Physics of the Interstellar and Intergalactic Medium
Errata in the fourth and fifth printings.
Updated 2022.09.03

Bruce T. Draine
Which printing of the book you have can be determined from the last line on the copyright page:

First printing: 1 3 5 7 9 10 8 6 4 2
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Fifth printing: 5 7 9 10 8 6
Sixth printing: 7 9 10 8 6
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Errata in the fourth and fifth printings.

• Plate 5 caption, typo:
  ...seen in Plate 6. → ...seen in Plate 4.
  noted 2018.04.07 by L. Bouma.

• §3.6, p. 28, Eq. 3.31, typo: factor of 2 error. Eq. (3.31) should read
  \[
  \sigma_{rr,\ell u}(E) = \frac{1}{2} \frac{g(X_u)}{g(X_{u+1})} \sigma_{\ell u}(h\nu = I_{X,\ell u} + E),
  \]
  noted 2015.06.01 by E. B. Jenkins

• §3.7, p. 28, Eq. (3.33), typo: sign error. Change \( e^{-I_n/kT} \) → \( e^{I_n/kT} \).
  noted 2017.02.09

• §3.8, p. 31, Eq. (3.48), typo: change
  \[
  I_{n\alpha} \propto A_{n\alpha} h\nu_{n\alpha} \int n[H(n)] ds \propto n^{-6} b_n \int n_e n(H^+) ds
  \]
  → \[
  I_{n\alpha} \propto A_{n\alpha} h\nu_{n\alpha} \int n[H(n+1)] ds \propto n^{-6} b_{n+1} \int n_e n(H^+) ds
  \]
  noted 2019.02.06

• §7.5, p. 69, Eq. (7.29), typo: missing a factor \( n_\ell \). Should read
  \[
  \kappa_\nu = n_\ell \sigma_{\ell u} \left(1 - \frac{n_a / g_u}{n_\ell / g_\ell}\right) < 0
  \]
  noted 2020.10.12 by Yan Liang.

• §9.8, p. 84, typo in line following Eq. (9.35): change
  \[
  (v_{\text{FWHM}}/2 \text{ km s}^{-1})^2/3 \rightarrow (v_{\text{FWHM}}/2 \text{ km s}^{-1})^2/3.
  \]
  noted 2020.09.09 by Roohi Dalal.

• §10.2, sentence preceding Eq. (10.5): change
  ...the Gaunt factor from quantum-mechanical calculations is approximately
  →
  ...the Gaunt factor is approximately (Scheuer 1960)
  noted 2018.11.18 by S. Weinberg.
• §10.5, p. 97, Eq. (10.25), typo (missing factor of 2): should read

\[ j_{b,\nu} = \frac{g_{b}}{g_{e} g_{i}} \frac{2 h^{4} \nu^{3}}{(2 \pi m_{e} kT)^{3/2} c^{2}} e^{(h_{\nu} - h \nu)/kT} \sigma_{b,pi}(\nu) n_{e} n_{i} \]

noted 2021.02.14 by Shigenobu Hirose.

• §11.4, p. 110, Eq. (11.34), typo (was off by factor 10^4): should read

\[ = 6.53 \times 10^{-5} \text{arcsec} \left( \frac{D/kpc}{L/10^{14} \text{ cm}} \right)^{1/2} \frac{(\Delta n_{e})_{L,\text{rms}}}{10^{-3} \text{ cm}^{-3} \nu_{9}^{-2}} \]

noted 2021.10.25 by I. Wasserman.

• §13.1, pp. 128, eq. (13.1), (13.3), (13.4): for notational consistency with the rest of the chapter, change \( \sigma_{pe} \rightarrow \sigma_{pi} \)

noted 2018.01.07 by L. Bouma.

• §13.1, p. 130, second paragraph, typo: ...to \( 3 \times 10^{-10} \text{s}^{-1} \) for Si \( \rightarrow \) ...to \( 3 \times 10^{-9} \text{s}^{-1} \) for Si

noted 2017.03.05

• §14.7.1, p. 156, Eq. (14.21), typo:

\[ H(1S_{1/2}) \rightarrow H(2S_{1/2}) \]

noted 2022.07.06 by S. R. Kulkarni.

• §14.9, p. 159, typo: factor of 2 error. Eq. (14.41) should read

\[ \sigma_{rr}(E) = \frac{g_{e}}{2g_{i}} \frac{(I + E)^{2}}{E_{m}c^{2}} \sigma_{pi}(h\nu = I + E) \]  

(14.41)

noted 2015.06.01 by E. B. Jenkins.

• §14.9, p. 160, typo: factor of 2 error. Eq. (14.43) should read

\[ \frac{\langle \sigma v \rangle_{rr}}{\langle \sigma v \rangle_{ci}} \approx 2 \pi \alpha^{3} \frac{f_{pi}}{C} \frac{I}{kT} e^{I/kT} \]  

(14.43)

noted 2015.06.01 by E. B. Jenkins.

• §14.9, p. 160, typo: factor of 2 error. Eq. (14.44) and following should read

\[ \frac{I}{kT} e^{I/kT} = \frac{C}{2\pi f_{pi}} \frac{1}{\alpha^{3}} \]  

(14.44)

If \( C \approx 1 \) and \( f_{pi} \approx 1 \), this has solution \( I/kT \approx 10.6 \). ...

noted 2015.06.01 by E. B. Jenkins.

• §15.5, p. 174, sentence preceding Eq. (15.36), typo:

\( N(\text{He}^{+})/N(\text{H}^{+}) < n_{H}/n_{\text{He}} \rightarrow N(\text{He}^{+})/N(\text{H}^{+}) < n_{\text{He}}/n_{H} \)

noted 2020.09.29 by H. Jia
• §16.5, p. 188, Eq. (16.16), typo: should read

\[ \text{H}_2 + \text{CR} \rightarrow \text{H}_2^+ + e^- + \text{CR} \]

noted 2020.09.29 by R. Córdova

• §17.3, p. 195, footnote 3, typos:

...frequency \( \sim 8 \times 10^{10} \text{ Hz} \ldots \rightarrow \ldots \) frequency \( \sim 1.1 \times 10^{10} \text{ Hz} \ldots \)

...\( \sim 10^2 \) precession periods. \( \rightarrow \ldots \sim 18 \) precession periods.

noted 2020.10.02

• §20.1, p. 229, typo just below Eq. (20.2): replace

...unit time that level \( x \) will... \rightarrow \ldots \) unit time the level \( u \) will...

noted 2020.10.12 by Yan Liang

• §22.6, p. 256, footnote 6: the DDSCAT website has moved. Change

http://code.google.com/p/ddscat \rightarrow \text{http://www.ddscat.org}

noted 2019.03.25

• §23.3.2, p. 268, typo: Si-O-Si bending mode \rightarrow O-Si-O bending mode

noted 2020.10.12

• §25.3, p. 299, typo following Eq. (25.11): change

...charge \( Z_{gr} = \frac{U_e}{e} \text{ can}\ldots \rightarrow \ldots \) charge \( Z_{gr} = \frac{U_a}{e} \text{ can}\ldots

noted 2021.06.25 by Yu Fung Wong.

• §28.3, p. 328, 4th paragraph, typo: change distance from \( \Theta_1 \text{Ori C} \) to the Orion Bar ionization front:

\( \sim 7.8 \times 10^{18} \text{ cm} \rightarrow \sim 7.8 \times 10^{17} \text{ cm} \)

noted 2020.10.26

• §32.9, p. 368, just before eq. (32.11), typo: change

\( A_V/N_H = 1.87 \times 10^{21} \text{ cm}^2 \rightarrow A_V/N_H = 5.3 \times 10^{-22} \text{ mag cm}^2. \)

noted 2016.03.04 by Ilsang Yoon.

• §32.11, p. 372, prepenultimate paragraph: terminological correction. Change “core” to “clump” (three occurrences).

noted 2015.04.16

• §34.4, p. 386, Eq. (34.10): sign mistake on RHS; change

\[ -4\pi r^2 \kappa \frac{dT}{dr} \rightarrow 4\pi r^2 \kappa \frac{dT}{dr} \]

noted 2019.04.18 by G. Halevi.

• §36.2.3, p. 400, Eq. (36.10): \( v_x \) multiplying \( B_y B_x \) should be \( v_y \), and \( v_x \) multiplying \( B_z B_x \) should be \( v_z \).
noted 2015.12.17 by J. Miralda-Escudé.
The equation should read
\[
\left\{ \frac{\rho v^2}{2} + \frac{\gamma p}{\gamma-1} \right\} v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x = \frac{(B_x B_y v_y + B_x B_z v_z)}{4\pi} - \kappa \frac{dT}{dx}
\]
\[
\left\{ \frac{\rho v^2}{2} + \frac{\gamma p}{\gamma-1} \right\} v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x = \frac{(B_x B_y v_y + B_x B_z v_z)}{4\pi} - \kappa \frac{dT}{dx} \right\}_1 =
\]
\[
\left\{ \frac{\rho v^2}{2} + \frac{\gamma p}{\gamma-1} \right\} v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x - \frac{(B_x B_y v_y + B_x B_z v_z)}{4\pi} - \kappa \frac{dT}{dx} \right\}_2. \quad (36.10)
\]

• §37.1, p. 413, 2nd paragraph: Change
Cases of astrophysical interest will normally have..
→
Many cases of astrophysical interest will have...
noted 2018.04.09.

• §37.1, p. 413, typo just above Eq. (37.3):
\[ Jh\nu/c = \rho_1 u_1 h\nu/\mu_i c \ll \rho_1 (u_1^2 + c_i^2 + B_i^2/8\pi). \]
→
\[ Jh\nu/c = \rho_1 u_1 h\nu/\mu_i c \ll \rho_1 (u_1^2 + c_i^2 + B_i^2/8\pi). \]
noted 2016.12.08 by Ryohei Nakatani.

• §37.1, Eq. (37.8): The correction terms for \( u_R, x_R, u_D, \) and \( x_D \) can be improved by analyzing the full cubic equation (37.3): change
\[
u_R \approx 2c_2 \quad \rightarrow \quad u_R \approx 2c_2 \left[ 1 - \frac{2c_1^2}{3v_{A1}^2} \right]
\]
\[
x_R \approx \frac{1}{2} + \frac{2c_1^2 + v_{A1}^2}{16c_2^2} \quad \rightarrow \quad x_R \approx \frac{1}{2}
\]
\[
u_D \approx \frac{2c_1^2 + v_{A1}^2}{4c_2} \quad \rightarrow \quad \frac{2c_1^2 + v_{A1}^2}{4c_2} \left[ 1 + \frac{2c_1^2 + v_{A1}^2}{8c_2^2} \right]
\]
\[
x_D \approx \frac{4c_2^2}{2c_1^2 + v_{A1}^2} \quad \rightarrow \quad x_D \approx \frac{4c_2^2}{2c_1^2 + v_{A1}^2} \left[ 1 - \frac{v_{A1}^2}{8c_2^2} \right]
\]
noted 2018.02.19 by Woong-Tae Kim.

• §37.1 and §37.2, pp. 414-416: the mathematics is correct, but the “weak-type”, and “strong-type” terminology was unfortunately inverted: all occurrences of “weak-type” should be changed to “strong-type”, and vice-versa:
• §37.1.1, p. 414, first paragraph:
...are called **strong R-type**. Strong R-type solutions...
→
...are called **weak R-type**. Weak R-type solutions...
• §37.1.1, p. 414, second paragraph:
  ...referred to as weak R-type,... → ...referred to as strong R-type,...

• §37.1.1, p. 414, second paragraph:
  Hence, only strong R-type I-fronts are physically relevant.
  →
Hence, only weak R-type I-fronts are physically relevant.

• §37.1.2, p. 414, first paragraph:
  ...is termed weak D-type. → ...is termed strong D-type.

• §37.1.2, p. 414, second paragraph:
  ...is termed strong D-type. → ...is termed weak D-type.

• Fig. 37.1 and caption should be:

\[ \frac{u_2}{u_1} = \frac{\rho_1}{\rho_2}, \text{ as a function of the velocity } u_1 \text{ of the I-front relative to the neutral gas just ahead of the I-front, for D-type and R-type ionization front solutions (see text) for an example with } c_1 = 1 \text{ km s}^{-1}, \, v_{A1} = 2 \text{ km s}^{-1}, \text{ and } c_2 = 11.4 \text{ km s}^{-1}. \text{ The astrophysically relevant solutions are the strong D-type and weak R-type cases, shown as heavy curves. There are no solutions with } u_1 \text{ between } u_D \text{ and } u_R. \]

\[ \begin{align*}
\text{strong D} & \quad x_D = 1 \text{ km/s} \\
\text{weak D} & \quad v_{A1} = 2 \text{ km/s} \\
\text{strong R} & \quad x_R = 11.4 \text{ km/s} \\
\end{align*} \]

\[ u_2/u_1 = \rho_1/\rho_2, \text{ as a function of the velocity } u_1 \text{ of the I-front relative to the neutral gas just ahead of the I-front, for D-type and R-type ionization front solutions (see text) for an example with } c_1 = 1 \text{ km s}^{-1}, \, v_{A1} = 2 \text{ km s}^{-1}, \text{ and } c_2 = 11.4 \text{ km s}^{-1}. \text{ The astrophysically relevant solutions are the strong D-type and weak R-type cases, shown as heavy curves. There are no solutions with } u_1 \text{ between } u_D \text{ and } u_R. \]

• §37.1, p. 416, first paragraph:
  ...will be strong R-type, ... → ...will be weak R-type, ...

• §37.1, p. 417, fourth line:
  ...will now be weak D-type, ... → ...will now be strong D-type, ...

noted 2016.12.06 by Ryohei Nakatani.

• §37.2, p. 418, typos:
  ...moving at a speed \( v_s \) that will be close to (just slightly larger than) the speed of the I-front:

\[ v_s \approx V_i \] \hspace{1cm} (37.21)

→
...moving at a speed \( V_s \) that will be close to (just slightly larger than) the
speed of the I-front:

\[ V_s \approx V_i \quad (37.21) \]

noted 2016.12.08 by Ryohei Nakatani.

• §38.3, p. 428, last paragraph, typo:

\[ \dot{M}_w \approx 2 \times 10^{-5} \text{ km s}^{-1} \rightarrow \dot{M}_w \approx 2 \times 10^{-5} \text{ M}_\odot \text{ yr}^{-1} \]

noted 2015.12.17 by J. Miralda-Escudé.

• §41.3, p. 456, typo: missing factor of \( G \). Eq. (41.36) should read

\[ E_{\text{grav}} = -\frac{G}{2} \int dV_1 \int dV_2 \frac{\rho_{1} \rho_{2}}{|\mathbf{r}_1 - \mathbf{r}_2|} \quad (41.36) \]

noted 2015.04.30 by J. Greco.

• Appendix B, p. 476: typo: incorrect units for Stefan-Boltzmann constant \( \sigma \):

\[ 5.67040 \times 10^{-5} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ K}^{-4} \rightarrow 5.67040 \times 10^{-5} \text{ erg s}^{-1} \text{ cm}^{-2} \text{ K}^{-4} \]

noted 2019.05.14 by Aaron Tran.

• Appendix D, p. 481: corrected typos:

F VI \rightarrow VII: \( I = 147.163 \rightarrow 157.163 \)
Ne VI \rightarrow VII: \( I = 154.214 \rightarrow 157.934 \)
Ti III \rightarrow IV: \( I = 24.492 \rightarrow 27.492 \)
Ti V \rightarrow VI: \( I = 123.7 \rightarrow 99.299 \)
Zn VI \rightarrow VII: \( I = 133.903 \rightarrow 108.0 \)

noted 2015.07.10 by Guangtun Ben Zhu.

• Appendix F, Table F.2, p. 497, typo: the first transition listed for S III: change \( ^3\text{P}_{0} - ^3\text{P}_{0} \rightarrow ^3\text{P}_{0} - ^3\text{P}_{1} \)

noted 2016.10.03 by C.D. Kreisch.

• Appendix F, Table F.5, p. 500: Level \( u \) in the fourth line in the table should be \( ^2\text{P}_{3/2} \) rather than \( ^2\text{P}_{5/2} \).

noted 2022.09.03 by S. R. Kulkarni

• Appendix F, Table F.6, p. 501: The table title should be “Rate Coefficients for ... Deexcitation...” rather than “... Excitation...”.

noted 2015.07.03

• Appendix F, Table F.6, p. 501: the rates for entries 5 and 6 should be interchanged, so that entries 4-6 read

\[
\begin{array}{ccc}
\text{H} & \text{CI} & ^3\text{P}_0 - ^3\text{P}_1 \\
1.26 \times 10^{-10} T_2^{0.115+0.057 \ln T_2} & b \\
\text{H} & \text{CI} & ^3\text{P}_0 - ^3\text{P}_2 \\
8.90 \times 10^{-11} T_2^{0.228+0.046 \ln T_2} & b \\
\text{H} & \text{CI} & ^3\text{P}_1 - ^3\text{P}_2 \\
2.64 \times 10^{-10} T_2^{0.231+0.046 \ln T_2} & b \\
\end{array}
\]

noted 2015.07.03 by Munan Gong.
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• Appendix F, Table F.6, p. 501: the rates for entries 23-28 should be changed to

\[
\begin{align*}
H_2\text{(para)} & \quad O I \quad ^3P_2 - ^3P_1 & \quad 1.49 \times 10^{-10} T_2^{0.369-0.026 \ln T_2} \quad h \\
H_2\text{(ortho)} & \quad O I \quad ^3P_2 - ^3P_1 & \quad 1.37 \times 10^{-10} T_2^{0.395-0.005 \ln T_2} \quad h \\
H_2\text{(para)} & \quad O I \quad ^3P_2 - ^3P_0 & \quad 2.37 \times 10^{-10} T_2^{0.255+0.016 \ln T_2} \quad h \\
H_2\text{(ortho)} & \quad O I \quad ^3P_2 - ^3P_0 & \quad 2.23 \times 10^{-10} T_2^{0.284+0.035 \ln T_2} \quad h \\
H_2\text{(para)} & \quad O I \quad ^3P_1 - ^3P_0 & \quad 2.10 \times 10^{-12} T_2^{1.117+0.070 \ln T_2} \quad h \\
H_2\text{(ortho)} & \quad O I \quad ^3P_1 - ^3P_0 & \quad 3.00 \times 10^{-12} T_2^{0.792+0.188 \ln T_2} \quad h
\end{align*}
\]

noted 2015.08.24 by E.B. Jenkins.

• Appendix G, p. 503, typo just before Eq. (G.7): change

...solution \( x_0 = e^{-i\omega t} \) → ...solution \( x = x_0 e^{-i\omega t} \).

noted 2019.02.11

• Appendix I, p. 507, typo (15.78 → 31.56): Eq. (I.7) should read

\[
\frac{Z e^2}{a_0 k T} = \frac{31.56 Z}{T_4}
\]

noted 2019.01.14.

• Appendix J, p. 510, Eq. (J.8): missing sign:

\[
Y_3 = E_{grav} = \frac{1}{2} \int dV_1 \int dV_2 G \frac{\rho(r_1) \rho(r_2)}{|r_1 - r_2|}
\]

→

\[
Y_3 = E_{grav} = -\frac{1}{2} \int dV_1 \int dV_2 G \frac{\rho(r_1) \rho(r_2)}{|r_1 - r_2|}
\]

noted 2020.11.13

• Appendix J, p. 510, Eq. (J.13), typo:

\[
\Pi_0 \equiv \oint dS \cdot r p \quad \rightarrow \quad \Pi_0 \equiv \frac{1}{3} \oint dS \cdot r p
\]

noted 2017.03.08.