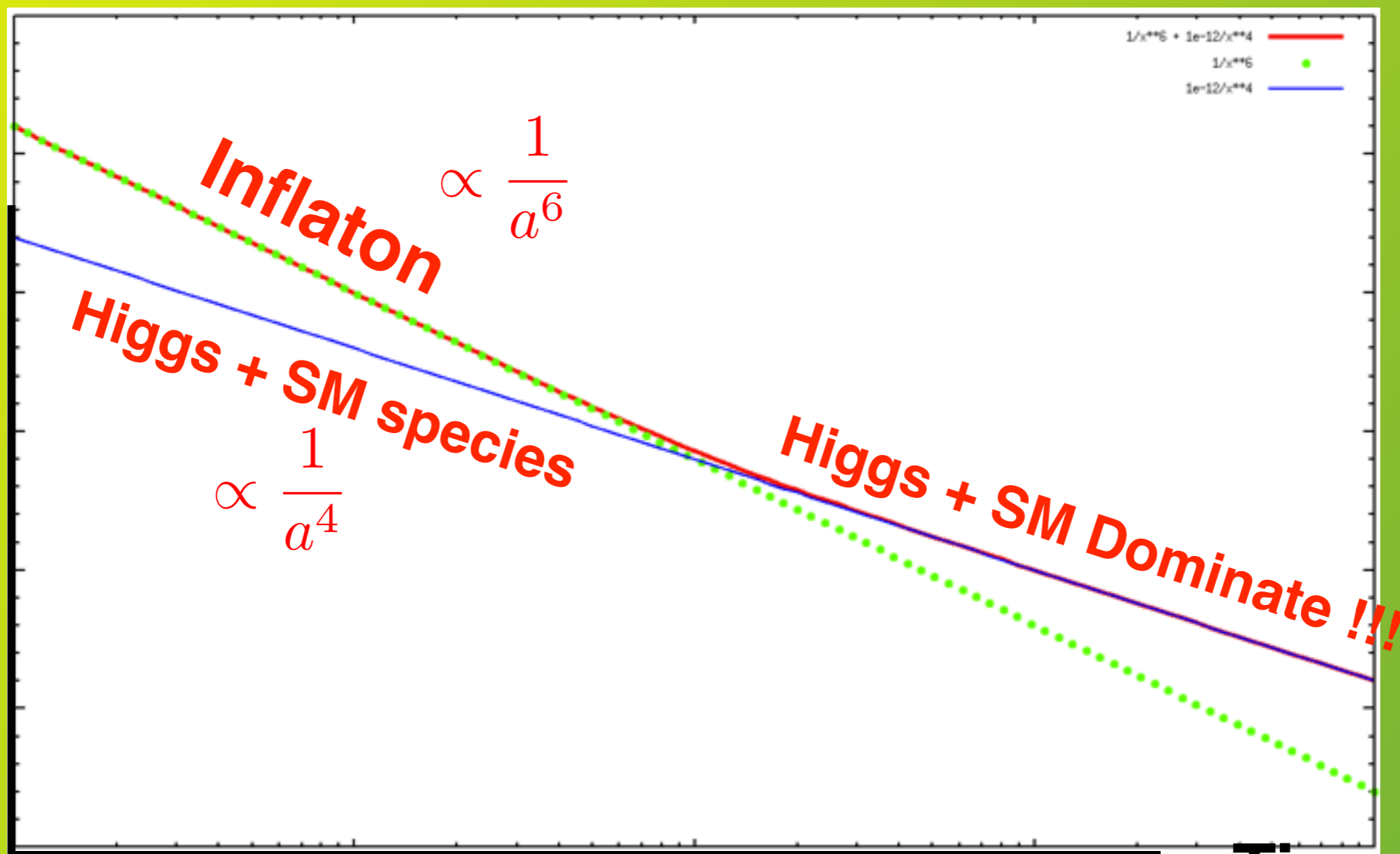


Initially : $\langle \lambda \phi_*^4 \rangle \ll H_*^2 m_p^2$

**SM produced!
but subdominant**



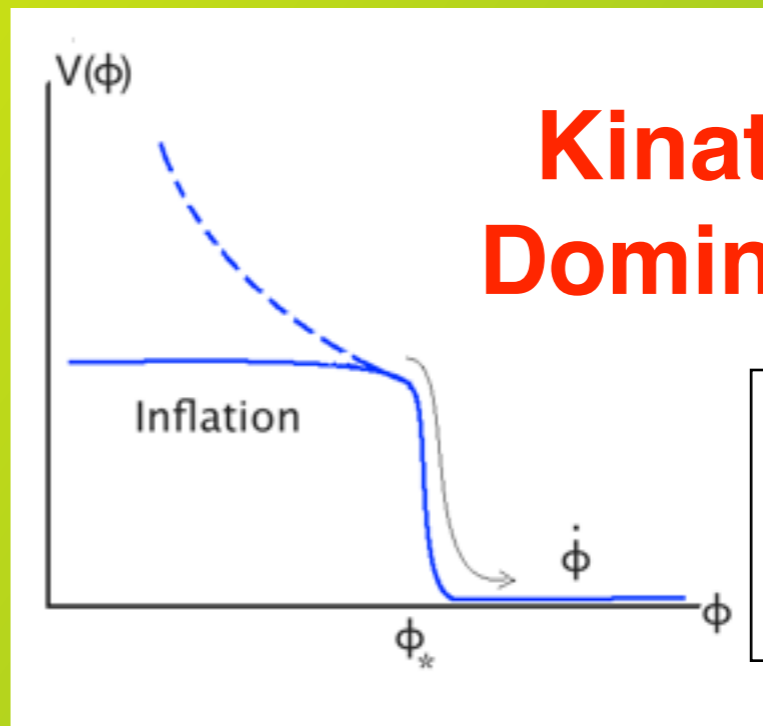
Energy



Time

Initially : $\langle \lambda \varphi_*^4 \rangle \ll H_*^2 m_p^2$

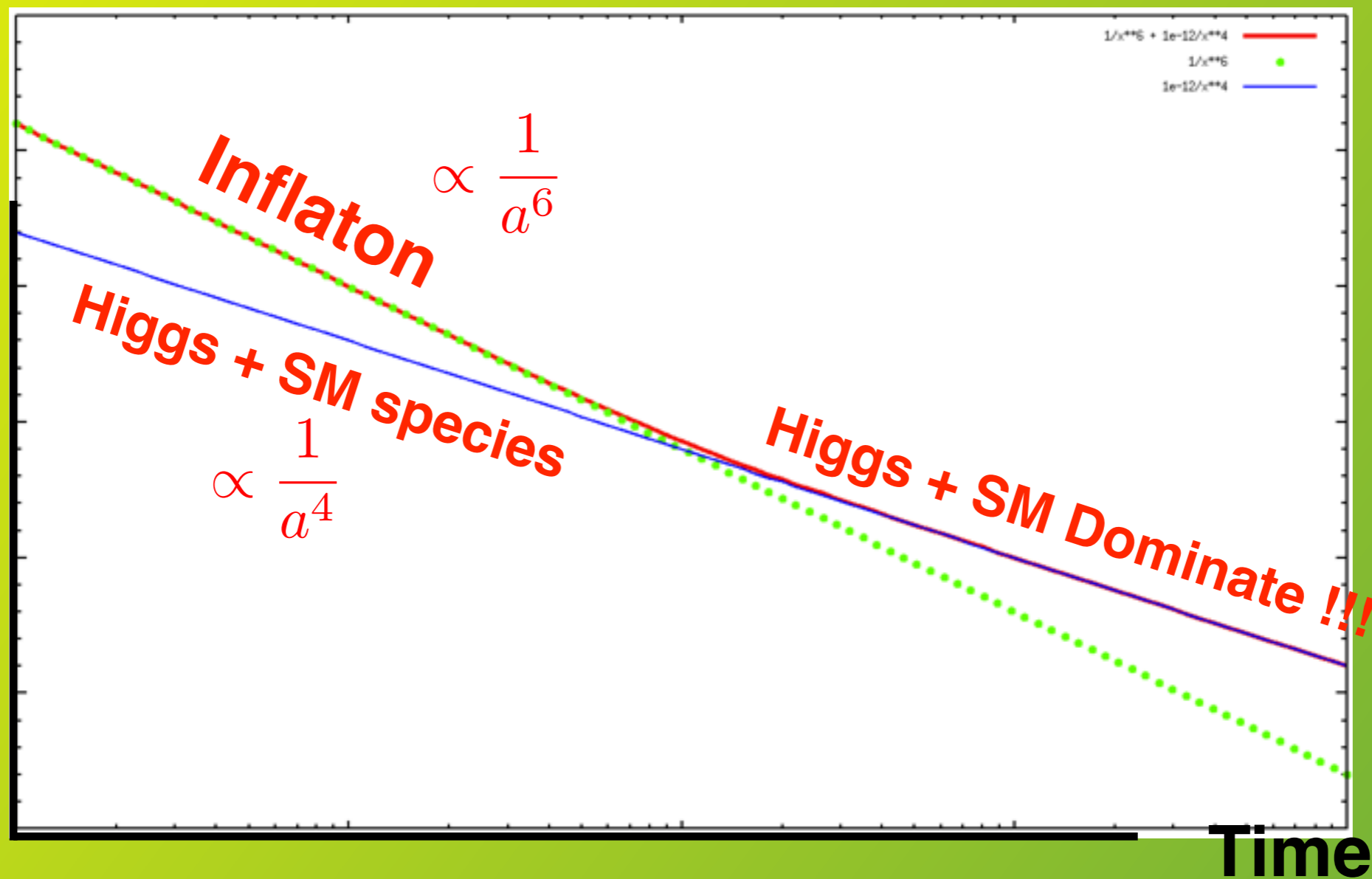
**SM produced!
and dominates**



**Kination-
Domination**

Energy
 $\propto \frac{1}{a^6}$

Energy



Summary:

*** Universal Mechanism to produce the SM**

*** SM subdominant \rightarrow irrelevant?
(baryogenesis, magnetogenesis, DM, GW)**

*** If Kination-Domination: SM species dominate!
(eventually)**

Reheating the Universe into the SM!!!

DANIEL G. FIGUEROA



Ph.D. Madrid 2010

1st Postdoc, Helsinki 2010-2012

2nd Postdoc, Geneva 2012-2014

Since Jan. 2015 @ CERN

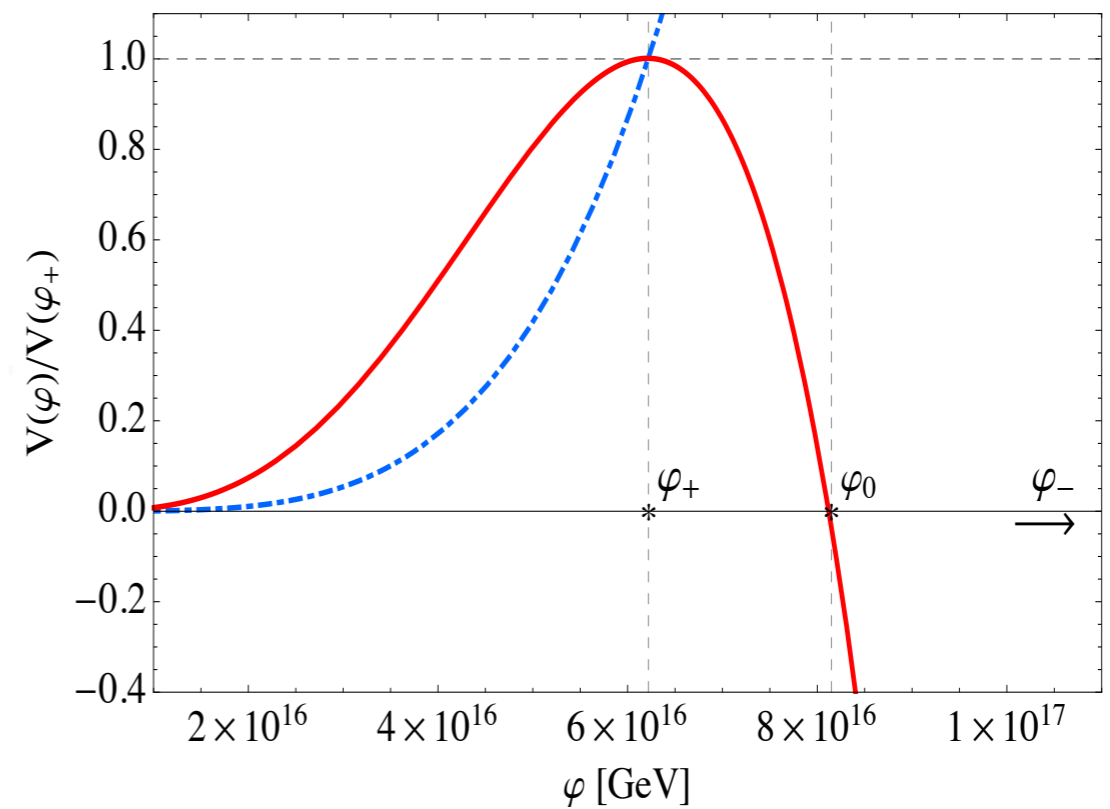
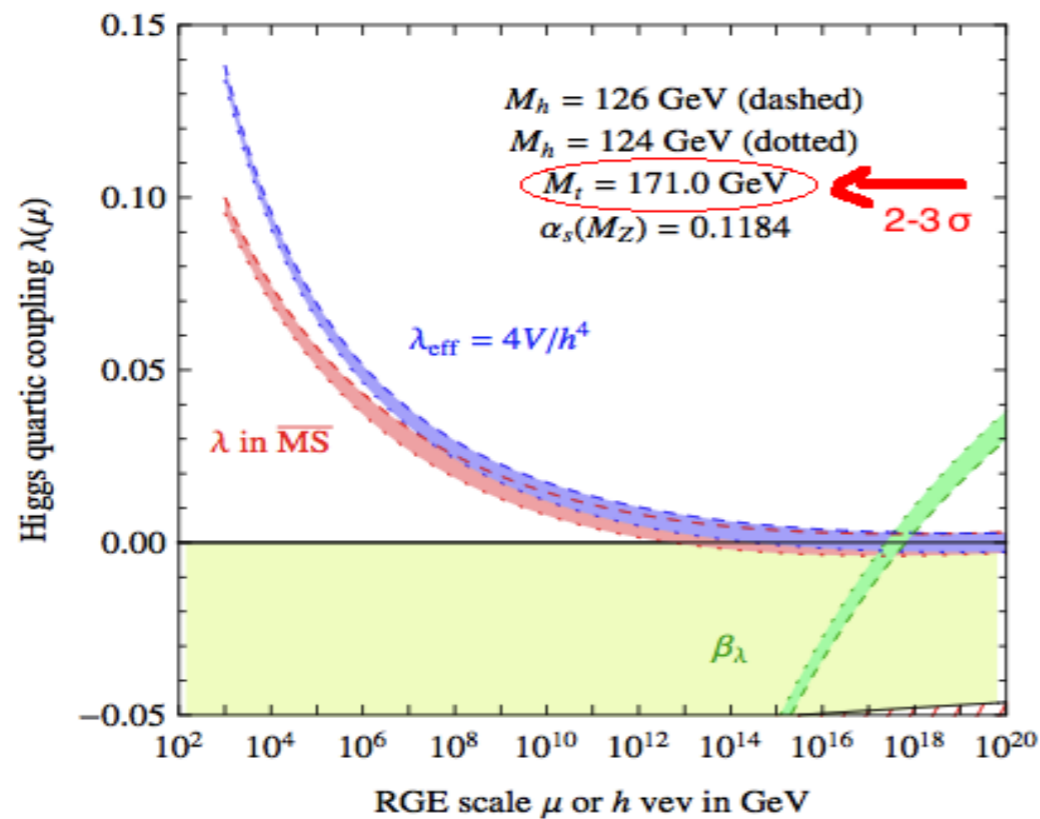
CURRENT WORK:

SM Higgs + Inflation ...

... Higgs-Inflation, Curvaton(s), Reheating,
Topological Defects, Inflation, Phase Transitions,
Gravitational Waves, Sphalerons, ...

Stability of the SM during Inflation ?

$$V(\varphi) = \frac{\lambda(\varphi)}{4} \varphi^4 \quad \lambda \sim 10^{-5} - 10^{-2}$$



(Degrassi et al 2012, Bezrukov and Shaposhnikov 2012)