Errata of the book "Gravitational Waves. Vol. 1"

Last update: Apr. 24, 2022.

Note: Corrections with a date earlier then Dec. 2013 have been implemented in the version that has been reprinted in Dec. 2013.

A. Significant corrections

- Page 82, eq. (2.125), "$\lambda_g > 300 h_0$ kpc" should read "$\lambda_g > 300 h_0^{-1}$ kpc" and, in eq. (2.126), "$m_g < 2 \times 10^{-29} h_0^{-1}$ eV" should read "$m_g < 2 \times 10^{-29} h_0$ eV". Four lines above eq. (2.125), "$(1-10)h_0$ Mpc" should read "$(1-10)h_0^{-1}$ Mpc".

  (11/11/13).

- Sect. 3.3.5, pages 121-124. The discussion in this section is not correct. The energy-momentum tensor given in eq. (3.121) is valid only for free particles, and is conserved only if all $\dot{p}^i_A = 0$ for all particles. A priori, evaluating it on a pre-assigned trajectory such as the circular orbit of a binary system, is therefore not consistent. When we take into account the interaction, in a post-Newtonian expansion $T^{\mu\nu}$ must be replaced by $\tau^{\mu\nu}$, which also contains potential terms, see e.g. (5.111)-(5.113), that ensure its conservation on the trajectories determined by the same potential. What allows us to use consistently the free-particle energy-momentum tensor to compute the mass quadrupole radiation for a binary system in a bound orbit is the fact that for a self-gravitating system the interaction terms, such as the gravitational potential $-Gm_1m_2/r$, are $O(v^2)$. Since the mass quadrupole M^{ij} is obtained from T^{00}, and T^{00} is $O(v^0)$, to lowest order the terms $O(v^2)$ generated by the interaction can be neglected when we compute mass quadrupole radiation (and, to lowest order in the PN expansion, the conservation equation $\partial_0 T^{00} + \partial_i T^{0i} = 0$ is satisfied independently of the trajectory). The same is true for mass octupole and current quadrupole radiation.

  (27/12/11. Thanks to N. Johnson-McDaniel).

  The correct text that replaces pages 121-124 in the revised printing is available as the file pages121-124.pdf, on the errata web page.

- Page 123, eq. (3.127). The second term in the last line is not there, and the correct result is:

$$M^{ij} = m x^i_{CM} x^j_{CM} + \mu x^i_0 x^j_0$$

The discussion below this equation is therefore not correct. The correct statement is that, if the system is closed, x_{CM} is independent of time, and does not contribute to GW production.

(09/12/11. Thanks to T. Schoenenbach)

Again, the correct text is available in the file pages121-124.pdf

- Page 126, eq. (3.142). In the expression for M^{ijk} is missing a factor $\delta m/m$, where $\delta m = m_2 - m_1$ and $m = m_1 + m_2$. It is derived observing that, in the CM frame, the positions of the two bodies are $\mathbf{x}_1 = +(m_2/m)\mathbf{x}$ and $\mathbf{x}_2 = -(m_1/m)\mathbf{x}$. Therefore

$$T^{00}(t, \mathbf{x}) = m_1 c^2 \delta^{(3)} \left(\mathbf{x} - \frac{m_2}{m} \mathbf{x}_0(t) \right) + m_2 c^2 \delta^{(3)} \left(\mathbf{x} + \frac{m_1}{m} \mathbf{x}_0(t) \right) ,$$

and

$$\begin{aligned} M^{ijk}(t) &= \frac{1}{c^2} \int d^3x \, T^{00}(t, \mathbf{x}) x^i(t) x^j(t) x^k(t) \\ &= \mu \frac{\delta m}{m} x^i_0(t) x^j_0(t) x^k_0(t) \, . \end{aligned}$$

(27/12/11).

- Page 127-128. A double dot is missing over all occurrences of $J^{p,l}$ in eqs. (3.151)

(06/09/10. Thanks to E. Mitsou),

and a triple dot is missing over all occurrences of $J^{p,l}$ in (3.152)

(12/06/13. Thanks to L. Philippoz).

- Page 139, eq. (3.211). In the third line, the term $\epsilon_{ijk} S^{(l+1)}_{jL-1}(u) S^{(l+1)}_{kL-1}(u)$ should read $\epsilon_{ijk} M^{(l+1)}_{jL-1}(u) S^{(l+1)}_{kL-1}(u)$.

(05/05/21. Thanks to K. Fransen).

- Page 161-162. In the solution of Problem 3.3 there is a conceptual error: the quantity $\dot{S}^{kl,m}$ that gives the sum of the mass octupole plus current quadrupole cannot be computed consistently using the energy-momentum tensor of the free particle and neglecting the contribution from the gravitational potential, as done in the text. The reason is that $S^{kl,m}$ is given by the spatial components T^{kl} of the energy-momentum tensor, which are $O(v^2)$ and therefore, for a self-gravitating system, they are of the same order as the interaction term due to the gravitational potential. In contrast, the mass octupole and the current quadrupole *can* be computed neglecting the potential terms, since they are obtained from T^{00} and T^{0i}, respectively. Since $T^{00} = O(v^0)$ and $T^{0i} = O(v)$, the contribution of the gravitational potential to the mass octupole and to the current quadrupole is of higher order in v/c. The correct calculation should then be performed as follows: (1) starting from eq. (3.34), transform S^{kl} and $\dot{S}^{kl,m}$ into the mass quadrupole, mass octupole and current quadrupole using (3.52) and (3.54). Since the derivation of these equations makes use of the exact energy-momentum conservation, here the gravitational potential terms in $T^{\mu\nu}$ are automatically taken into account. Then (2): compute the mass quadrupole, mass octupole and current quadrupole using the free-particle energy-momentum tensor, since here the inclusion of the gravitational potential term would give a higher-order contribution. It is instead incorrect to use the free-particle energy-momentum tensor directly into $\dot{S}^{kl,m}$. Unfortunately, in Problem 3.3, after correctly computing the mass octupole radiation, I computed the current quadrupole radiation by evaluating first the contribution from $\dot{S}^{kl,m}$ with the free-particle energy-momentum tensor (which is wrong) and subtracting from it the mass octupole. Once the computation is performed correctly one finds that the current quadruple radiates only at the frequency ω_s (rather than at ω_s and at $3\omega_s$, as the mass octupole). Furthermore, one recovers exactly the result obtained in Eqs. (5.266-5.267) from the full relativistic Blanchet-Damour approach (the reason being that also the relativistic corrections to the orbit are of higher order).

  (27/12/2011. Thanks to N. Johnson-McDaniel)

  A revised version of this Problem can be found in the file pages161-162.pdf, in the errata web page.

- Page 163, eq. (3.354), "$\mathbf{3} \oplus \mathbf{2} \oplus \mathbf{2} \oplus \mathbf{1}$" should be "$\mathbf{3} \oplus \mathbf{2} \oplus \mathbf{2} \oplus \mathbf{0}$".

  (4/12/13).

- Page 172, second line, "$R_0^2 = ...$" should be "$R_0^3 = ...$".

  (25/12/2021. Thanks to Emmanuele Battista)

- Page 194, 6 lines above the end of the section, "Up to distances of order 600 Mpc" should read "Up to distances of order 25 Mpc".

  (13/6/08).

- Page 201, eq. (4.211), in the second line "$1 + \ldots$"should read "$(I_1 + I_2)/2 + \ldots$" and, in eq. (4.213), "$1 - \ldots$"should read "$(I_1 + I_2)/2 - \ldots$"

  (22/11/10. Thanks to J. Romano and M. Normandin)

- Page 245, eq. (5.47). The correct expression for the energy-momentum tensor of a set of free particles in curved space is

  $$T^{\mu\nu} = \frac{1}{\sqrt{-g}} \sum_a m_a \frac{d\tau_a}{dt} \frac{dx_a^\mu}{d\tau_a} \frac{dx_a^\nu}{d\tau_a} \, \delta^{(3)}(\mathbf{x} - \mathbf{x}_a(t)) \, ,$$

  where $c^2 d\tau_a^2 = -g_{\mu\nu} dx_a^\mu dx_b^\mu$.

  (4/12/13)

- Page 246, eq. 5.50, "$2\phi c^2$" should read "ϕc^2".

  (9/7/08)

- Page 246, three lines below eq. 5.52: "The total action of the system is the sum over all particles, ...". Actually, one must also add the contribution from the Einstein-Hilbert action. A detailed explicit derivation (provided by Justin Vines) can be found in the file EIHLagrangian.pdf, on the errata web page.

  (22/3/17. Thanks to J. Vines)

- Page 318, eq. (6.67). In the last term in square bracket "$-Gm/r$", should read "$+Gm/r$".

  (10/6/08. Thanks to S. Foffa)

- Page 344, eq. (7.43). In the first two lines, $\hat{s}(t)$ should be $\hat{s}$ ($\hat{s}$ is a quantity already integrated in time, see eq. (7.41), and no longer depends on t).

  (18/3/16)

B. Minor typos

- Page 7, in eq. (1.23), d^4x should read d^4y.

  (08/07/13. Thanks to Y. Lay)

- Page 7, after eq. (1.26), "$(1/c^2)\partial_0^2$" should read "∂_0^2".

  (29/03/10. Thanks to J. Enander)

- Page 12, first line "Problem 1.1" should read "Problem 2.1".

  (27/12/2011. Thanks to N. Johnson-McDaniel).

- Page 18, eq. (1.81), $d\xi^i/d\tau$ should be $d\xi^j/d\tau$.

  (22/10/2023).

- Page 33, eq. (1.123). On the right-hand side, $\bar{T}^{\mu\nu}$ should be $\bar{T}_{\mu\nu}$ (lower indices, as in the other terms of the equation). One line above the equation, again $\bar{T}^{\mu\nu}$ should be $\bar{T}_{\mu\nu}$, and one line below, $\bar{T} = \bar{g}_{\mu\nu}\bar{T}^{\mu\nu}$ should be $\bar{T} = \bar{g}^{\mu\nu}\bar{T}_{\mu\nu}$ and "by definition, $\bar{T}^{\mu\nu}$..." should read "by definition, $\bar{T}_{\mu\nu}$...".

  Since in this section we are writing everywhere the Einstein equations with lower indices, we need to define a smoothed energy-momentum tensor $\bar{T}_{\mu\nu}$ with lower indices. One can similarly define $\bar{T}^{\mu\nu}$ by writing eq. (1.123) with all upper indices. Note that, since $\bar{g}^{\mu\nu}$ only has low frequencies, it can be carried inside the average in eq. (1.123), and therefore $\bar{T}^{\mu\nu} = \bar{g}^{\mu\rho}\bar{g}^{\nu\sigma}\bar{T}_{\rho\sigma}$.

  (18/6/2019. Thanks to Yuntao Bai for a question that stimulated this correction)

- Page 36, after eq. (1.135), "$\partial_t = (1/c)\partial_0$" should read "$\partial_t = c\partial_0$"

  (29/03/10. Thanks to J. Enander)

- Page 37, second line : “to trow it” should read to “throw it”

  (12/06/13. Thanks to L. Philippoz)

- Page 68, end of note 11 : “where $\mathbf{x}_2 - \mathbf{x}_2 = \mathbf{x}$” should read “where $\mathbf{x}_2 - \mathbf{x}_1 = \mathbf{x}$”

  (12/06/13. Thanks to L. Philippoz)

- Page 82. The reduced Compton wavelength $1/m_g$ is sometimes denoted λ_g and sometimes $\lambdabar_g$.

  (4/12/13).

- Page 85, two lines below eq. (2.134), “two solution” should read “two solutions”

- Page 92, eq. (2.173), $\delta\theta^2$ should be $d\theta^2$.

  (4/12/13).

- Page 96, line after eq. (2.189) : “the matrix whole elements” should read “ the matrix whose elements”

  (12/06/13. Thanks to L. Philippoz)

- Page 106, eq. (3.30): the derivatives are with respect to t, not with respect to $x_0 = ct$.

  (09/12/11. Thanks to T. Schoenenbach)

- Page 121, footnote 24: “Straumann (2003)” should be “Straumann (2004)”

  (12/06/13. Thanks to T. Schoenenbach).

- Page 122, eq. (3.123), $\int d^3x\, x^i x^i (...)$ should be $\int d^3x\, x^i x^j (...)$

  (12/06/13. Thanks to L. Philippoz)

- Page 149, two lines after eq. (3.273), “$\mathbf{T}^{E2}_{lm}$ and $\mathbf{T}^{E2}_{lm}$” should read “$\mathbf{T}^{E2}_{lm}$ and $\mathbf{T}^{B2}_{lm}$”

  (23/11/14).

- Page 186, eq. (4.120), the first equality "$L = ma^2\omega_0 = ...$" should read "$L = \mu a^2\omega_0 = ...$".

  (13/3/12. Thanks to S. Dinkgreve).

- Page 208, six lines below eq. (4.252), the letter "i" should actually be a iota, $0 \leq \iota \leq \pi$.

  (12/06/13. Thanks to L. Philippoz)

- Pag 221, caption of 4.19, "the the star" should be "the star"

  (4/12/13).

- Page 241, eq. (5.11), dt^2 should be c^2dt^2. The same in Note 10.

  (19/08/13).

- Page 245, eq. (5.48): $\sum_i {}^{(2)}g_{ij}$ should read $\sum_i {}^{(2)}g_{ii}$.

  (11/01/2012. Thanks to N. Johnson-McDaniel)

- Page 246, eqs. (5.56): in all previous equations, eg. (5.49)–(5.52), I used $\sum_{a\neq b}$ as a compact notation for the sum over a *and* over b, with the condition $a \neq b$. In the third term in eq. (5.56), I wrote instead explicitly $\sum_a \sum_{b\neq a}$. For consistency, it should have been written more simply as $\sum_{a\neq b}$, as in the other similar occurrences.

  (11/04/2022. Thanks to Emmanuele Battista)

- Page 252, 13th line before the end : "the GWs compute at" should read "the GWs computed at"

  (12/06/13. Thanks to L. Philippoz)

- Page 267, line after eq.(5.145) : Λ_{ijab} should be $\Lambda_{ij,ab}$

  (12/06/13. Thanks to L. Philippoz)

- Page 275. In the subtitle to 5.3.5, "Radiation radiation" should read "Radiation reaction".

  (08/05/12. Thanks to T. Schoenenbach).

- Page 275. In the sentence below eq. (5.180), "up to second in v/c" should read "up to second order in v/c".

  (08/05/12. Thanks to T. Schoenenbach).

- Page 281. In eq. (5.199) "m!" should be "l!"

  (08/05/12. Thanks to T. Schoenenbach).

- Page 286, 4th line after eq. (5.224) : "expecially " should read "especially"

  (12/06/13. Thanks to L. Philippoz)

- Page 301, fourth bullet point: "Scäfer" should be "Schäfer"

  (12/06/13. Thanks to T. Schoenenbach, and my apologies to Gerhard Schäfer).

- Pag. 304-330, in the header of the left pages "[...] incompact binaries" should be "[...] in compact binaries" (a weird LaTeX bug).

  (4/12/13)

- Page 305, 9th line before the end: "which can very dramatically" should read "which can vary dramatically"

  (12/06/13. Thanks to L. Philippoz)

- Page 317. In eqs. (6.62) and (6.64) Δ_R should be replaced by $c\Delta_R$.

  (13/3/12. Thanks to S. Dinkgreve).

- Page 320. In eq. (6.90) Δ_R should be replaced by $c\Delta_R$ (while eq. (6.95) is correct since Δ_S and $r \equiv Gm/c^3$ both have dimensions of time)

  (13/3/12 and 12/6/13. Thanks to S. Dinkgreve and L. Philippoz).

- Page 331, 5th point of the Further reading section: "This corrections" should be "This correction"

  (12/06/13. Thanks to T. Schoenenbach).

- Page 351, note 17, "multipole detectors" should be "multiple detectors"

  (27/04/20)

- Page 388, line 2, "esplicitly'" should be "explicitly"

  (26/05/20. Thanks to Pau Amaro Seoane).

- Page 391, eq. (7.183), $f_0^{-4/3}$ should read $f_0^{-2/3}$.

  (19/12/16. Thanks to Yota Watanabe).

- Page 471, two lines below eq. (9.3), "$2L_x = \dots$" should read "$2L_y = \dots$"

  (26/8/08. Thanks to P. Zimmerman)

  and, in eq. (9.4), the overall minus sign should not be there.

  (25/2/16. Thanks to S. Sello).

- Page 477 line before eq. (9.36): "The equation of the geodesic equation" should be "The equation of the geodesic deviation"

  (12/06/13. Thanks to T. Schoenenbach).

- Page 494, three lines below eq. (9.129), "$h_{xx} = h_+$ and $h_{xx} = -h_+$" should read "$h_{xx} = h_+$ and $h_{yy} = -h_+$".

  (25/1/10. Thanks to B. Aylott)

- Page 515, below eq. (9.205): "which is smaller that the size" should be "which is smaller than the size"

  (12/06/13. Thanks to T. Schoenenbach).

- Page 520, line 9, $E_\gamma = |\mathbf{p}|/c$ should read $E_\gamma = |\mathbf{p}|c$. The subsequent factors of c are correct.

  (29/02/20. Thanks to Lorenzo Aiello).

- Bibliography: "S. L. Finn" should read "L. S. Finn".

  (27/12/2011. Thanks to N. Johnson-McDaniel, and my apologies to Lee Samuel Finn)

I will be glad to receive further corrections from readers.