An Introduction to General Relativity and Cosmology – corrections of typos and errors in the book

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Most of the defects were found and corrected by Przemysław Jacewicz. Those marked by (E) are errors or typos leading to errors, the other ones are mostly harmless. The nontrivial errors are explained in comments.

The defects marked by (C) had been introduced by the Cambridge UP editors without the authors' knowledge.

Page 29, equation (4.17), was:

$$\epsilon^{a_1,\ldots,a_n}$$

Should be:

$$\epsilon^{a_1\ldots a_n}$$

(*Correction to be done:* remove the commas)

Page 31, equation (4.32), 3rd line, was:

$$e_{b_j\,\beta_j}\ldots e_{b_l}{}^{\beta_l}$$

Should be:

$$e_{b_j}{}^{\beta_j}\ldots e_{b_l}{}^{\beta_l}$$

(*Correction to be done:* raise β_j)

Page 32, equation (4.33), 1st line, was:

$$0 = w\Gamma^{\rho}{}_{\rho\gamma}T^{\alpha_1\ldots\alpha_k}_{\beta_1\ldots\beta_l} \quad \text{etc.}$$

Should be:

$$0 = -w\Gamma^{\rho}{}_{\rho\gamma}T^{\alpha_1\ldots\alpha_k}_{\beta_1\ldots\beta_l} \quad \text{etc.}$$

(*Correction to be done:* insert minus in front of the first term)

Page 32, the first displayed equation in exercise 2, was:

$$\delta^{\alpha}_{\beta}$$

Should be:

$$\delta^{\alpha}{}_{\beta}$$

(*Correction to be done:* upper and lower indices not aligned)

Pages 33 – 34, equations (5.4), (5.6), (5.7), (5.10), (5.11) and (5.13), was (C):

$$\Gamma^{\alpha}_{\sigma\rho}$$

Should be:

$$\Gamma^{\alpha}{}_{\sigma\rho}$$

(*Correction to be done:* upper and lower indices not aligned)

Page 34, equations (5.8) and (5.14), was:

$$\frac{\mathrm{D}}{\mathrm{D}\tau}$$

Should be:

$$\frac{\mathrm{D}}{\mathrm{d}\tau}$$

(*Correction to be done:* d instead of D in the denominator)

Page 34, equation (5.10), was (C):

$$\int_{G}^{\tau} \tau_0$$

Should be:

$$\int_{G}^{\tau}{}_{\tau_0}$$

(*Correction to be done:* τ_0 is the lower limit of the integral, not the first factor of the integrand)

Page 41, equations (6.32) and (6.33), was (C):

$$\Gamma^{\rho}_{\rho\sigma}$$

Should be:

$$\Gamma^{\rho}{}_{\rho\sigma}$$

(*Correction to be done:* upper and lower indices not aligned)

Page 41, equation (6.34), was (C):

$$\oint_{C} \Gamma^{\rho}_{\rho\sigma}(x)\mathrm{d}x^{\sigma} = -\int_{S_C} \Gamma^{\rho}_{\rho[\gamma,\delta]}\mathrm{d}x^{\gamma}\wedge\mathrm{d}x^{\delta} = \frac{1}{2}\int_{S_C} B^{\rho}_{\rho\gamma\delta}\mathrm{d}x^{\gamma}\wedge\mathrm{d}x^{\delta}$$

Should be:

$$\oint_{C} \Gamma^{\rho}{}_{\rho\sigma}(x)\mathrm{d}x^{\sigma} = -\int_{S_C} \Gamma^{\rho}{}_{\rho[\gamma,\delta]}\mathrm{d}x^{\gamma}\wedge\mathrm{d}x^{\delta} = \frac{1}{2}\int_{S_C} B^{\rho}{}_{\rho\gamma\delta}\mathrm{d}x^{\gamma}\wedge\mathrm{d}x^{\delta}$$

(*Correction to be done:* upper and lower indices not aligned in 3 terms)

Page 41, equation (6.35), was (C):

$$B^{\rho}_{\rho\gamma\delta}$$

Should be:

$$B^{\rho}{}_{\rho\gamma\delta}$$

(*Correction to be done:* upper and lower indices not aligned)

Page 45, line below equation (6.52), was:

(5.8)

Should be:

(6.16)

(*Correction to be done:* change equation number referred to)

Page 46, line above equation (6.55), was:

(6.52)

Should be:

(6.53)

(*Correction to be done:* change equation number referred to)

Page 59, equation (7.51), was (C):

$$g_{\beta_{\gamma}}\psi^{;\alpha}$$

Should be:

$$g_{\beta\gamma}\psi^{;\alpha}$$

(*Correction to be done:* $\beta\gamma$ are subscripts to g on the same level)

Page 59, equation (7.52), was:

$$\psi_{\rho}\psi^{;\rho}$$

Should be:

$$\psi_{,\rho}\,\psi^{;\rho}$$

(*Correction to be done:* insert comma in front of the subscript ρ)

Page 63, section 7.15, paragraph 2, line 3, was:

(i.e. subspaces whose normal vectors have zero length)

Should be:

(i.e. subspaces whose tangent spaces contain vectors of zero length)

(*Correction to be done:* replace the words "normal vectors have" with the words "tangent spaces contain vectors of")

Page 67, equation (7.86), was:

$$\Omega_{(\widehat{A})\alpha\beta} \qquad \text{and} \qquad X_{\widehat{A}}{}^{S} \quad \text{(twice)}$$

Should be:

$$\Omega_{(\widehat{S})\alpha\beta} \qquad \text{and} \qquad X_{\widehat{S}}{}^{S}$$

(*Correction to be done:* $\widehat{S}$ instead of $\widehat{A}$, in 3 places)

Page 68, equation (7.91), 3rd line, was:

$$\Omega_{(\widehat{S})\nu\beta} \qquad \text{and} \qquad \Omega_{(\widehat{S})\nu\gamma}$$

Should be:

$$\Omega_{(\widehat{P})\nu\beta} \qquad \text{and} \qquad \Omega_{(\widehat{P})\nu\gamma}$$

(*Correction to be done:* $\widehat{P}$ instead of $\widehat{S}$, in 2 places)

Page 68, equation (7.92), 2nd line, was:

$$\Omega_{(\widehat{T})\mu\gamma} \qquad \text{and} \qquad \Omega_{(\widehat{T})\mu\beta}$$

Should be:

$$\Omega_{(\widehat{S})\mu\gamma} \qquad \text{and} \qquad \Omega_{(\widehat{S})\mu\beta}$$

(*Correction to be done:* $\widehat{S}$ instead of $\widehat{T}$, in 2 places)

Page 69, line 12 below equation (7.95), was (C):

suggests that $N = n(n+1)/2$, ... etc

Should be:

suggests that if $N = n(n+1)/2$, ... etc

(*Correction to be done:* insert 'if')

Page 78, line below equation (8.22), was:

$$R^{\alpha}{}_{\alpha\beta\gamma}$$

Should be:

$$R^{\rho}{}_{\alpha\beta\gamma}$$

(*Correction to be done:* superscript ρ instead of α)

Page 81, equation (8.30), was (C):

$$[\underset{(i)}{k}, \underset{(j)}{k}{}^{\alpha}]$$

Should be:

$$[\underset{(i)}{k}, \underset{(j)}{k}]^{\alpha}$$

(*Correction to be done:* superscript α behind the square bracket, not inside)

Page 82, caption to Fig. 8.2, line 3, was (C):

may or may need not

Should be:

may or may not

(*Correction to be done:* delete 'need')

Page 83, equation (8.35), first line, second equation, was:

$$x'^{i} = -x^{i} \sin\alpha ... \qquad \text{etc}$$

Should be:

$$x'^{j} = -x^{i} \sin\alpha ... \qquad \text{etc}$$

(*Correction to be done:* superscript j instead of i on the left)

Page 92, line above equation (8.79), was (C):

(Haantjes, 1937, 1940)

Should be:

(Haantjes, 1937)

(*Correction to be done:* delete ', 1940')

Page 97, equations (9.20) (line 2) and (9.21), was:

$$e_{l}]^{\alpha}$$

Should be:

$$e_{l]}{}^{\alpha}$$

(*Correction to be done:* the square bracket should be in the subscript)

Page 99, equation (10.1), was (C):

$$\overset{\alpha}{\underset{(j)}{k}}$$

Should be:

$$k^{\alpha}_{(j)}$$

(*Correction to be done:* α is a superscript to k, not overset)

Page 107, the two lines above equation (10.23), was (C):

$$k_{(i)}$$

Should be:

$$\underset{(i)}{k}$$

(*Correction to be done:* (i) is underset to k, not a subscript)

Page 109, equation (10.32), and page 111, equation (10.43) was:

$$\mathrm{d}\phi^{2}$$

Should be:

$$\mathrm{d}\varphi^2$$

(*Correction to be done:* φ instead of ϕ)

Page 128, equation (12.7), was (C):

$$e_0^{\widehat{A}}(p')$$

Should be:

$$e^{\widehat{A}}{}_0(p')$$

(*Correction to be done:* upper and lower indices not aligned)

Page 131, line below equation (12.18), was:

$$\delta^{\alpha}{}_{\gamma}$$

Should be:

$$\delta^{\gamma}{}_{\alpha}$$

(*Correction to be done:* interchange upper and lower index)

Page 131, equation (12.21), was:

$$g^{\alpha\beta}$$

Should be:

$$g_{\alpha\beta}$$

(*Correction to be done:* lower both indices)

Page 138, equation (12.39), first line, was:

$$\frac{v^I}{t}$$

Should be:

$$\frac{v^I}{c}$$

(*Correction to be done:* c instead of t)

Page 138, line below equation (12.39), was:

$$cg_{0I}/\sqrt{g_{00}}$$

Should be:

$$g_{0I}/\left(c\sqrt{g_{00}}\right)$$

(*Correction to be done:* c in the denominator, not in the numerator)

Page 143, equation (12.74), was (E):

$$(\epsilon + p)u_\alpha u_\beta$$

Should be:

$$\epsilon u_\alpha u_\beta$$

(*Correction to be done:* remove + p and the parentheses)

Page 152, equation (12.119), was:

$$\varepsilon N^2 \left(\mathrm{d}x^4\right)^2$$

Should be:

$$\varepsilon \mathcal{N}^2 \left(\mathrm{d}x^4\right)^2$$

(*Correction to be done:* replace N with $\mathcal{N}$ (script))

Comment: N was used with two meanings: as the dimension of a space and as a metric function. This correction must be applied in several other places further on.

Page 152, line 2 below equation (12.119), was:

$$1/N$$

Should be:

$$1/\mathcal{N}$$

(*Correction to be done:* replace N with $\mathcal{N}$)

Page 153, line 2 above equation (12.120), was:

$$1/N$$

Should be:

$$1/\mathcal{N}$$

(*Correction to be done:* replace N with $\mathcal{N}$)

Page 153, equation (12.121), was:

$$-R_{4IJK}(V_4)/N$$

Should be:

$$-R_{4IJK}(V_4)/\mathcal{N}$$

(*Correction to be done:* replace N with $\mathcal{N}$)

Page 153, line 4 below equation (12.121), was:

$$R_{4IJK}(V_4)/N \qquad \ldots \qquad \text{but } N \text{ and} \ldots$$

Should be:

$$R_{4IJK}(V_4)/\mathcal{N} \qquad \ldots \qquad \text{but } \mathcal{N} \text{ and} \ldots$$

(*Correction to be done:* replace N with $\mathcal{N}$ in two places)

Page 153, first line of equation (12.122), was:

$$\varepsilon N^2$$

Should be:

$$\varepsilon \mathcal{N}^2$$

(*Correction to be done:* replace N with $\mathcal{N}$)

Page 153, second line of equation (12.122), was:

$$\varepsilon N^2$$

Should be:

$$\varepsilon \mathcal{N}^2$$

(*Correction to be done:* replace N with $\mathcal{N}$)

Page 153, last line of equation (12.122), was:

$$= \varepsilon N \left(-N_{|IJ} + \varepsilon N g^{RS} \Omega_{RJ} \Omega_{IS} + \varepsilon N \Omega_{IJ,S} X^S \right)$$

Should be:

$$= \varepsilon \mathcal{N} \left(-\mathcal{N}_{|IJ} + \varepsilon \mathcal{N} g^{RS} \Omega_{RJ} \Omega_{IS} + \varepsilon \mathcal{N} \Omega_{IJ,S} X^S \right)$$

(*Correction to be done:* replace N with $\mathcal{N}$ in 4 places)

Page 155, equation (12.130), was:

$$\widetilde{h}_{\alpha\beta}{}^{,\rho}{}_{,\rho} + ...\text{etc}$$

Should be:

$$-\widetilde{h}_{\alpha\beta}{}^{,\rho}{}_{,\rho} + ...\text{etc}$$

(*Correction to be done:* insert minus in front of the first term)

Page 163, equation (13.16), was (E):

$$\kappa \overset{\text{mat}}{T}_{\alpha\beta} + \overset{\text{e-m}}{T}_{\alpha\beta}$$

Should be:

$$\kappa \left(\overset{\text{mat}}{T}_{\alpha\beta} + \overset{\text{e-m}}{T}_{\alpha\beta} \right)$$

(*Correction to be done:* insert parentheses)

Page 177, equation (14.47), first line, was (E):

$$\left(\frac{\mathrm{d}t}{\mathrm{d}s} \right)^2$$

Should be:

$$\left(\frac{\mathrm{d}t}{\mathrm{d}s}\right)^2$$

(*Correction to be done:* raise the exponent "2")

Page 192, equation (14.98), was (E):

$$\mathrm{e}^{\widetilde{q}/a} \qquad \text{and} \qquad \ln q$$

Should be:

$$\mathrm{e}^{-\widetilde{q}/a} \qquad \text{and} \qquad -\ln q$$

(*Correction to be done:* change sign in front of $\widetilde{q}/a$ and in front of $\ln q$)

Page 202, equation (14.112), was (C):

$$\left(E^2 - 1 + \frac{2m}{r}\right)_{1/2}$$

Should be:

$$\left(E^2 - 1 + \frac{2m}{r}\right)^{1/2}$$

(*Correction to be done:* raise $1/2$ to the exponent level)

Page 204, line 3 below equation (14.122), was:

$$\mathrm{e}^f(t)$$

Should be:

$$\mathrm{e}^{f(t)}$$

(*Correction to be done:* raise (t) to the exponent level)

Page 204, equation (14.125), was (E):

$$\sqrt{-g}$$

Should be:

$$\sqrt{g_3}$$

(*Correction to be done:* replace $-g$, the determinant of the spacetime metric, by g_3, the determinant of the metric of a 3-space of constant time)

Page 206, equation (14.131), was:

$$\frac{4\pi G}{3c^2}$$

Should be:

$$\frac{4\pi}{3c^2}$$

(*Correction to be done:* no G in the numerator)

Page 207, line 1 of the page, was (E):

$$g_{IJ,r}/N \text{ at } r = R, \text{ where } N = \sqrt{1 - 2GM/(c^2 R)}$$

Should be:

$$g_{IJ,r}/\mathcal{N} \text{ at } r = R, \text{ where } \mathcal{N} = 1/\sqrt{1 - 2GM/(c^2 R)}$$

(*Correction to be done:* change N to $\mathcal{N}$ in 2 places, the second $\mathcal{N}$ must be the inverse of what it was)

Page 207, line 2 of the page, was (E):

$$N = \sqrt{1 - DR^2}$$

Should be:

$$\mathcal{N} = 1/\sqrt{1 - DR^2}$$

(*Correction to be done:* change N to $\mathcal{N}$, the $\mathcal{N}$ must be the inverse of what it was)

Page 207, line below equation (14.137), was (E):

$g_{22,r}/N$ being equal on both sides of Σ, which implies N being

Should be:

$g_{22,r}/\mathcal{N}$ being equal on both sides of Σ, which implies $\mathcal{N}$ being

(*Correction to be done:* change N to $\mathcal{N}$ in 2 places)

Page 209, equation (14.152), second exponent in the numerator, was:

$$1 + 2\gamma {r_+}^2$$

Should be:

$$1 + 2\gamma {r_-}^2$$

(*Correction to be done:* r_- instead of r_+)

Page 210, second sentence below equation (14.156), was (E):

The image of the true singularity at $r = 0$ and the lines $r = \text{const}$ are still hyperbolae, given by equations of the form $\alpha^2 \left[(U + 1/\alpha)^2 - V^2\right] = 1$, where $\alpha = \text{const}$, see Exercise 13.

(*Correction to be done:* delete this whole sentence; what it says is not true)

Page 212, equation (14.158), the denominator of the first square root, was (C):

$$-2m'/r$$

Should be:

$$-2m/r'$$

(*Correction to be done:* prime on r, not on m)

Page 218, line 3 above equation (14.170), was (in 2 places):

$$\mu$$

Should be (in both places):

$$\gamma$$

Page 219, penultimate paragraph of Section 14.16, penultimate line, was:

Exercise 14

Should be:

Exercise 13

(*Correction to be done:* change the exercise number from 14 to 13)

Page 219, last paragraph of Section 14.16, last line, was:

Exercise 15

Should be:

Exercise 14

(*Correction to be done:* change the exercise number from 15 to 14)

Page 220, Exercise 6, line 4, was:

$$\epsilon$$

Should be:

$$\varepsilon$$

Page 221, Exercise 13 (E):

(*Correction to be done:* delete the whole exercise)

Comment: The thesis of the exercise is false.

Page 221, Exercises 14 and 15:

(*Correction to be done:* change the numbers of these exercises to 13 and 14, respectively)

Page 222, equation (15.3), was:

$$(\delta x)^2$$

Should be:

$$\delta x^2$$

(*Correction to be done:* no parentheses)

Page 223, line below equation (15.12), was:

$$\omega_{il}\delta x_l S$$

Should be:

$$\omega_{il}\delta x_l$$

(*Correction to be done:* delete S)

Page 225, second paragraph below equation (15.21), line 4, was:

$$h^{\alpha}{}_{\beta}\left(P_0\right)\delta x^{\alpha}$$

Should be:

$$h^{\alpha}{}_{\beta}\left(P_0\right)\delta x^{\beta}$$

(*Correction to be done:* β instead of α in the last superscript)

Page 226, first two (unnumbered) equations and equations (15.22), (15.23), was:

$$\delta_{\perp}x^{\beta}$$

Should be:

$$\delta_{\perp}x^{\rho}$$

(*Correction to be done:* ρ instead of β in 4 places)

Page 226, line 2 below equation (15.27), was:

(15.27)

Should be:

(15.26)

(*Correction to be done:* change equation number referred to)

Page 228, equation (15.41), first line, was:

$$u_{;\gamma\delta}$$

Should be:

$$u_{\gamma;\delta}$$

(*Correction to be done:* the semi-colon should be between the indices in the subscript, not in front of them, in two places)

Page 228, equation (15.41), first line, was (C) (E):

$$-\left(u^{\gamma}u_{;\gamma\delta}\right)$$

Should be:

$$-\left(u^{\gamma}u_{\gamma;\delta}\right)^{\cdot}$$

(*Correction to be done:* insert dot in the exponent behind the right parenthesis)

Page 233, equation (15.57), was:

$$\left(\mathcal{H}u_{\alpha}\right)_{\beta}-\left(\mathcal{H}u_{\beta}\right)_{\alpha}$$

Should be:

$$\left(\mathcal{H}u_\alpha\right)_{,\beta} - \left(\mathcal{H}u_\beta\right)_{,\alpha}$$

(*Correction to be done:* commas behind both right parentheses)

Page 237, equation (16.1) and the line below it, was:

$$\phi_0$$

Should be:

$$\phi$$

(*Correction to be done:* no subscript, in two places)

Page 246, line above equation (16.59), was (E):

$$C^s{}_{0s0} = 0$$

Should be:

$$C^s{}_{isj} = 0$$

(*Correction to be done:* two subscripts '0' changed to i and j)

Page 246, equation (16.59), first line, was (E):

$$-C_{0101} = C_{0213} + C_{0312} = -C_{2323}$$

Should be:

$$-C_{0101} = C_{0213} + C_{0312} = -C_{2323} = 0$$

(*Correction to be done:* insert '$= 0$' at the end)

Page 248, equation (16.77), was:

$$\left(k^\gamma m^\alpha k_{\alpha;\gamma}\right);_\beta \qquad \text{and} \qquad k_\alpha;_\gamma$$

Should be:

$$\left(k^\gamma m^\alpha k_{\alpha;\gamma}\right)_{;\beta} \qquad \text{and} \qquad k_{\alpha;\gamma}$$

(*Correction to be done:* both semi-colons should be at the subscript level)

Page 254, second line of main text from below, was:

$$r_S{}^2\delta\Omega_G/(4\pi)$$

Should be:

$$r_S{}^2\delta\Omega_G$$

(*Correction to be done:* delete $/(4\pi)$)

Page 300, line above equation (18.29), was (C):

$$\alpha(t) < \infty, \text{ implies}$$

Should be:

$\alpha(t) < \infty$ implies

(*Correction to be done:* delete the comma)

Page 301, equation (18.31), was:

$$\beta = \left(\frac{6}{\kappa\alpha}\right)^{1/3}$$

Should be:

$$\beta = \left(\frac{6}{\kappa\alpha c^2}\right)^{1/3}$$

(*Correction to be done:* insert c^2 in the denominator)

Page 301, line below equation (18.32), was:

$$\rho(t, r_c) = 0$$

Should be:

$$\epsilon(t, r_c) = 0$$

(*Correction to be done:* change ρ to ϵ)

Page 301, the segment of the text beginning with line 2 below equation (18.32) and ending with equation (18.34), was (E):

Note (from (18.20)) that (18.31) is always fulfilled when $E = 0$. For the other two models, from (18.19) and (18.21), Eq. (18.31) implies that

$$\beta(t) + O_0(M) = \begin{cases} -\dfrac{M^{2/3}}{2E}(1 - \cos\eta) & \text{for} \quad E < 0 \\ \\ \dfrac{M^{2/3}}{2E}(\cosh\eta - 1) & \text{for} \quad E > 0 \end{cases} \tag{18.33}$$

Thus, in order to allow for a well-defined value of η at $r = r_c$ (which is necessary for the density to have a well-defined value at the centre at all times), E must behave in the neighbourhood of the centre as

$$E = -CM^{2/3} + O_{2/3}(M), \qquad C\beta = 1 - \cos\eta(t, r_c). \tag{18.34}$$

Should be:

Note (from (18.20)) that (18.31) is always fulfilled when $E = 0$. For the other two models, defining

$$\gamma = \frac{1}{2}\beta_{,t}{}^2 - \frac{1}{\beta} + \frac{1}{6}\Lambda\beta^2 \tag{18.33}$$

we get from (18.14) $\gamma =$ constant and

$$E = \gamma M^{2/3} + O_{2/3}(M). \tag{18.34}$$

(*Correction to be done:* a complete replacement of the first segment by the second)

Comment: A well-defined value of η is not a necessary condition for the density to be well-defined. As a counterexample consider the evolution with $E > 0$ at such a location $r = r_{sl}$ where $M(r_{sl}) = 0$. With $\Lambda = 0$, eq. (18.14) gives $R(t, r_{sl}) = \pm\sqrt{2E}(t - t_B(r_{sl}))$, which agrees with the limit $M \to 0$ of (18.21), although $\eta \underset{r\to r_{sl}}{\longrightarrow} \pm\infty$.

Page 304, equation (18.41), line 2, was:

$$(2E)^{(3/2)}$$

Should be:

$$(2E)^{3/2}$$

(*Correction to be done:* delete parentheses in the exponent)

Page 304, equation (18.42), was (C):

arccosh

Should be:

arcosh

(*Correction to be done:* delete one of the two 'c'-s)

Comment: 'arc', short for Latin 'arcus', is correct only with the trigonometric functions. With the hyperbolic functions the inverses are called 'ar', short for Latin 'area'.

Page 311, line 5 above equation (18.70), was:

$$\varepsilon R_{,r} / \sqrt{1 + 2E} k^1$$

Should be:

$$\left(\varepsilon R_{,r} / \sqrt{1 + 2E}\right) k^1$$

(*Correction to be done:* add parentheses)

Page 316, equation (18.94), was:

$$(t - t_B)_{\mathrm{AH}^+}$$

Should be:

$$t_{\mathrm{AH}^+} - t_B$$

(*Correction to be done:* subscript $_{\mathrm{AH}^+}$ only at the first t)

Page 329, equation (18.126), was:

$$\ln(1 + z(r)) = \int_{r_{\mathrm{em}}}^{r_{\mathrm{obs}}} \frac{R_{,tr}\left(T(r), r\right)}{\sqrt{1 + 2E(r)}} \mathrm{d}r.$$

Should be:

$$\ln(1+z(r)) = \int_{r_{\rm obs}}^{r_{\rm em}} \frac{R_{,tr}\left(T(r),r\right)}{\sqrt{1+2E(r)}}\mathrm{d}r.$$

(*Correction to be done:* interchange the integration limits)

Page 333, equation (18.139) and the line above it, was:

$$g^{\mu\nu} n_{,\mu}\, n_{,\nu}$$

Should be:

$$g^{\mu\nu} n_{\mu} n_{\nu}$$

(*Correction to be done:* delete commas behind n, in 4 places)

Page 336, equation (18.148), first line, was (E):

$$4ar^{4/3}$$

Should be:

$$4ar^{1/3}$$

(*Correction to be done:* change exponent 4/3 to 1/3)

Page 338, equations (18.149), (18.150) – line 2, (18.151) and (18.153), was:

$$+\frac{1}{3}\Lambda R^2$$

Should be:

$$-\frac{1}{3}\Lambda R^2$$

(*Correction to be done:* change sign in front of $\frac{1}{3}\Lambda R^2$, 4 times)

Page 338, equation (18.150) – line 1, was:

$$-\frac{1}{3}\Lambda R^2$$

Should be:

$$+\frac{1}{3}\Lambda R^2$$

(*Correction to be done:* change sign in front of $\frac{1}{3}\Lambda R^2$)

Page 351, line below equation (18.179), was (E):

$$\epsilon_{,r}\,/\epsilon \underset{\eta\to 0}{\longrightarrow} +\infty$$

Should be:

$$\epsilon_{,r}\,/\epsilon \underset{\eta\to 0}{\longrightarrow} 0$$

(*Correction to be done:* replace $+\infty$ by 0)

Page 365, Exercise 12, line 1, was (E):

is invariant

Should be:

is conformally invariant

(*Correction to be done:* insert the word 'conformally')

Page 367, line above equation (19.1), was:

$$(x, y, z)$$

Should be:

$$(x, y)$$

(*Correction to be done:* delete ", z")

Page 367, first line of equation (19.1), was:

$$(x', y', z') = (x + a_1, y, z), \qquad (x', y', z') = (x, y + a_2, z),$$

Should be:

$$(x', y') = (x + a_1, y), \qquad (x', y') = (x, y + a_2),$$

(*Correction to be done:* delete ", z" in 2 places and ", z'" in 2 places)

Page 367, second line of equation (19.1), was:

$$(x', y', z') = (x\cos a_3 + y\sin a_3, -x\sin a_3 + y\cos a_3, z)\,,$$

Should be:

$$(x', y') = (x\cos a_3 + y\sin a_3, -x\sin a_3 + y\cos a_3)\,,$$

(*Correction to be done:* delete ", z" and ", z'")

Page 382, line 2 of second paragraph of subsection 19.3.5, was (E):

$$\sqrt{-g}$$

Should be:

$$\sqrt{g_3}$$

(*Correction to be done:* replace $-g$, the determinant of the spacetime metric, by g_3, the determinant of the metric of a 3-space of constant time)

Page 385, equation (19.99), was (E):

$$\mathrm{e}^{A/2}\mathrm{d}r^2$$

Should be:

$$\mathrm{e}^{A}\mathrm{d}r^2$$

(*Correction to be done:* change exponent $A/2$ to A)

Page 388, beginning of line 2, was:

$$-\kappa p$$

Should be:

$$\kappa p$$

(*Correction to be done:* delete the minus)

Page 388, end of line 2, was:

$$\kappa p = -\Lambda$$

Should be:

$$\kappa p = \Lambda$$

(*Correction to be done:* delete the minus)

Page 388, line 3, was:

$$\kappa\widetilde{\epsilon} + \Lambda$$

Should be:

$$\kappa\widetilde{\epsilon} - \Lambda$$

(*Correction to be done:* change sign in front of Λ)

Page 390, equation (19.133), was:

$$\left(\mathrm{e}^{-\nu}\sigma\right)_{\xi\xi} = \left(\mathrm{e}^{-\nu}\sigma\right)_{\overline{\xi}\overline{\xi}} = 0$$

Should be:

$$\left(\mathrm{e}^{-\nu}\sigma\right)_{,\xi\xi} = \left(\mathrm{e}^{-\nu}\sigma\right)_{,\overline{\xi}\overline{\xi}} = 0$$

(*Correction to be done:* insert commas before subscripts, 2 times)

Page 392, line 6 from the end of subsection 19.5.1 up, was:

$$\kappa p = -\Lambda$$

Should be:

$$\kappa p = \Lambda$$

(*Correction to be done:* delete the minus)

Page 394, line 6 below equation (19.150), was:

$$\kappa p = -\Lambda$$

Should be:

$$\kappa p = \Lambda$$

(*Correction to be done:* delete the minus)

Comment: All the changes on page 395 resulted from correcting the same error: with ℓ as defined before, the case $1/h^2 + k < 0$ was not covered.

Page 395, middle of line 5, was (E):

$$\ell^2 \stackrel{\text{def}}{=} 1/h^2 + k \neq 0$$

Should be:

$$g \stackrel{\text{def}}{=} 1/h^2 + k \neq 0$$

(*Correction to be done:* change ℓ^2 to g)

Page 395, end of line 5, was (E):

$$A = |\ell(z)|/(2S)$$

Should be:

$$A = \sqrt{|g|}/(2S)$$

(*Correction to be done:* change $|\ell(z)|$ to $\sqrt{|g|}$)

Page 395, line 6, was (E):

$-|\ell(z)|P/(2S)$, $B_2 = -|\ell(z)|Q/(2S)$, $\varepsilon \stackrel{\text{def}}{=} \ell/|\ell|$ and redefining Φ by $\Phi = \widetilde{\Phi}|\ell(z)|$, we can

Should be:

$-\sqrt{|g|}P/(2S)$, $B_2 = -\sqrt{|g|}Q/(2S)$, $\varepsilon \stackrel{\text{def}}{=} g/|g|$, and redefining Φ by $\Phi = \widetilde{\Phi}\sqrt{|g|}$ and k by $k = |g|\widetilde{k}$, we can

(*Correction to be done:* replace $|\ell|$ by $\sqrt{|g|}$ (3 times), replace $\ell/|\ell|$ by $g/|g|$, insert the redefinition of k at the end)

Page 395, line 1 of equation (19.152), was (E):

$$\mathrm{e}^{-\nu} \stackrel{\text{def}}{=} \mathcal{E} = \frac{S}{2}\text{...etc}$$

Should be:

$$\mathrm{e}^{-\nu} = \sqrt{|g|}\mathcal{E}, \qquad \mathcal{E} \stackrel{\text{def}}{=} \frac{S}{2}\text{...etc}$$

(*Correction to be done:* insert $\sqrt{|g|}$ in front of $\mathcal{E}$, split the double equation into two independent ones, the defining equation is now to the right of $\mathcal{E}$)

Page 395, line 1 below equation (19.152), was (E):

$$\ell = 0$$

Should be:

$$g = 0$$

(*Correction to be done:* replace ℓ by g)

Page 395, the footnote at the bottom, was (E):

The Φ in (19.152) is in fact $\widetilde{\Phi}$, the $\mathrm{e}^{-\nu}$ is $\mathrm{e}^{-\widetilde{\nu}} \stackrel{\text{def}}{=} \mathrm{e}^{-\nu}/|\ell|$, and the $k(z)$ is $\widetilde{k}(z) \stackrel{\text{def}}{=} k(z)/\ell^2$.

Should be:

The Φ in (19.152) is in fact $\widetilde{\Phi}$ and the $k(z)$ is $\widetilde{k}(z)$.

(*Correction to be done:* a complete replacement of the old text by the new one)

Page 397, line 10, was (E):

$$g(z) = (AC - {B_1}^2 - {B_2}^2)$$

Should be:

$$g(z) = 4(AC - {B_1}^2 - {B_2}^2)$$

(*Correction to be done:* insert coefficient 4 on the r.h.s.; for consistency with the definition of g on page 395)

Page 399, line above equation (19.157), was:

$$\kappa p = -\Lambda$$

Should be:

$$\kappa p = \Lambda$$

(*Correction to be done:* delete the minus)

Page 399, equation (19.157), was:

$$+\frac{1}{3}\Lambda\Phi^2$$

Should be:

$$-\frac{1}{3}\Lambda\Phi^2$$

(*Correction to be done:* change sign in front of $\frac{1}{3}\Lambda\Phi^2$)

Page 399, equation (19.158), was:

$$-\frac{1}{3}\Lambda\lambda\Phi^2$$

Should be:

$$+\frac{1}{3}\Lambda\lambda\Phi^2$$

(*Correction to be done:* change sign in front of $\frac{1}{3}\Lambda\lambda\Phi^2$)

Page 399, line above equation (19.160), was:

$$\epsilon = \widetilde{\epsilon} - \Lambda$$

Should be:

$$\kappa\epsilon = \kappa\widetilde{\epsilon} - \Lambda$$

(*Correction to be done:* replace ϵ by $\kappa\epsilon$, and the same for $\widetilde{\epsilon}$)

Page 399, line 4 below equation (19.160), was:

large positive Λ

Should be:

large absolute value of negative Λ

Page 399, line 5 from below, was:

$$\Lambda > 0$$

Should be:

$$\Lambda < 0$$

(*Correction to be done:* replace $>$ by $<$)

Page 400, line above equation (19.161), was:

$$\kappa p = -\Lambda$$

Should be:

$$\kappa p = \Lambda$$

(*Correction to be done:* delete the minus)

Page 400, equation (19.161), was:

$$+\frac{1}{3}\Lambda\Phi^2$$

Should be:

$$-\frac{1}{3}\Lambda\Phi^2$$

(*Correction to be done:* change sign in front of $\frac{1}{3}\Lambda\Phi^2$)

Page 400, line above equation (19.162), was:

$$\widetilde{\epsilon} = \epsilon - \Lambda$$

Should be:

$$\kappa\widetilde{\epsilon} = \kappa\epsilon - \Lambda$$

(*Correction to be done:* replace ϵ by $\kappa\epsilon$, and the same for $\widetilde{\epsilon}$)

Page 401, equation (19.163), was (E):

$$(-g)^{1/2}$$

Should be:

$$\sqrt{g_3}$$

(*Correction to be done:* replace $-g$, the determinant of the spacetime metric, by g_3, the determinant of the metric of a 3-space of constant time, and replace the exponent 1/2 by the square root)

Comment: The changes within subsection 19.6.3 (pages 402 – 403) resulted from correcting an insufficiently general design of the limiting transition. The earlier design was meant to be an improvement of that of Hellaby (1996b), as explained in footnote 1 on page 402. However, it did not reproduce the $\beta_{,z} = 0$ limit in the general parametrisation (limitations on U or W resulted), and, in consequence, the limit $k \to 0$ was not covered. The key change is the assumption $\lim_{k\to\varepsilon}(1/h^2)_{,z}/\sqrt{\varepsilon - k} = 0$ (see below).

Page 402, lines 1 – 3, was (E):

Equation (19.147) does not in fact put any limitations on the functions A, B_1, B_2 and C; given A, B_1, B_2, C and k it simply defines the function $h(z)$. Choose the arbitrary functions in (19.150) and (19.161) as follows

Should be:

In the $\beta_{,z} = 0$ family the parameter g determining the type of quasi-symmetry, defined above (19.152), coincides with the parameter k determining the type of evolution, and both are constant. Thus, the limit will be $k \to g \to \varepsilon =$ constant. We assume that k tends to g sufficiently fast so that $1/h^2 = g - k$ defined in (19.147) has the property $\lim_{k\to\varepsilon}(1/h^2)_{,z}/\sqrt{\varepsilon - k} = 0$. We choose the arbitrary functions in (19.150) and (19.161) as follows

(*Correction to be done:* a complete replacement of the old text by the new one)

Page 402, line 1 of equation (19.164), was (E):

$$+\frac{1}{4}k$$

Should be:

$$+\frac{1}{4}\varepsilon$$

(*Correction to be done:* replace k by ε)

Page 402, line 4 of equation (19.164), was (E):

$$M = \int X(z)\sqrt{\varepsilon - k}\,\mathrm{d}z + M_0$$

Should be:

$$M = -\int X(z)\sqrt{\varepsilon - k}\,\mathrm{d}z + M_0$$

(*Correction to be done:* change sign in front of the integral (this is a change of sign of X))

Page 402, line 5 of equation (19.164) (E):

[delete the first equation in this line that said $h = 1/\sqrt{\varepsilon - k}$]

Page 402, lines 1 – 3 below equation (19.164) (E):

[delete the second sentence in these lines that said 'We will take the limit $k \to \varepsilon$ of all these quantities, but first we must check what happens with the other quantities entering the metric under such a reparametrisation.']

Page 402, equation (19.165), was (E):

$$\lim_{k\to\varepsilon}\left(-\frac{\nu_{,z}}{\sqrt{\varepsilon - k}}\right) = \mathcal{E}_0.$$

Should be:

$$\lim_{k\to\varepsilon}\left(-\frac{\nu_{,z}}{\sqrt{\varepsilon - k}}\right) = \frac{\mathcal{E}_0}{\mathcal{E}_1}.$$

(*Correction to be done:* replace $\mathcal{E}_0$ by $\mathcal{E}_0/\mathcal{E}_1$)

Page 402, line 2 of equation (19.166), was (E):

$$\frac{M_{,z}}{\sqrt{\varepsilon - k}} \to X(z)$$

Should be:

$$\frac{M_{,z}}{\sqrt{\varepsilon - k}} \to -X(z)$$

(*Correction to be done:* change sign in front of X)

Page 402, line 3 of equation (19.166), was (E):

$$\frac{k_{,z}}{\sqrt{\varepsilon - k}} \to -2(U + \varepsilon W).$$

Should be:

$$\frac{(1/h^2)_{,z}}{\sqrt{\varepsilon - k}} \to 0, \qquad \frac{k_{,z}}{\sqrt{\varepsilon - k}} \to 2(U + \varepsilon W)$$

(*Correction to be done:* insert the first equation, change sign of the r.h.s. in the second one, delete the full stop at the end of the equation)

Page 402, line below equation (19.166), was (E):

Knowing this, we define

Should be:

(the last limit follows from (19.147) differentiated by z). Then we define

(*Correction to be done:* a complete replacement of the old text by the new one)

Page 402, equation (19.167), was (E):

$$\lim_{k\to\varepsilon}\frac{\Phi_{,z}}{\sqrt{\varepsilon - k}} \stackrel{\text{def}}{=} \lambda(t, z)$$

Should be:

$$\lim_{k\to\varepsilon} \frac{\Phi_{,z}}{\sqrt{\varepsilon - k}} \stackrel{\text{def}}{=} -\lambda(t,z)$$

(*Correction to be done:* change sign in front of λ)

Page 403, equation (19.168), was (E):

$$\mathrm{d}s^2 = \mathrm{d}t^2 - \left(\lambda - \Phi_1\mathcal{E}_1/\mathcal{E}_0\right)^2 \mathrm{d}z^2 - \left(\Phi_1/\mathcal{E}_0\right)^2 \left(\mathrm{d}x^2 + \mathrm{d}y^2\right)$$

Should be:

$$\mathrm{d}s^2 = \mathrm{d}t^2 - \left(\lambda + \Phi_1\mathcal{E}_0/\mathcal{E}_1\right)^2 \mathrm{d}z^2 - \left(\Phi_1/\mathcal{E}_1\right)^2 \left(\mathrm{d}x^2 + \mathrm{d}y^2\right)$$

(*Correction to be done:* change sign in front of the first Φ_1 and interchange $\mathcal{E}_0$ with $\mathcal{E}_1$)

Page 403, the two lines below equation (19.169), was (E):

Using this and (19.167) we can verify that the explicit solution for λ that results from (19.169) in the limit $k \to \varepsilon$ coincides with (19.101).

Should be:

Using this and (19.167) we can verify that the explicit solution for e^α implied via (19.137) in the spherically symmetric case ($U = kW$, $V_1 = V_2 = 0$, $k \to \varepsilon = 1$) coincides with (19.101) (with (X, Y) of (19.101) replaced by $(X/M_0 + 6W, t_1)$).

(*Correction to be done:* a complete replacement of the old text by the new one)

Page 403, equation (19.170), was:

$$\Phi\mathcal{E}_z/\mathcal{E}$$

Should be:

$$\Phi\mathcal{E}_{,z}/\mathcal{E}$$

(*Correction to be done:* insert comma in front of the subscript)

Page 403, line below equation (19.171):

[Insert footnote mark at the end of this line, and insert a footnote at the bottom of the page, saying:]

The M in (19.171) is in fact $\widetilde{M} = (|g|)^{3/2}M$; the tilde was dropped for better readability.

Page 409, equation (19.207), was:

$$6M/R^3$$

Should be:

$$6M/\Phi^3$$

(*Correction to be done:* replace R by Φ)

Page 414, equation (19.241), was:

$$\frac{\chi^2}{1-k}...\text{etc}$$

Should be:

$$\frac{{\chi_1}^2}{1-k}...\text{etc}$$

(*Correction to be done:* replace χ by χ_1)

Comment: The definition of D actually used in equations (19.244) and following was the corrected one given below.

Page 415, the first five lines including equation (19.243), was (E):

Now define $D \stackrel{\text{def}}{=} \sqrt{1-k} - \sqrt{2M/\Phi - k}$. Then $(D > 0) \Longleftrightarrow (\Phi > 2M)$. Since $M/\Phi > 0$, we see that $D \geq 1$ leads to a contradiction, and hence $D < 1$, but $D < -1$ is not prohibited. We have

$$(D < -1) \Longrightarrow \left[\Phi < M/\left(1 + \sqrt{1-k}\right)\right]. \tag{19.243}$$

This will always occur when Φ is close to the Big Bang/Big Crunch.

Should be:

Now define

$$D \stackrel{\text{def}}{=} \sqrt{\frac{1-k}{2M/\Phi - k}} - 1. \tag{19.243}$$

Then $(D > 0) \Longleftrightarrow (\Phi > 2M)$ and $D > -1$.

(*Correction to be done:* a complete replacement of the first segment by the second)

Page 416, line 3 above equation (19.251), was:

$$r = \text{const}$$

Should be:

$$z = \text{const}$$

(*Correction to be done:* replace r by z)

Page 416, equation (19.252), was:

$$-\Phi\mathcal{E}_{,z}/\mathcal{E}$$

Should be:

$$-\ell j\Phi\mathcal{E}_{,z}/\mathcal{E}$$

(*Correction to be done:* insert ℓj in front of this term)

Page 420, line 7 below equation (19.266), was:

$$r = \text{constant}$$

Should be:

$$z = \text{constant}$$

(*Correction to be done:* replace r by z)

Page 426, equation (19.301), was:

$$\theta = 3S_{,t}\,/S - F/H, \qquad 2\sigma_{11} = 2\sigma_{22} = -\sigma_{33} = 2F/(3H). \tag{19.301}$$

Should be:

$$\theta = 3S_{,t}\,/S - F_{,t}\,/H, \qquad 2\sigma^1{}_1 = 2\sigma^2{}_2 = -\sigma^3{}_3 = 2F_{,t}\,/(3H). \tag{19.301}$$

(*Correction to be done:* replace F by $F_{,t}$ in two places, raise the first index of the shear tensor in three places)

Page 426, line 8 after equation (19.301), was:

When $\beta(z_0) > 0$

Should be:

When $\beta_-(z_0) > 0$

(*Correction to be done:* add the subscript "$-$" to β.)

Page 426, first line of subsection 19.9.1, was:

$$\beta' = 0$$

Should be:

$$\beta_{,z} = 0$$

(*Correction to be done:* replace the prime by $_{,z}$)

Page 430, line 2 below equation (19.316), was:

$$\varepsilon = 3p$$

Should be:

$$\epsilon = 3p$$

(*Correction to be done:* replace ε by ϵ)

Page 441, equation (20.17), second equation in each line, was:

$$\ell_\alpha =$$

$$m_\alpha =$$

$$\overline{m}_\alpha =$$

Should be:

$$\ell_\alpha \mathrm{d}x^\alpha =$$
$$m_\alpha \mathrm{d}x^\alpha =$$
$$\overline{m}_\alpha \mathrm{d}x^\alpha =$$

(*Correction to be done:* insert $\mathrm{d}x^\alpha$ in front of each equality sign)

Page 443, first line of equation (20.25) and first line of equation (20.28), was:

$$Y_{u\rho}$$

Should be:

$$Y_{,u\rho}$$

(*Correction to be done:* insert comma in front of the subscripts at Y, 2 times)

Page 443, first line of equation (20.25), equation (20.27) and second line of equation (20.28), was:

$$\overline{Y}_{u\rho}$$

Should be:

$$\overline{Y}_{,u\rho}$$

(*Correction to be done:* insert comma in front of the subscripts at $\overline{Y}$, 3 times)

Page 444, equation (20.34), was:

$$B\phi_u$$

Should be:

$$B\phi_{,u}$$

(*Correction to be done:* insert comma in front of the subscript)

Page 449, line 3 of equation (20.56), was:

$$-a^2$$

Should be:

$$+a^2$$

(*Correction to be done:* change sign in front of a^2)

Page 459, equation (20.95), was:

$$-2mr\cos\vartheta$$

Should be:

$$-2mr$$

(*Correction to be done:* delete $\cos\vartheta$)

Page 507, the reference to Hellaby and Lake (1985), was:

Shell crossings an the Tolman model

Should be:

Shell crossings and the Tolman model

(*Correction to be done:* replace 'an' with 'and')