ERRATA-CORRIGE

A primer on the physics

of the Cosmic Microwave Background

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Abstract

This note contains a list of typos appearing in my book "A primer on the physics of the Cosmic Microwave Background" published in 2008.

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- page 9. Equation (1.8)

$$\rho_\gamma(t_0) = \frac{T_\gamma^4}{\pi^2}\int_0^\infty \frac{x^3}{e^x - 1} = \frac{\pi^2}{15}T_\gamma^4 \to \rho_\gamma(t_0) = \frac{T_\gamma^4}{\pi^2}\int_0^\infty \mathbf{dx}\,\frac{x^3}{e^x - 1} = \frac{\pi^2}{15}T_\gamma^4. \tag{1}$$

- page 65. Equation (2.123). The correct form of Eq. (2.123) is

$$\frac{\tau_{\rm rec}}{\tau_{\rm p}} = \sqrt{\frac{z_{\rm p}}{z_{\rm eq}}}\biggl[\sqrt{1 + \frac{z_{\rm eq}}{z_{\rm rec}}} - 1\biggr], \tag{2}$$

and not

$$\frac{\tau_{\rm rec}}{\tau_{\rm p}} = \sqrt{\frac{z_{\rm p}}{z_{\rm eq}}}\biggl[\sqrt{1 + \frac{z_{\rm eq}}{z_{\rm rec}} - 1}\biggr] \tag{3}$$

- page 71. Equation (3.8)

$$r_H(t_{\rm P}) = 4.08\,\times 10^{-4}\biggl(\frac{0.7}{h_0}\biggr)\biggl(\frac{T}{\rm eV}\biggr) \to r_H(t_{\rm P}) = 4.08\,\times 10^{-4}\biggl(\frac{0.7}{h_0}\biggr)\biggl(\frac{T}{\rm eV}\biggr)\,\mathbf{cm}. \tag{4}$$

- page 83. Equation (4.11) must be corrected as:

$$H_{\rm i}^{-1}\biggl(\frac{a_{\rm f}}{a_{\rm i}}\biggr)_{\rm dS}\biggl(\frac{a_{\rm r}}{a_{\rm f}}\biggr)_{\rm reh}\biggl(\frac{a_{\rm eq}}{a_{\rm r}}\biggr)_{\rm rad}\biggl(\frac{a_0}{a_{\rm eq}}\biggr)_{\rm mat} \geq H_0^{-1}. \tag{5}$$

- page 84. Equation (4.17), second equality:

$$1.22 \times 10^{-61}\, M_{\rm P} \to 1.22 \times 10^{-61}\, M_{\rm P}\biggl(\frac{h_0}{0.7}\biggr). \tag{6}$$

- page 96. before Eq. (4.36), the sentence “Consequently, the radiation of $H_{\rm rh}^{-1}$ to $H_{\rm i}^{-1}$ will be given by a different equation and [...]” must be corrected as “Consequently, the evolution from $H_{\rm rh}^{-1}$ to $H_{\rm i}^{-1}$ will be given by a different equation and [...]” ;

- page 124. second line after Equation (5.17). The adverb **Recently** must be erased since it is a spurious character.

- page 133. the correct form of Equation (6.10) is

$$\delta T_{\mu\nu} \to \tilde{\delta T}_{\mu\nu} = \delta T_{\mu\nu} - T_\mu^\lambda \nabla_\nu \epsilon_\lambda - T_\nu^\lambda \nabla_\mu \epsilon_\lambda - \epsilon^\lambda \nabla_\lambda T_{\mu\nu}, \tag{7}$$

  i.e. the indices of the third term at the right hand side are inverted.

- page 191. Equation (7.100). The second term at the left hand side contains a term $(1 + 2c_{\rm st}^2)$ which must be changed into $(1 + 3c_{\rm st}^2)$. The correct form of Eq. (7.100) reads:

$$\psi'' + \mathcal{H}[\phi' + (2 + 3c_{\rm st}^2)\psi'] + [\mathcal{H}^2(1 + 3c_{\rm st}^2) + 2\mathcal{H}']\phi$$
$$-c_{\rm st}^2\nabla^2\psi + \frac{1}{3}\nabla^2(\phi - \psi) = 4\pi G a^2 \delta p_{\rm nad},$$

- page 202. Equations (7.151), (7.152) and (7.153) have some minor typos generated by an incorrect action during the copyediting process of the editorial office. Expressions like $(3 - n)/2$ have been incorrectly simplified as $3 - n/2$ by arbitrarily erasing the brackets. The correct expression of Eq. (7.151) is:

$$\int_0^\infty dy_0\, y_0^{n-3}\, J^2_{\ell+1/2}(y_0) = \frac{1}{2\sqrt{\pi}} \frac{\Gamma\left(\frac{3-n}{2}\right)\Gamma\left(\ell + \frac{n}{2} - \frac{1}{2}\right)}{\Gamma\left(\frac{4-n}{2}\right)\Gamma\left(\frac{5}{2} + \ell - \frac{n}{2}\right)}. \tag{8}$$

The correct expression of Eq. (7.152) is:

$$\Gamma\left(\frac{3-n}{2}\right) = \frac{\sqrt{2\pi}\Gamma(3-n)}{2^{5/2-n}\Gamma\left(\frac{4-n}{2}\right)}. \tag{9}$$

The correct expression of Eq. (7.153) is:

$$\mathcal{Z}(n,\ell) = \frac{\pi^2}{4}\left(\frac{k_0}{k_{\rm p}}\right)^{n-1} 2^n \frac{\Gamma(3-n)\Gamma\left(\ell + \frac{n}{2} - \frac{1}{2}\right)}{\Gamma^2\left(\frac{4-n}{2}\right)\Gamma\left(\frac{5}{2} + \ell - \frac{n}{2}\right)}. \tag{10}$$

- page 208. Equation (8.18). After the second equality the factor at the right hand side must be $-3/2$ and not -2. The correct form of Eq. (8.18) is:

$$\delta_{\rm c}(k,\tau) = \frac{3}{4}\delta_{\rm r}(k,\tau) = -\frac{3}{2}\psi_{\rm r}(k). \tag{11}$$

- page 209. The correct form of Eq. (8.23) is:

$$\delta_{\rm c}(k,y) = 3\psi(y,k) - 3\int^y \frac{dw}{w}\int^w z\,\psi(k,z)dz. \tag{12}$$

- page 211. A prime is missing in the second term at the left hand side of Eqs. (8.31) and (8.32). The correct form of Eq. (8.31) is

$$\delta_{\rm c}'' + \mathcal{H}\delta_{\rm c}' + k^2\psi = 0. \tag{13}$$

The correct form of Eq. (8.32) is

$$\delta_{\rm c}'' + \mathcal{H}\delta_{\rm c}' - 4\pi G a^2 \rho_{\rm c}\left[\delta_{\rm c} = 0, + \frac{\rho_{\rm r}}{\rho_{\rm c}}\delta_{\rm r}\right]. \tag{14}$$

- page 212. In Eq. (8.36), at the left hand side, we have $\mathcal{H}^2/\mathcal{H}'$ but this quantity must be inverted. The correct form of Eq. (8.36) is:

$$2 + \frac{\mathcal{H}'}{\mathcal{H}^2} = \frac{2+3\alpha}{2(1+\alpha)}. \tag{15}$$

- page 213. Equation (8.47). In the argument of the logarithm at the right hand side there should be a + (rather than a −) in the numerator. The correct form of Eq. (8.47) is:

$$\Delta(\alpha) = 3\sqrt{\alpha+1} - \left(1 + \frac{3}{2}\alpha\right)\ln\left[\frac{\sqrt{\alpha+1}+1}{\sqrt{\alpha+1}-1}\right]. \tag{16}$$

- page 218. A "+" sign is missing in Eq. (8.72). The correct form of Eq. (8.72) is

$$(p+\rho)\theta' + \theta[(p'+\rho') + 4\mathcal{H}(p+\rho)] + \nabla^2\delta p + (p+\rho)\nabla^2\phi = \frac{4}{3}\eta\nabla^2\theta. \tag{17}$$

- page 239. The correct expression of Eq. (8.142) is:

$$\theta_{\gamma\mathrm{b}} \simeq -\frac{3}{4}\delta'_{\gamma} = \frac{3}{4}\,k\,c_{\mathrm{sb}}^{3/2}C_1(k)\sin\left(k\int c_{\mathrm{sb}}d\tau\right)e^{-\frac{k^2}{k_{\mathrm{D}}^2}}. \tag{18}$$

- page 257. The correct form of Eq. (9.62) is:

$$\Delta_{\mathrm{I}} = -f^{(1)}\left(\frac{\partial\ln f_0}{\partial\ln q}\right)^{-1}, \qquad \mathcal{F}_{\gamma} = -\Delta_{\mathrm{I}}\frac{\int q^3\,dq\,f_0\,\frac{\partial\ln f_0}{\partial\ln q}}{\int q^3 dq f_0} = 4\Delta_{\mathrm{I}}. \tag{19}$$

- page 282. In Equations (9.192) and (9.193) the subscripts "Th" appearing in the cross-sections must be in roman style (i.e. "Th") for consistency with the other equations.

- page 295. Second line prior to Eq. (9.254): "encode" must be corrected and become "encodes".

- page 309. Equation (10.14). At the right hand side of Eq. (10.14) there must be $\delta^{(\mathrm{gi})}p_{\varphi}$ and not $\delta^{(\mathrm{gi})}\rho_{\varphi}$. The correct form of Eq. (10.14) is

$$\Psi'' + \mathcal{H}(\Phi' + 2\Psi') + (\mathcal{H}^2 + 2\mathcal{H}')\Phi + \frac{1}{3}\nabla^2(\Phi - \Psi) = 4\pi G a^2\delta^{(\mathrm{gi})}p_{\varphi}. \tag{20}$$

- page 316. Equation (10.59): the ℓ_{P} appearing at the right hand side should be ℓ_{P}^2. The correct form of Eq. (10.59) is then:

$$\mathcal{P}_{\mathrm{T}}(k) = \ell_{\mathrm{P}}^2\,H^2\frac{2^{2\nu}}{\pi^3}\Gamma^2(\nu)(1-\epsilon)^{2\nu-1}\left(\frac{k}{aH}\right)^{3-2\nu}. \tag{21}$$

- page 318. Equation (10.75). In the first relation there must be a square in the numerator at the right hand side. The correct form of Eq. (10.75) is:

$$\dot{\varphi}^2 = \frac{V_{,\varphi}^2}{9H^2}, \qquad \frac{1}{2\pi^2}\frac{H^4}{\dot{\varphi}^2} = \frac{1}{12\pi^2}\frac{V}{\epsilon\overline{M}_{\mathrm{P}}}. \tag{22}$$

- page 370. Equations (11.171), (11.172) and (11.173). A factor a^2 is missing in the first term at the right hand side of each of the mentioned equations. These equations read:

$$\mathcal{A}_{\varphi\varphi} = a^2\frac{\partial^2 W}{\partial\varphi^2} + 4\pi G\Big[4\frac{\partial W}{\partial\varphi}a^2\Big(\frac{\varphi'}{\mathcal{H}}\Big) + \varphi'^2\Big(4 + 2\frac{\mathcal{H}'}{\mathcal{H}^2}\Big)\Big],$$
$$\mathcal{A}_{\sigma\sigma} = a^2\frac{\partial^2 W}{\partial\sigma^2} + 4\pi G\Big[4\frac{\partial W}{\partial\sigma}a^2\Big(\frac{\sigma'}{\mathcal{H}}\Big) + \sigma'^2\Big(4 + 2\frac{\mathcal{H}'}{\mathcal{H}^2}\Big)\Big],$$
$$\mathcal{A}_{\varphi\sigma} = a^2\frac{\partial^2 W}{\partial\sigma\partial\varphi} + 4\pi G\Big[2\frac{\partial W}{\partial\sigma}a^2\Big(\frac{\sigma'}{\mathcal{H}}\Big) + 2\frac{\partial W}{\partial\varphi}a^2\Big(\frac{\varphi'}{\mathcal{H}}\Big)$$
$$+\varphi'\sigma'\Big(4 + 2\frac{\mathcal{H}'}{\mathcal{H}^2}\Big)\Big].$$

- page 371. Equation (11.175). The term inside the squared brackets must be $\mathcal{A}_{\sigma\sigma}$ and not $\mathcal{A}_{\varphi\varphi}$. The correct form of Eq. (11.175) is:

$$q_\sigma'' - \nabla^2 q_\sigma + \Big[-\frac{a''}{a} + \mathcal{A}_{\sigma\sigma}\Big]q_\sigma + \mathcal{A}_{\varphi\sigma}q_\varphi = 0. \tag{23}$$

- page 373. **The sentence** "Taking then the difference of Eqs. (11.184) and (11.185) and using repeatedly Eq. (11.141) the evolution equation for $\epsilon_{\rm m}$ turns out to be..." **should read** "Taking then the difference of Eqs. (11.183) and (11.184) and using repeatedly Eq. (11.141) the evolution equation for $\epsilon_{\rm m}$ turns out to be..."

- page 375. A plus sign must be changed into a minus sign in front of the last term at the left hand side of Eq. (11.196). The correct form of Eq. (11.196) is:

$$\frac{d\Theta_{\rm g}}{d\alpha} + \frac{\Theta_{\rm g}}{\alpha} - \frac{3}{\tau_1}\frac{\sqrt{\alpha+1}}{\alpha^2}\epsilon_{\rm m} = 0. \tag{24}$$

- page 414. Equation (A.21). A factor 2 is missing in the second term at the right hand side. The correct form of Eq. (A.21) is:

$$q_0 = -\frac{\ddot{a}_0 a_0}{\dot{a}_0^2} = \frac{\Omega_{\rm M0}}{2} + \frac{(1 + 3w_\Lambda)}{2}\Omega_{\Lambda 0}. \tag{25}$$

- page 421. An extra comma appears in the expression written in the text after Eq. (B.3). The expression $\sigma\mathcal{E} = \mathcal{E}(\sigma S, , \sigma V, \sigma N)$ must be replaced by $\sigma\mathcal{E} = \mathcal{E}(\sigma S, \sigma V, \sigma N)$.

- page 446. Equation (D.1). In the last relation appearing in Eq. (D.1) an equality sign (i.e. "=") is missing. The correct form of the last relation appearing in Eq. (D.1) is:

$$\delta_{\rm s}\Gamma_{0i}^{j} = -\psi'\delta_i^j + \partial_i\partial^j E'. \tag{26}$$

- page 450. Second line after Eq. (D.27). The **incorrect** sentence reads: “The velocity fields $\overline{v}$ and v defined in Eqs. (2.8) and (2.16) are not equivalent.” This sentence must be **corrected** as: “The velocity fields $\overline{v}$ and v defined in Eqs. (D.26) and (D.27) are not equivalent.”

- page 450. First line after Eq. (D.30). The **incorrect** sentence reads: “In this book we always define the velocity field as in Eq. (2.8)”.This sentence must be **corrected** as: “In this book we always define the velocity field as in Eq. (D.26)”.