Kinetics description of W and Z bosons vacuum creation in the Early Universe

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Outline

1. Motivation
   - Important role of W, Z in different physical problems (including cosmology)
   - Simplest model of QFT with higher spin
   - Others
2. Our Results
   - Kinetic equations
   - Numerical calculation
   - Step-like approximation

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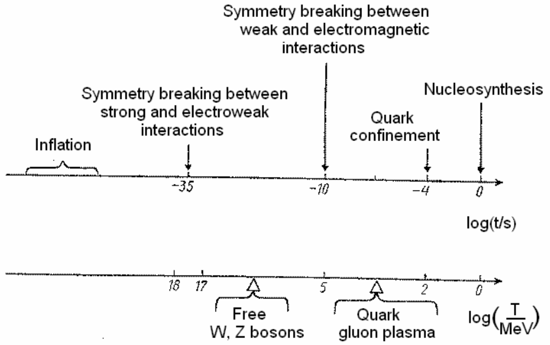
W, Z bosons in early Universe



Universe evolution

- Radiation dominated Universe with EoS

$$p = \varepsilon/3$$

- The corresponding scale factor

$$a(\eta) = a_1 \sinh(\eta), \quad t = a_1(\cosh(\eta) - 1)$$

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Kinetic equations

- Distribution function of vector bosons

$$f_s(J,\eta) =< 0|A_s^\dagger(J,\eta)A_s(J,\eta)|0 >$$

- Kinetic equations

$$f_s'(J,\eta) = \frac{1}{2}w_s(J,\eta)\int\limits_{\eta_0}^{\eta} d\eta' w_s(J,\eta')\left[1+2f_s(J,\eta')\right]\cos 2\theta(J;\eta,\eta')$$

Kinetic equations

- Amplitudes

$$w_{\perp}(J,\eta) = \omega'(J,\eta)/\omega(J,\eta)$$

$$w_{||}(J,\eta) = -w_{\perp}(J,\eta) + 2a'(\eta)/a(\eta)$$

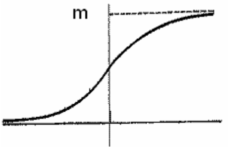
- where frequency

$$\omega(J,\eta) = \left[\lambda^2 + m^2 a^2(\eta)\right]^{1/2}$$

Vacuum creation mechanisms

$$w_{\perp}(J,\eta) = \left(\frac{ma}{\omega}\right)^2 \left[\frac{m'}{m} + \frac{a'}{a}\right]$$

- Inertial mechanism



$$m(\eta) = \frac{1}{2} m_W \left[1 + th\frac{\eta - \eta_0}{\tau_m}\right]$$

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ODEs

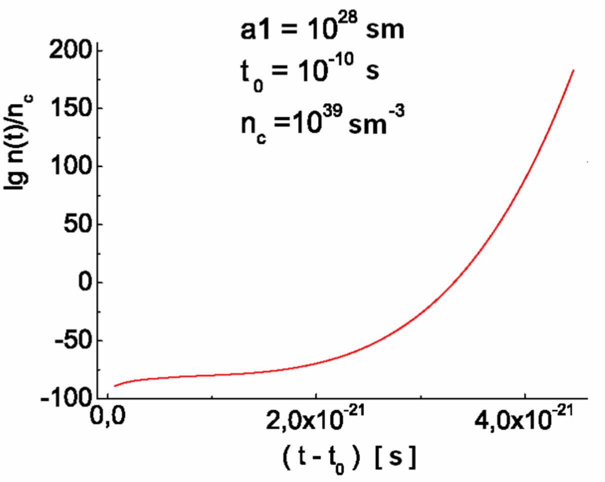
- ODE system

$$f_s' = \frac{1}{2} w_s u_s, \qquad u_s' = w_s \left[1 + 2f_s\right] - 2\omega v_s, \qquad v_s' = 2\omega u_s$$

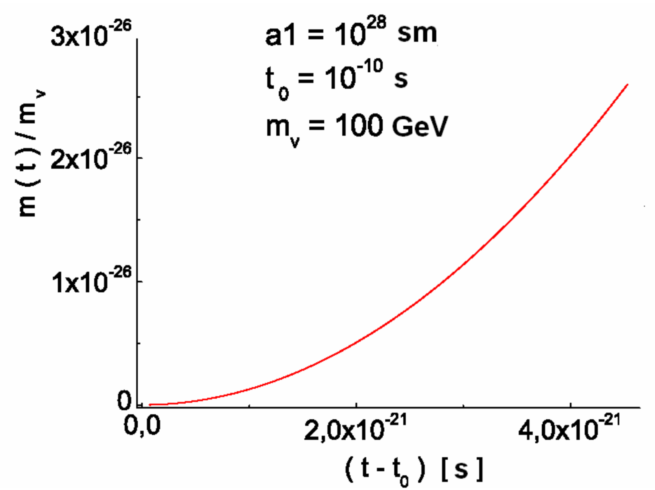
- Number density

$$n_s(\eta) = \frac{3g_s}{2\pi^2 a^3(\eta)} \int d\mu(\lambda) f_s(J, \eta)$$

Numerical calculation



Numerical calculation



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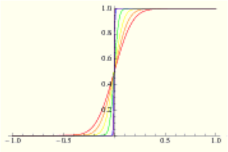
Step-like law

- the mass of the vector bosons is changed according to a step-like law

$$m(\eta) \rightarrow m(\eta) = m_W \theta\left(\eta - \eta_0\right)$$



- kinetic equation can be solved exactly !!!

Step-like

- Distribution function

$$f(J,\eta) = \frac{m_w^4}{8\omega^4 - m_w^4}\theta(\eta - \eta_0)$$

- Total particle number density

$$n = \frac{g m_w^3}{2\pi^2}\int_0^\infty \frac{x^2 dx}{8(1/2 + x^2)^2 - 1} \sim 0.1 \cdot m_w^3$$

Summary

T.W.B. Kibble, Phys. Rept. 67, 183 (1980).

t (s)	T (eV)	R/R_{now}	$\mathcal{N}$	
10^{-44}	10^{28}	10^{-32}		Planck time
			160.75	
10^{-37}	10^{24}	10^{-28}	••••••	GU
			106.75	
10^{-11}	10^{11}	10^{-15}	••••••	WS
			96.75	
10^{-7}	10^{9}	10^{-13}	⋮?	N pairs ↘
			14.25	
10^{-4}	10^{8}	10^{-12}	——	$\mu^{\pm}$↘
			10.75	
1	10^{6}	10^{-10}	——	$e^{\pm}$↘
			7.25	
10^{13}	1	10^{-3}	(effect. ~5)	recombination
10^{18}	3 K	1		present

Taking into account that $a_{ph}/a_{nd} \sim 10^{-15} \div 10^{-14}$, we get $n_{nd} \sim 10 \div 10^4\ \mathrm{cm}^{-3}$, that corresponds to nowaday CMB photon density satisfactorily.