Physics of the Interstellar and Intergalactic Medium

Errata in the second and third printings.

Updated 2023.05.23

Bruce T. Draine

PRINCETON UNIVERSITY PRESS
PRINCETON AND OXFORD

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
Second printing:	3 5 7 9 10 8 6 4 2
Third printing:	3 5 7 9 10 8 6 4
Fourth printing:	5 7 9 10 8 6 4
Fifth printing:	5 7 9 10 8 6
Sixth printing:	7 9 10 8 6
Seventh printing:	7 9 10 8
Eighth printing:	9 10 8

Errata in the second and third printings.

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

- §1.2, p. 8, Table 1.4: change abundance of P from $N_{\rm P}/N_{\rm H} = 3.23 \times 10^{-7\pm0.03}$, $M_{\rm P}/M_{\rm H} = 1.00\times10^{-5}$ to $N_{\rm P}/N_{\rm H} = 2.82\times10^{-7\pm0.03}$, $M_{\rm P}/M_{\rm H} = 8.73 \times 10^{-6}$
  noted 2013.10.21 by Bon-Chul Koo.

- §3.6, p. 28, Eq. 3.31, typo: factor of 2 error. Eq. (3.31) should read

$$\sigma_{{\rm rr},u\ell}(E) = \frac{1}{2}\frac{g(X_\ell)}{g(X_u^+)}\frac{(I_{X,\ell u}+E)^2}{Em_ec^2}\sigma_{{\rm pi},\ell u}(h\nu = I_{X,\ell u}+E) \quad , \qquad (3.31)$$

  noted 2015.06.01 by E. B. Jenkins

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

- §3.8, p. 31, Eq. (3.48), typo: change

$$I_{n\alpha} \propto A_{n\alpha}h\nu_{n\alpha}\int n[{\rm H}(n)]ds \propto n^{-6}b_n\int n_e n({\rm H}^+)ds$$

$$\rightarrow I_{n\alpha} \propto A_{n\alpha}h\nu_{n\alpha}\int n[{\rm H}(n+1)]ds \propto n^{-6}b_{n+1}\int n_e n({\rm H}^+)ds$$

  noted 2019.02.06

- §5.2.2, p. 50, 3rd paragraph, typos: change
  para-H_2O must have $K_{-1}+K_{+1}$ odd →
  para-H_2O must have $K_{-1}+K_{+1}$ even
  and
  ortho-H_2O must have $K_{-1}+K_{+1}$ even →
  ortho-H_2O must have $K_{-1}+K_{+1}$ odd
  noted 2015.01.15 by Neal Evans.

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

- §8.3, p. 74, Eq. (8.26), typos: $T_A^{\rm on}(v) \rightarrow T_A^{\rm off}(v)$ (two occurrences).
noted 2013.02.14 by Munan Gong.

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

- §9.10, Table 9.4, p. 88, typos: for C II and N III, change ${}^2{\rm D}^o_J \rightarrow {}^2{\rm D}_J$ for $J=3/2$ and $J=5/2$.
noted 2015.02.12 by Semyeong Oh.

- §10.2, sentence preceding Eq. (10.5): change
...the Gaunt factor from quantum-mechanical calculations is approximately
$\rightarrow$
...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
$$j_{{\rm fb},\nu} = \frac{g_{\rm b}}{g_e g_i}\frac{2\,h^4\nu^3}{(2\pi m_e kT)^{3/2}c^2}\,{\rm e}^{(I_{\rm b}-h\nu)/kT}\,\sigma_{\rm b,pi}(\nu) n_e n_i$$
noted 2021.02.14 by Shigenobu Hirose.

- §11.4, p. 110, Eq. (11.35) should read
$$\nu \ll \frac{e^2(\Delta n_e)_{L,\rm rms}}{2\pi m_e c}\,(2LD)^{1/2} = 1{\times}10^3\,{\rm GHz}\frac{(\Delta n_e)_{L,\rm rms}}{10^{-3}\,{\rm cm^{-3}}}\left(\frac{L}{10^{14}\,{\rm cm}}\frac{D}{\rm kpc}\right)^{1/2}.$$
noted 2013.02.03 by W. Vlemmings.

- §11.4, p. 110, Eq. (11.34), typo (was off by factor 10^4): should read
$$= 6.53\times10^{-5}\,{\rm arcsec}\left(\frac{D/\,{\rm kpc}}{L/10^{14}\,{\rm cm}}\right)^{1/2}\frac{(\Delta n_e)_{L,\rm rms}}{10^{-3}\,{\rm cm^{-3}}}\nu_9^{-2}$$
noted 2021.10.25 by I. Wasserman.

- §12, p. 121, Table 12.1, typos:

CMB, $T=2.725\,{\rm K}$	:	$4.19{\times}10^{-13}$	$\rightarrow$	4.17×10^{-13}
$T_2=4000\,{\rm K}$, $W_2=1.65{\times}10^{-13}$	:	$3.19{\times}10^{-13}$	$\rightarrow$	$3.20{\times}10^{-13}$
$T_3=7500\,{\rm K}$, $W_3=1{\times}10^{-14}$	:	$2.29{\times}10^{-13}$	$\rightarrow$	$2.39{\times}10^{-13}$
Starlight total	:	$1.05{\times}10^{-12}$	$\rightarrow$	$1.06{\times}10^{-12}$
ISRF total	:	$2.19{\times}10^{-12}$	$\rightarrow$	$1.98{\times}10^{-12}$.

noted 2012.11.08

- §12.5, p. 123, below eq. (12.4): change
  ...W_1 by 40%, from $W_1 = 5\times10^{-13}$ to 7×10^{-13}. $\rightarrow$
  ...W_1 by 75%, from $W_1 = 4\times10^{-13}$ to 7×10^{-13}, and raised W_2 from 1.0×10^{-13} to 1.65×10^{-13}.
  noted 2014.11.11 by S. Bianchi.

- §13.1, pp. 128, eq. (13.1), (13.3), (13.4): for notational consistency with the rest of the chapter, change $\sigma_{\rm pe} \rightarrow \sigma_{\rm pi}$
  noted 2018.01.07 by L. Bouma.

- §13.1, p. 130, second paragraph, typo:
  ...to $3\times10^{-10}\,{\rm s}^{-1}$ for Si $\rightarrow$ ...to $3\times10^{-9}\,{\rm s}^{-1}$ for Si
  noted 2017.03.05

- §14.6, p. 154, Table 14.8 update: replace
  $\rm H_3^+ + e^- \rightarrow H_2 + H$ $\quad 1.1\times10^{-7}T_2^{-0.56}$ McCall et al. (2004)
  with
  $\rm H_3^+ + e^- \rightarrow H + H + H$ $\quad 8.9\times10^{-8}T_2^{-0.48}$ McCall et al. (2004)
  $\rm H_3^+ + e^- \rightarrow H_2 + H$ $\quad 5.0\times10^{-8}T_2^{-0.48}$ McCall et al. (2004)
  noted 2013.04.03

- §14.7.1, p. 156, Eq. (14.21), typo:
  $\rm H(^1S_{1/2}) \rightarrow H(^2S_{1/2})$
  noted 2022.07.06 by S. R. Kulkarni.

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

$$\sigma_{\rm rr}(E) = \frac{g_\ell}{2g_u}\frac{(I+E)^2}{Em_ec^2}\sigma_{\rm pi}(h\nu = I+E) \quad . \tag{14.41}$$

  noted 2015.06.01 by E. B. Jenkins.

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

$$\frac{\langle\sigma v\rangle_{\rm rr}}{\langle\sigma v\rangle_{\rm ci}} \approx 2\pi\alpha^3\frac{f_{\rm pi}}{C}\frac{I}{kT}e^{I/kT} \quad , \tag{14.43}$$

  noted 2015.06.01 by E. B. Jenkins.

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

$$\frac{I}{kT}e^{I/kT} = \frac{C}{2\pi f_{\rm pi}}\frac{1}{\alpha^3} \quad . \tag{14.44}$$

  If $C \approx 1$ and $f_{\rm pi} \approx 1$, this has solution $I/kT \approx 10.6$. ...
  noted 2015.06.01 by E. B. Jenkins.

- Table 15.1, p. 164, typo: $M/\,M_\odot$ for O6.5V star: $38.0 \rightarrow 28.0$
  noted 2013.01.31

- §15.5, p. 174, sentence preceding Eq. (15.36), typo:
  $N({\rm He^+})/N({\rm H^+}) < n_{\rm H}/n_{\rm He}$ $\rightarrow$ $N({\rm He^+})/N({\rm H^+}) < n_{\rm He}/n_{\rm H}$
  noted 2020.09.29 by H. Jia

- §16.4, p. 186, Eq. (16.9, 16.10), update: change

$$\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H}_2 + \mathrm{H} \quad , \quad k_{16.9} = 4.1\times10^{-8} T_2^{-0.52}\,\mathrm{cm}^3\,\mathrm{s}^{-1}\ ,$$
$$\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H} + \mathrm{H} + \mathrm{H} \quad , \quad k_{16.10} = 7.7\times10^{-8} T_2^{-0.52}\,\mathrm{cm}^3\,\mathrm{s}^{-1}\ ,$$

  to

$$\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H}_2 + \mathrm{H} \quad , \quad k_{16.9} = 5.0\times10^{-8} T_2^{-0.48}\,\mathrm{cm}^3\,\mathrm{s}^{-1}\ ,$$
$$\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H} + \mathrm{H} + \mathrm{H} \quad , \quad k_{16.10} = 8.9\times10^{-8} T_2^{-0.48}\,\mathrm{cm}^3\,\mathrm{s}^{-1}\ ,$$

  and cite McCall et al. (2004) for $k_{16.9}$ and $k_{16.10}$.
  noted 2013.04.03

- §16.4, p. 187, typo: in paragraph below Eq. (16.15), change
  $x_e \approx x_M \approx 1.9\times10^{-4}$ $\rightarrow$ $x_e \approx x_M \approx 1.1\times10^{-4}$ (see Eq. 16.3)
  noted 2013.04.04

- §16.5, p. 188, Eq. (16.16), typo: should read

$$\mathrm{H}_2 + \mathrm{CR} \rightarrow \mathrm{H}_2^+ + e^- + \mathrm{CR}$$

  noted 2020.09.29 by R. Córdova

- §16.5, p. 189, Fig. 16.3. The original figure was evaluated with a too-large rate for $k_{16.19}$. The figure has been redone, now also showing the result if $\zeta_{\rm CR} = 1\times10^{-17}\,\mathrm{s}^{-1}$:

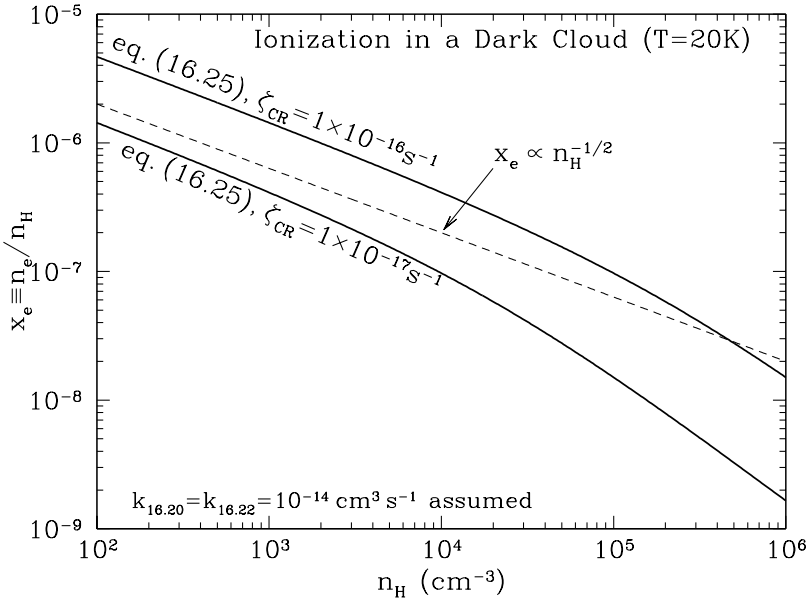


Figure 16.3 Fractional ionization in a dark cloud, estimated using Eq. (16.25), with the grain recombination rate coefficients set to $k_{16.20} = k_{16.22} = 10^{-14}\,\mathrm{cm}^3\,\mathrm{s}^{-1}$ (see Fig. 14.6). The dashed line is a simple power-law approximation $x_e \approx 2\times 10^{-5}(n_\mathrm{H}/\,\mathrm{cm}^{-3})^{-1/2}$.

noted 2013.03.05.

- §17.3, p. 195, footnote 3, typos:
...frequency $\sim 8\times 10^{10}$ Hz... → ...frequency $\sim 1.1\times 10^{10}$ Hz...
...$\sim 10^2$ precession periods. → ...~ 18 precession periods.
noted 2020.10.02

- §18.5, p. 214, Eq. (18.11): Change
... Ω_{03} is approximately independent of T_e, we have

$$\frac{n(\mathrm{O\,III})}{n(\mathrm{H}^+)} = C\frac{I([\mathrm{O\,III}]5008)}{I(\mathrm{H}\beta)}T_4^{-0.37}\mathrm{e}^{2.917/T_4}\,, \qquad (18.11)$$

to
... $\Omega_{03}\propto T_4^{0.12}$ (see Appendix F), we have

$$\frac{n(\mathrm{O\,III})}{n(\mathrm{H}^+)} = C\frac{I([\mathrm{O\,III}]5008)}{I(\mathrm{H}\beta)}T_4^{-0.49}\mathrm{e}^{2.917/T_4}\,, \qquad (18.11)$$

noted 2015.02.27

- §19.3, p. 222: revise value for A_{10}: replace
$A_{10} = 6.78\times 10^{-8}\,\mathrm{s}^{-1} \rightarrow A_{10} = 7.16\times 10^{-8}\,\mathrm{s}^{-1}$ (see Eq. 5.7).
noted 2013.04.17

- §19.3, p. 223: revised numbers according to revised value for A_{10}:
Eq. (19.15): $281 \rightarrow 297$, Eq. (19.17): $281 \rightarrow 297$, Eq. (19.19): $46 \rightarrow 50$
noted 2013.04.17

- §20.1, p. 229, typo just below Eq. (20.2): replace
...unit time that level x will... → ...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 → http://www.ddscat.org
noted 2019.03.25

- §23.1, p. 265, typo:
lower oscillator strength $f(\mathrm{C\,II}]2325\,\text{Å}) = 1.0\times 10^{-7}$
→
larger oscillator strength $f(\mathrm{C\,II}]2325\,\text{Å}) = 1.0\times 10^{-7}$
noted 2012.12.27

- §23.3.2, p. 268, typo: Si-O-Si bending mode → O-Si-O bending mode
noted 2020.10.12

- §25.3, p. 299, typo following Eq. (25.11): change
...charge $Z_{\rm gr} = Ua$ can... $\rightarrow$ ...charge $Z_{\rm gr} = Ua/e$ can...
noted 2021.06.25 by Yu Fung Wong.

- §26.2, p. 308, Eq. (26.23), numerical error: should read

$$\frac{\omega}{2\pi} = 4.6\,{\rm GHz}\left(\frac{T_{\rm rot}}{100\,{\rm K}}\right)^{1/2}\left(\frac{0.001\,\mu{\rm m}}{a}\right)^{5/2} \tag{26.23}$$

noted 2014.06.27 by B. Jiang.

- §27.3.1, p 320, typos in coefficient of $\ln(T_4/Z^2)$ term: Eq. (27.19) and (27.20) should read

$$\gamma_A = -1.2130 - 0.0115\ln(T_4/Z^2) \tag{27.19}$$
$$\gamma_B = -1.3163 - 0.0208\ln(T_4/Z^2) \tag{27.20}$$

and (27.22) and (27.23) should read

$$\langle E_{\rm rr}\rangle_A = \left[0.787 - 0.0115\ln(T_4/Z^2)\right]kT \tag{27.21}$$
$$\langle E_{\rm rr}\rangle_B = \left[0.684 - 0.0208\ln(T_4/Z^2)\right]kT \tag{27.22}$$

noted 2023.01.29 by S. R. Kulkarni.

- §28.3, p. 328, 4th paragraph, typo: change distance from Θ_1Ori C to the Orion Bar ionization front: $\sim 7.8\times10^{18}\,{\rm cm}$ $\rightarrow$ $\sim 7.8\times10^{17}\,{\rm cm}$
noted 2020.10.26

- §29.1, p. 332, 1st paragraph, typo: $b=0 \rightarrow b=90^\circ$, so that the 2nd sentence reads
...vary as $N({\rm H\,I}, b) = N({\rm H\,I}, b=90^\circ)/\sin|b| = N_0\csc|b|$.
noted 2012.11.04 by R. Simons.

- §31.4, p. 349, Eq. (31.24), typo: on RHS, change

$$\frac{\pi e^2}{m_e c^2 h}\sum_u f_{\ell u}\lambda_{\ell u}^3 u_\lambda f_{{\rm shield},\ell u} \rightarrow \frac{\pi e^2}{m_e c^2 h}\sum_u f_{\ell u}\lambda_{\ell u}^3 u_\lambda f_{{\rm shield},\ell u}\, p_{{\rm diss},u}$$

noted 2013.04.12 by Ai-Lei Sun.

- §32.9, p. 368, just before eq. (32.11), typo: change
$A_V/N_{\rm H} = 1.87\times10^{21}\,{\rm cm}^2$ $\rightarrow$ $A_V/N_{\rm H} = 5.3\times10^{-22}{\rm mag\,cm}^2$.
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

$$-4\pi r^2\kappa\frac{dT}{dr} \quad \rightarrow \quad 4\pi r^2\kappa\frac{dT}{dr}$$

noted 2019.04.18 by G. Halevi.

- §34.4, p. 387, typo: Eq. (34.17) is off by a factor 3, and should read

$$t_{\rm evap} = \frac{3M}{2\dot{M}} = \frac{25\times 2.3(n_{\rm H})_c R_c^2 m_e^{1/2} e^4 \ln\Lambda}{8\times 0.87(kT_h)^{2.5}} \tag{34.17}$$

Eq. (34.18) is numerically correct, but should have shown the dependence on $\ln\Lambda$:

$$= 5.1{\times}10^4\,{\rm yr}\left(\frac{(n_{\rm H})_c}{30\,{\rm cm}^{-3}}\right)\left(\frac{R_c}{\rm pc}\right)^2\left(\frac{T_h}{10^7\,{\rm K}}\right)^{-2.5}\left(\frac{\ln\Lambda}{30}\right)\,. \tag{34.18}$$

noted 2013.01.05 by B. Hensley.

- §36.2.3, p. 400, Eq. (36.10): v_x multiplying B_yB_x should be v_y, and v_x multiplying B_zB_x should be v_z.
noted 2015.12.17 by J. Miralda-Escudé.
The equation should read

$$\left\{\left[\frac{\rho v^2}{2}+\frac{\gamma p}{(\gamma-1)}\right]v_x+\frac{(B_y^2+B_z^2)}{4\pi}v_x-\frac{(B_xB_yv_y+B_xB_zv_z)}{4\pi}-\kappa\frac{dT}{dx}\right\}_1 =$$

$$\left\{\left[\frac{\rho v^2}{2}+\frac{\gamma p}{(\gamma-1)}\right]v_x+\frac{(B_y^2+B_z^2)}{4\pi}v_x-\frac{(B_xB_yv_y+B_xB_zv_z)}{4\pi}-\kappa\frac{dT}{dx}\right\}_2\,. \tag{36.10}$$

- §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):
$Jh\nu/c = \rho_1 u_1 h\nu/\mu_i c \ll \rho_1(u_1^2+c_1^2+B_1^2/8\pi)$.
→
$Jh\nu/c = \rho_1 u_1 h\nu/\mu_i c \ll \rho_1(u_1^2+c_1^2)+B_1^2/8\pi$.
noted 2016.12.08 by Ryohei Nakatani.

- §37.1, Eq. (37.8): The correction terms for $u_{\rm R}$, $x_{\rm R}$, $u_{\rm D}$, and $x_{\rm D}$ can be improved by analyzing the full cubic equation (37.3): change

$$u_{\rm R}\approx 2c_2 \quad\rightarrow\quad u_{\rm R}\approx 2c_2\left[1-\frac{2c_1^2-3v_{A1}^2}{8c_2^2}\right]$$

$$x_{\rm R} \approx \frac{1}{2} + \frac{2c_1^2+v_{A1}^2}{16c_2^2} \quad \rightarrow \quad x_{\rm R} \approx \frac{1}{2}$$

$$u_{\rm D} \approx \frac{2c_1^2+v_{A1}^2}{4c_2} \quad \rightarrow \quad \frac{2c_1^2+v_{A1}^2}{4c_2}\left[1+\frac{2c_1^2+v_{A1}^2}{8c_2^2}\right]$$

$$x_{\rm D} \approx \frac{4c_2^2}{2c_1^2+v_{A1}^2} \quad \rightarrow \quad x_{\rm D} \approx \frac{4c_2^2}{2c_1^2+v_{A1}^2}\left[1-\frac{v_{A1}^2}{8c_2^2}\right]$$

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:

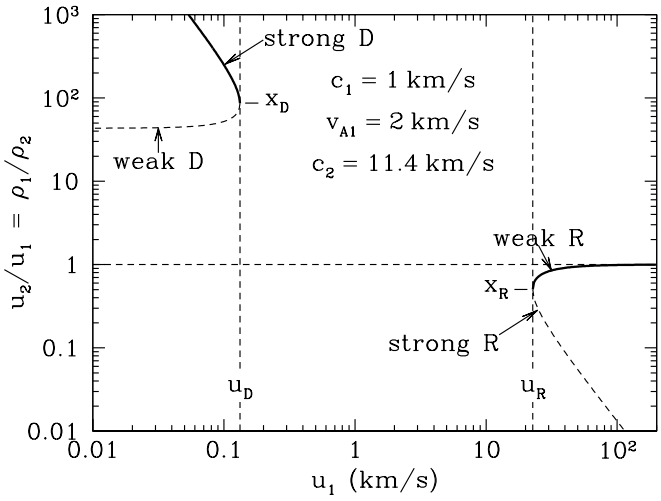


Figure 37.1 $u_2/u_1 = \rho_1/\rho_2$, as a function of the velocity u_1 of the I-front relative to the neutral gas just ahead of the I-front, for D-type and R-type ionization front

solutions (see text) for an example with $c_1 = 1\,\mathrm{km\,s^{-1}}$, $v_{A1} = 2\,\mathrm{km\,s^{-1}}$, and $c_2 = 11.4\,\mathrm{km\,s^{-1}}$. 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 between u_D 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:

$$v_s \approx V_i \quad . \tag{37.21}$$

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

$$V_s \approx V_i \quad . \tag{37.21}$$

  noted 2016.12.08 by Ryohei Nakatani.

- §38.3, p. 428, last paragraph, typo:
  $\dot{M}_w \approx 2\times10^{-5}\,\mathrm{km\,s^{-1}} \rightarrow \dot{M}_w \approx 2\times10^{-5}\,M_\odot\,\mathrm{yr^{-1}}$
  noted 2015.12.17 by J. Miralda-Escudé.

- §39.1.2, p. 433, Eqs. (39.22, 39.23, 39.24), typos: the factor (E_{51}/n_0^2) should be $(E_{51}n_0^2)$, so that the equations should read

$$v_s(t_\mathrm{rad}) = 188\,\mathrm{km\,s^{-1}}(E_{51}n_0^2)^{0.07} \quad , \tag{39.22}$$
$$T_s(t_\mathrm{rad}) = 4.86\times10^5\,\mathrm{K}(E_{51}n_0^2)^{0.13} \quad , \tag{39.23}$$
$$kT_s(t_\mathrm{rad}) = 41\,\mathrm{eV}(E_{51}n_0^2)^{0.13} \quad . \tag{39.24}$$

  noted 2012.10.02 by G.B. Field.

- §39.4, p. 438, Eqs. (39.35) and (39.36), typos: they should read

$$N_\mathrm{SN} = 0.24 S_{-13} E_{51}^{1.26} n_0^{-1.47} c_{s,6}^{-13/5} \tag{39.35}$$
$$= 0.48 S_{-13} E_{51}^{1.26} n_0^{-0.17} p_4^{-1.30} \quad , \quad p_4 \equiv \frac{p/k}{10^4\,\mathrm{cm^{-3}\,K}} \tag{39.36}$$

  noted 2014.06.27 by B. Jiang.

- §39.4, p. 438, Eq. (39.37), typos: Eq. (39.37) should read

$$\frac{p}{k} = S_{-13}^{0.77} E_{51}^{0.97} n_0^{-0.13} \times 5700\,\mathrm{cm}^{-3}\,\mathrm{K} \qquad (39.37)$$

  noted 2014.06.27 by B. Jiang.

- §40.5, p. 447, typo: protons with $E \lesssim 10^5\,\mathrm{GeV}$ have $R_{\rm gyro} < 10^{-4}\,\mathrm{pc} \rightarrow$ protons with $E \lesssim 10^3\,\mathrm{GeV}$ have $R_{\rm gyro} < 10^{-4}\,\mathrm{pc}$
  noted 2011.04.26

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

$$E_{\rm grav} = -\frac{G}{2}\int dV_1 \int dV_2 \frac{\rho(\mathbf{r}_1)\rho(\mathbf{r}_2)}{|\mathbf{r}_1 - \mathbf{r}_2|} \qquad (41.36)$$

  noted 2015.04.30 by J. Greco.

- §41.3.2, p. 457, Eq. (41.46), typo: replace

$$E_{\rm mag} = \frac{B_{\rm rms}^2 - B_0^2}{8\pi} V \quad \rightarrow \quad E_{\rm mag} = \frac{B_{\rm rms}^2}{8\pi} V$$

  noted 2011.04.28

- §41.4, p. 460, Eq. (41.55), typo: $m_m \rightarrow m_n$
  noted 2013.04.30 by K. Silsbee

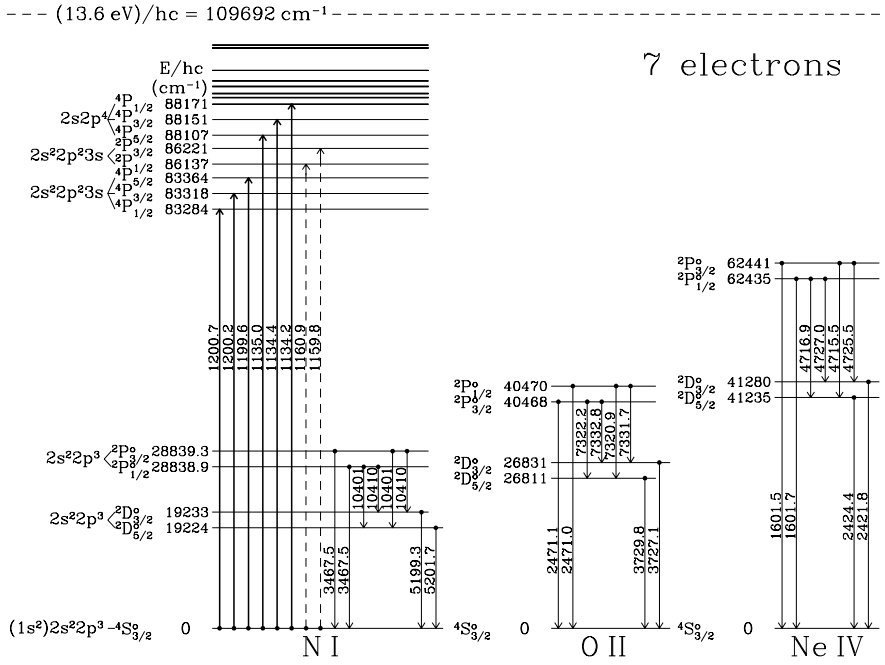
- Appendix A, p. 473, typo: entry for a_0 should read
  ...Bohr radius $\equiv \hbar^2/m_e e^2 =$...
  noted 2013.03.05 by Wenhua Ju.

- Appendix B, p. 476: typo: incorrect units for Stefan-Boltzmann constant σ:
  $5.67040\times10^{-5}\,\mathrm{erg\,s^{-1}\,cm^{-3}\,K^{-4}} \quad \rightarrow \quad 5.67040\times10^{-5}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,K^{-4}}$
  noted 2019.05.14 by Aaron Tran.

- Appendix D, p. 481: corrected typos:
  F VI → VII: $I = 147.163 \rightarrow 157.163$
  Ne VI → VII: $I = 154.214 \rightarrow 157.934$
  Ti III → IV: $I = 24.492 \rightarrow 27.492$
  Ti V → VI: $I = 123.7 \rightarrow 99.299$
  Zn VI → VII: $I = 133.903 \rightarrow 108.0$
  noted 2015.07.10 by Guangtun Ben Zhu.

- Appendix E, p. 485: diagrams for N IV and O V: the levels shown as $^2\mathrm{P}_1^o$ and $^2\mathrm{P}_2^o$ should be $^3\mathrm{P}_1^o$ and $^3\mathrm{P}_2^o$, respectively.
  noted 2023.05.23

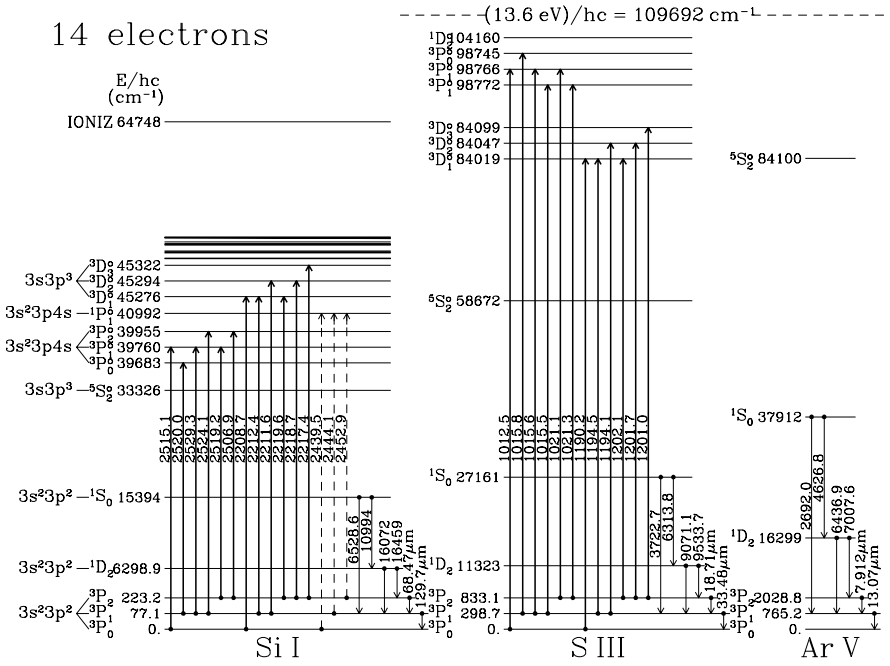
- Appendix E, p. 488: inadvertent omisssionof $^2P^o_{1/2}\rightarrow{}^2D^o_{5/2}$ emission lines for N I, O II, and Ne IV. Corrected figure:



noted 2023.04.16 by S.R. Kulkarni

- Appendix E, p. 494: inadvertent omission of $^1S_0\rightarrow{}^1D_2$ emission lines for

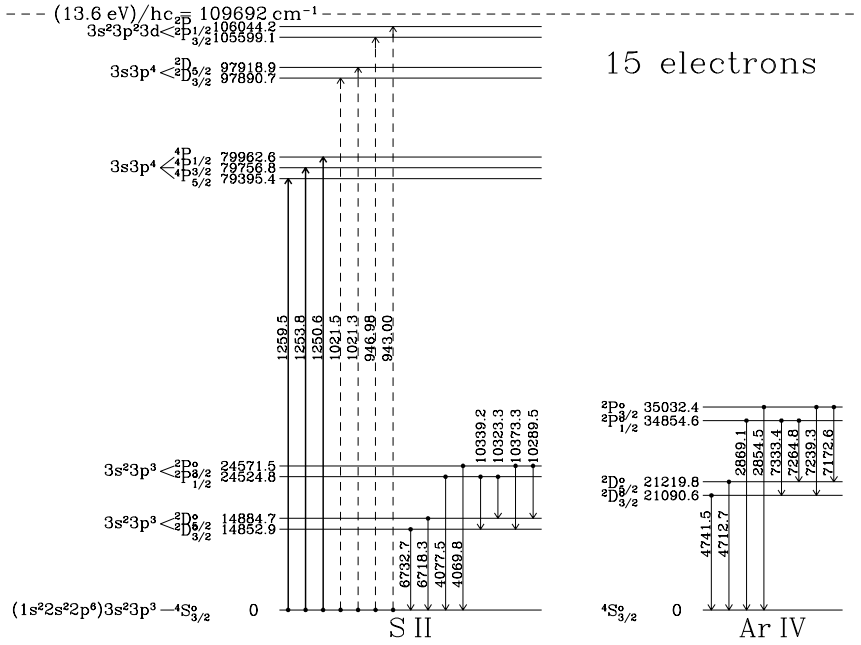
Si I and S III. Corrected figure:



noted 2023.04.16 by S.R. Kulkarni

- Appendix E, p. 495: $^2D^o_{3/2,5/2}$ energy levels were misplotted for S II and Ar IV.
  noted 2013.10.21 by Bon-Chul Koo.
  Corrected figure [Opportunity taken to update energy Ar IV energy levels

using latest values from NIST Atomic Spectra Database (ver. 5.1 [Online])]:



- Appendix F, Table F.2, p. 497, typo: the first transition listed for S III: change ^{3}P$_0$–^{1}P$_0$ → ^{3}P$_0$–^{3}P$_1$
  noted 2016.10.03 by C.D. Kreisch.

- Appendix F, Table F.3, p. 498: updated electron collision strengths for O I:

Ion	$\ell - u$	$\Omega_{u\ell}$	Note
O I	^{3}P$_2$–^{3}P$_1$	$0.0105\ T_4^{0.4861+0.0054\ln T_4}$	*a*
”	^{3}P$_2$–^{3}P$_0$	$0.00459\ T_4^{0.4507-0.0066\ln T_4}$	*a*
”	^{3}P$_1$–^{3}P$_0$	$0.00015\ T_4^{0.4709-0.1396\ln T_4}$	*a*
”	^{3}P$_J$–^{1}D$_2$	$0.0312(2J+1)\ T_4^{0.945-0.001\ln T_4}$	*b*
”	^{3}P$_J$–^{1}S$_0$	$0.00353(2J+1)\ T_4^{1.000-0.135\ln T_4}$	*b*
”	^{1}D$_2$–^{1}S$_0$	$0.0893\ T_4^{0.662-0.089\ln T_4}$	*b*
		...	

a fit to Bell et al. (1998)
b fit to Zatsarriny & Tayal (2003)
noted 2015.02.27

- Appendix F, Table F.5, p. 500: Level u in the fourth line in the table should be ^{2}P$^o_{3/2}$ rather than ^{2}P$^o_{5/2}$.
  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

H	C I	^{3}P$_0$ – ^{3}P$_1$	$1.26\times10^{-10}T_2^{0.115+0.057\ln T_2}$	*b*
H	C I	^{3}P$_0$ – ^{3}P$_2$	$8.90\times10^{-11}T_2^{0.228+0.046\ln T_2}$	*b*
H	C I	^{3}P$_1$ – ^{3}P$_2$	$2.64\times10^{-10}T_2^{0.231+0.046\ln T_2}$	*b*

noted 2015.07.03 by Munan Gong.

- Appendix F, Table F.6, p. 501: the rates for entries 23-28 should be changed to

H$_2$(para)	O I	^{3}P$_2$ – ^{3}P$_1$	$1.49\times10^{-10}T_2^{0.369-0.026\ln T_2}$	*h*
H$_2$(ortho)	O I	^{3}P$_2$ – ^{3}P$_1$	$1.37\times10^{-10}T_2^{0.395-0.005\ln T_2}$	*h*
H$_2$(para)	O I	^{3}P$_2$ – ^{3}P$_0$	$2.37\times10^{-10}T_2^{0.255+0.016\ln T_2}$	*h*
H$_2$(ortho)	O I	^{3}P$_2$ – ^{3}P$_0$	$2.23\times10^{-10}T_2^{0.284+0.035\ln T_2}$	*h*
H$_2$(para)	O I	^{3}P$_1$ – ^{3}P$_0$	$2.10\times10^{-12}T_2^{1.117+0.070\ln T_2}$	*h*
H$_2$(ortho)	O I	^{3}P$_1$ – ^{3}P$_0$	$3.00\times10^{-12}T_2^{0.792+0.188\ln T_2}$	*h*

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. 506, typo: ...a time $\sim E_{u\ell}/h \rightarrow$ ...a time $\sim h/E_{u\ell}$
noted 2013.02.07 by Munan Gong.

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

$$\frac{Ze^2}{a_0 kT} = \frac{31.56Z}{T_4}$$

noted 2019.01.14.

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

$$Y_3 = E_{\rm grav} = \frac{1}{2}\int dV_1 \int dV_2\, G\,\frac{\rho(\mathbf{r}_1)\rho(\mathbf{r}_2)}{|\mathbf{r}_1-\mathbf{r}_2|}$$

→

$$Y_3 = E_{\rm grav} = -\frac{1}{2}\int dV_1 \int dV_2\, G\,\frac{\rho(\mathbf{r}_1)\rho(\mathbf{r}_2)}{|\mathbf{r}_1-\mathbf{r}_2|}$$

noted 2020.11.13

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

$$\Pi_0 \equiv \oint d\mathbf{S}\cdot\mathbf{r}p \quad \rightarrow \quad \Pi_0 \equiv \frac{1}{3}\oint d\mathbf{S}\cdot\mathbf{r}p$$

noted 2017.03.08.