

Physics of the Interstellar and Intergalactic Medium

Errata in the first printing.

Updated 2024.12.08

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
Ninth printing:	9 10

Errata in the first printing.

- preface, p. xvii, typo: reaquaint → reacquaint
  noted 2011.02.13 by B. Hensley.

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

- §1, p. 2, 1st paragraph, typo:
  nuclear transitions and π^0 decays. → nuclear transitions, π^0 decays, and $e^+ - e^-$ annihilations.
  noted 2012.06.26

- §1.1, p. 6, Table 1.3: change range of densities for H II gas from $0.3 - 10^4\,\mathrm{cm}^{-3}$ to $0.2 - 10^4\,\mathrm{cm}^{-3}$.
  noted 2011.09.22 by B. Ménard.

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

- §2, p. 11, 3rd paragraph, typo: three basic types → four basic types
  noted 2012.06.22 by F. van der Tak.

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

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

  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

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

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

  noted 2019.02.06

- §5.2.2, p. 50, Fig. 5.5: add reference to caption: (Chandra et al. 1984)
  ref: Chandra, Kegel & Varshalovich 1984, *Astr. Astrophys. Suppl.*, **55**, 51.
  noted 2011.11.03.

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

- §5.2.2, p. 50: the text should have made clear that the selection rules given were specifically for H_2O: change
  The selection rules for electric dipole radiative transitions are $\Delta J = 0, \pm 1$; $\Delta K_{-1} = \pm 1, \pm 3$; and $\Delta K_{+1} = \pm 1, \pm 3$.
  to
  The selection rules for electric dipole radiative transitions in H_2O are $\Delta J = 0, \pm 1$; $\Delta K_{-1} = \pm 1, \pm 3$; and $\Delta K_{+1} = \pm 1, \pm 3$; for less symmetric molecules (e.g., HDO) additional transitions are allowed.
  noted 2011.11.03 by J. M. Shull.

- §6.4, p. 58, Eq. (6.29), typo: replace $7618\,\mathrm{cm\,s^{-1}} \rightarrow 7616\,\mathrm{cm\,s^{-1}}$
  and in the following line change $7618\,\mathrm{cm\,s^{-1}} \rightarrow 7616\,\mathrm{cm\,s^{-1}}$.
  noted 2011.08.18 by K.-G. Lee.

- §6.4, p. 58, typos: change
  H Lyman α ($\lambda = 1215\,\text{Å}$) has ... $f_{\ell u} = 0.4162$
  $\rightarrow$
  H Lyman α ($\lambda = 1215.67\,\text{Å}$) has ... $f_{\ell u} = 0.4164$,
  and in the following sentence, change 0.4162 $\rightarrow$ 0.4164.
  noted 2011.08.19

- §6.4, p. 60, Eq. (6.41), typo: replace

$$2924 \left[\frac{7618\,\mathrm{cm\,s^{-1}}}{\gamma_{u\ell}\lambda_{u\ell}} b_6 \right] \rightarrow 2925 \left[\frac{7616\,\mathrm{cm\,s^{-1}}}{\gamma_{u\ell}\lambda_{u\ell}} b_6 \right]$$

  and in Eq. (6.42) change $7618\,\mathrm{cm\,s^{-1}} \rightarrow 7616\,\mathrm{cm\,s^{-1}}$.
  noted 2011.08.18 by K.-G. Lee.

- §7.5, p. 69, Eq. (7.29), typo: missing a factor n_ℓ. Should read

$$\kappa_\nu = n_\ell \sigma_{\ell\to u}\left(1 - \frac{n_u/g_u}{n_\ell/g_\ell}\right) < 0$$

  noted 2020.10.12 by Yan Liang.

- §8.1, p. 71, 3 places: just before Eq. (8.4), just after Eq. (8.7), and between Eq. (8.8) and (8.9): change "absorption coefficient" $\rightarrow$ "attenuation coefficient".
  noted 2011.03.07

- §8.1, p. 71, Eq. (8.9), typo: missing a factor $n(\mathrm{H\,I})$. Should read:

$$\kappa_\nu = \frac{3}{32\pi}\frac{1}{\sqrt{2\pi}}\frac{A_{u\ell}\lambda_{u\ell}^2}{\sigma_V}\frac{hc}{kT_{\rm spin}} n(\mathrm{H\,I}) \mathrm{e}^{-u^2/2\sigma_V^2} \qquad (8.9)$$

  noted 2011.03.07 by P. Pattarakijwanich.

- §8.1, p. 71, Eq. (8.10), typo: omit the comma.
  noted 2010.02.09

- §8.2, p. 72, Eq. (8.17), typo: change 54.89 $\rightarrow$ 55.17
  noted 2011.07.06 by R. Allen.

- §8.2, p. 73, Eq. (8.21), typo: change $(1+z) \rightarrow (1+z)^{-1}$
  noted 2012.06.01 by B. Catinella and N. Evans.

- §8.3, p. 74, Eq. (8.26), typo: $T_{\rm sky}(v) \rightarrow T_{\rm sky}$ (two occurrences).
  noted 2011.02.10

- §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.

- §9.4, p. 79, Eq. (9.21), the second "=" should be changed to "$\approx$".
  noted 2011.08.18 by K.-G. Lee.

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

- §9.10, Table 9.4, p. 88, typos: for C II and N III, change ${}^2{\rm D}_J^o \rightarrow {}^2{\rm D}_J$ 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. 96, Eq. (10.23), typo (extraneous factor of cm^5):
$$...\nu_9^{-2.118}\,\mathrm{cm}^5\left(\frac{n_i}{n_p}\right)\frac{EM}{10^{25}\,\mathrm{cm}^{-5}} \quad\rightarrow\quad ...\nu_9^{-2.118}\left(\frac{n_i}{n_p}\right)\frac{EM}{10^{25}\,\mathrm{cm}^{-5}}$$
noted 2011.03.05 by B. Hensley and P. Pattarakijwanich.

- §10.5, p. 97, Eq. (10.25), typo (missing factor of 2): should read
$$j_{\mathrm{fb},\nu} = \frac{g_\mathrm{b}}{g_e g_i}\frac{2\,h^4\nu^3}{(2\pi m_e kT)^{3/2}c^2}\,\mathrm{e}^{(I_\mathrm{b}-h\nu)/kT}\,\sigma_{\mathrm{b,pi}}(\nu)n_e n_i$$
noted 2021.02.14 by Shigenobu Hirose.

- §10.5, p. 97, foonote 3, typo: $5\times10^6\,\mathrm{cm}^{-3}\,\mathrm{pc} \rightarrow 5\times10^6\,\mathrm{cm}^{-6}\,\mathrm{pc}$.
noted 2011.02.15 by C. Petrovich.

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

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

- §12.1, p. 120, Eq. (12.1), add: where $\nu_9 \equiv \nu/\,\mathrm{GHz}$
noted 2012.06.22 by F. van der Tak.

- §12, p. 121, Table 12.1, typos:

CMB, $T = 2.725\,\mathrm{K}$	:	4.19×10^{-13}	$\rightarrow$	4.17×10^{-13}
$T_2 = 4000\,\mathrm{K}$, $W_2 = 1.65\times10^{-13}$	:	3.19×10^{-13}	$\rightarrow$	3.20×10^{-13}
$T_3 = 7500\,\mathrm{K}$, $W_3 = 1\times10^{-14}$	:	2.29×10^{-13}	$\rightarrow$	2.39×10^{-13}
Starlight total	:	1.05×10^{-12}	$\rightarrow$	1.06×10^{-12}
ISRF total	:	2.19×10^{-12}	$\rightarrow$	1.98×10^{-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. 128, typo:
$\sigma_{\rm pe}({\rm H_2}) = 2.8\sigma_{\rm p.i.}({\rm H}) \rightarrow \sigma_{\rm pe}({\rm H_2}) = 2.8\sigma_{\rm pe}({\rm H})$
noted 2011.03.06

- §13.1, p. 129, clarification:
...photoionization cross sections for O... $\rightarrow$
...photoionization cross sections $\sigma_{\rm pi}$ for O...
noted 2011.03.06

- §13.1, p. 130, Eq. (13.5), clarification:
$\zeta_{\rm p.i.} \rightarrow \zeta_{\rm pi}$, $\sigma_{\rm pe} \rightarrow \sigma_{\rm pi}$
noted 2011.03.06

- §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

- §13.1, p. 131, Table 13.1, typo: $\zeta_{\rm p.i.} \rightarrow \zeta_{\rm pi}$, $\sigma_{\rm p.i.} \rightarrow \sigma_{\rm pi}$
noted 2011.03.06

- §13.4, p. 134, typos:
$\sigma_{\rm c.i.} \rightarrow \sigma_{\rm ci}$ (4 places), $k_{\rm c.i.} \rightarrow k_{\rm ci}$ (2 places).
noted 2011.03.06

- §14.2, p. 138, Table 14.1. A reference to Burgess (1965; *Mem. Royal Astr. Soc.*, **69**, 1) [the source of the hydrogenic radiative recombination rates] has been added in the table footnote. Upon recomputing the rates from Burgess, a few of the table entries had the last digit change by 1. Some of the coefficients in the approximate fitting formulae have also changed slightly. Here is the revised version:

Table 14.1 Recombination Coefficients $\alpha_{n\ell}$ $({\rm cm}^3\,{\rm s}^{-1})$ for H.[a] The approximation formulae are valid for $0.3 \lesssim T_4 \lesssim 3$. For a broader range of T, see Eq. (14.5,14.6).

	Temperature T			
$\alpha_n(^2L)$	5×10^3 K	1×10^4 K	2×10^4 K	approximation
α_{1s}	2.28×10^{-13}	1.58×10^{-13}	1.08×10^{-13}	$1.58\times10^{-13}T_4^{-0.540-0.017\ln T_4}$
α_{2s}	3.37×10^{-14}	2.34×10^{-14}	1.60×10^{-14}	$2.34\times10^{-14}T_4^{-0.537-0.019\ln T_4}$
α_{2p}	8.33×10^{-14}	5.36×10^{-14}	3.24×10^{-14}	$5.36\times10^{-14}T_4^{-0.681-0.061\ln T_4}$
α_2	1.17×10^{-13}	7.70×10^{-14}	4.84×10^{-14}	$7.70\times10^{-14}T_4^{-0.636-0.046\ln T_4}$
α_{3s}	1.13×10^{-14}	7.82×10^{-15}	5.29×10^{-15}	$7.82\times10^{-15}T_4^{-0.547-0.024\ln T_4}$
α_{3p}	3.17×10^{-14}	2.04×10^{-14}	1.23×10^{-14}	$2.04\times10^{-15}T_4^{-0.683-0.062\ln T_4}$
α_{3d}	3.03×10^{-14}	1.73×10^{-14}	9.09×10^{-15}	$1.73\times10^{-14}T_4^{-0.868-0.093\ln T_4}$
α_3	7.33×10^{-14}	4.55×10^{-14}	2.67×10^{-14}	$4.55\times10^{-14}T_4^{-0.729-0.060\ln T_4}$
α_{4s}	5.23×10^{-15}	3.59×10^{-15}	2.40×10^{-15}	$3.59\times10^{-15}T_4^{-0.562-0.026\ln T_4}$
α_{4p}	1.51×10^{-14}	9.66×10^{-15}	5.80×10^{-15}	$9.66\times10^{-15}T_4^{-0.691-0.064\ln T_4}$
α_{4d}	1.90×10^{-14}	1.08×10^{-14}	5.67×10^{-15}	$1.08\times10^{-14}T_4^{-0.870-0.094\ln T_4}$
α_{4f}	1.09×10^{-14}	5.54×10^{-15}	2.57×10^{-15}	$5.54\times10^{-15}T_4^{-1.041-0.100\ln T_4}$
α_4	5.02×10^{-14}	2.96×10^{-14}	1.64×10^{-14}	$2.96\times10^{-14}T_4^{-0.805-0.065\ln T_4}$
α_A	6.81×10^{-13}	4.17×10^{-13}	2.51×10^{-13}	$4.17\times10^{-13}T_4^{-0.721-0.018\ln T_4}$
α_B	4.53×10^{-13}	2.59×10^{-13}	1.43×10^{-13}	$2.59\times10^{-13}T_4^{-0.833-0.035\ln T_4}$

[a] $\alpha_{n\ell}$ from Burgess (1965); α_B from Hummer & Storey (1987) (for $n_e = 10^3\,\mathrm{cm}^{-3}$)

- §14.2, p. 139, typos: In Equations (14.3) and (14.4), the leading factor of Z should be to the first power, rather than Z^2: the equations should read

$$\alpha_A(T) \approx 4.13\times10^{-13}\,Z\,(T_4/Z^2)^{-0.7131-0.0115\ln(T_4/Z^2)}\,\mathrm{cm}^3\,\mathrm{s}^{-1}\ , \qquad (14.3)$$
$$\alpha_B(T) \approx 2.54\times10^{-13}\,Z\,(T_4/Z^2)^{-0.8163-0.0208\ln(T_4/Z^2)}\,\mathrm{cm}^3\,\mathrm{s}^{-1}\ . \qquad (14.4)$$

  noted 2012.01.04 by E. Jenkins.

- Fig. 14.1, p. 140, typos: the quantities plotted should be labelled $Z^{-2}T_4^{1/2}\alpha_\mathrm{A}$ and $Z^{-2}T_4^{1/2}\alpha_\mathrm{B}$ (rather than $Z^{-3}T_4^{1/2}\alpha_\mathrm{A}$ and $Z^{-3}T_4^{1/2}\alpha_\mathrm{B}$):

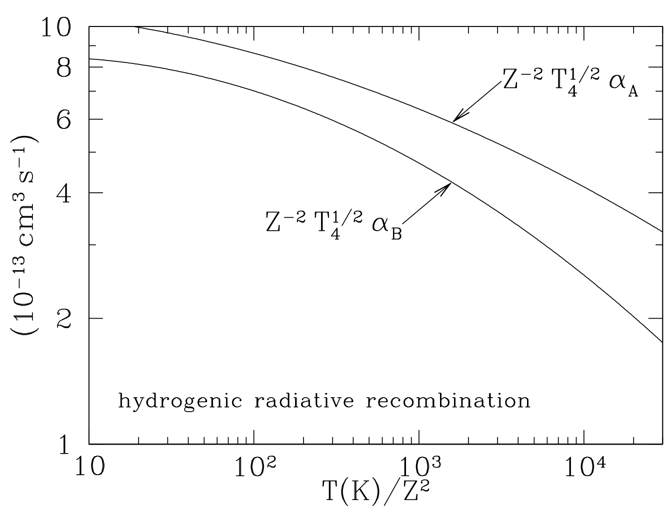


Figure 14.1 Case A and Case B rate coefficients α_A and α_B for radiative recombination of hydrogen, multiplied by $T_4^{1/2}$ (equations 14.5,14.6). Note that no single power-law fit can reproduce the T-dependence over a wide range in T.

noted 2012.01.04 by E. B. Jenkins.

- Table 14.2, p. 143, typo: Pfundt $\rightarrow$ Pfund
  noted 2011.03.05 by B. Hensley.

- §14.2.4, p. 144, Eq. (14.11), typo: $1880\,\mathrm{cm}^{-3} \rightarrow 1.55\times10^4\,\mathrm{cm}^{-3}$
  noted 2011.03.17

- §14.2.4, p. 145, Eq. (14.13), typo (was off by factor of 10): should read

$$\tau_0(\mathrm{Ly}\alpha) = 8.02\times10^3\left(\frac{15\,\mathrm{km\,s}^{-1}}{b}\right)\tau(\mathrm{Ly\,cont})$$

  noted 2024.06.11 by D. Chernoff.

- §14.5, p. 151, typo: [OIII]4959,5007 $\rightarrow$ [OIII]4960,5008
  noted 2012.06.22 by F. van der Tak.

- §14.6, p. 153, typo:
  ...from the wave function of AB... $\rightarrow$ ...from the wave function of AB^+...
  noted 2011.03.05 by P. Pattarakijwanich.

- §14.6, p. 154, Table 14.8 update: replace
  $\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H}_2 + \mathrm{H}$ $\quad 1.1\times10^{-7}T_2^{-0.56}$ McCall et al. (2004)
  with
  $\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H} + \mathrm{H} + \mathrm{H}$ $\quad 8.9\times10^{-8}T_2^{-0.48}$ McCall et al. (2004)
  $\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H}_2 + \mathrm{H}$ $\quad 5.0\times10^{-8}T_2^{-0.48}$ McCall et al. (2004)
  noted 2013.04.03

- §14.7.1, p. 155, typo:
  $$I_{\mathrm{O}(^3\mathrm{P}_0)} = 13.6181\,\mathrm{eV}, \quad \rightarrow \quad I_{\mathrm{O}(^3\mathrm{P}_2)} = 13.6181\,\mathrm{eV}),$$
  noted 2011.02.22 by Xu Huang.

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

- §14.7.1, p. 156, Eq. (14.31), for notational consistency: $n(\mathrm{H}) \rightarrow n(\mathrm{H}^0)$
  noted 2011.05.15 by E. B. Jenkins.

- §14.7.1, p. 156, just before Eq. (14.35), typo:
  In the low density limit... $\rightarrow$ In the high density limit...
  noted 2011.05.15 by E. B. Jenkins.

- §14.7.1, p. 157, Figure 14.5: plotted curves were numerically incorrect.
  Corrected Figure 14.5:

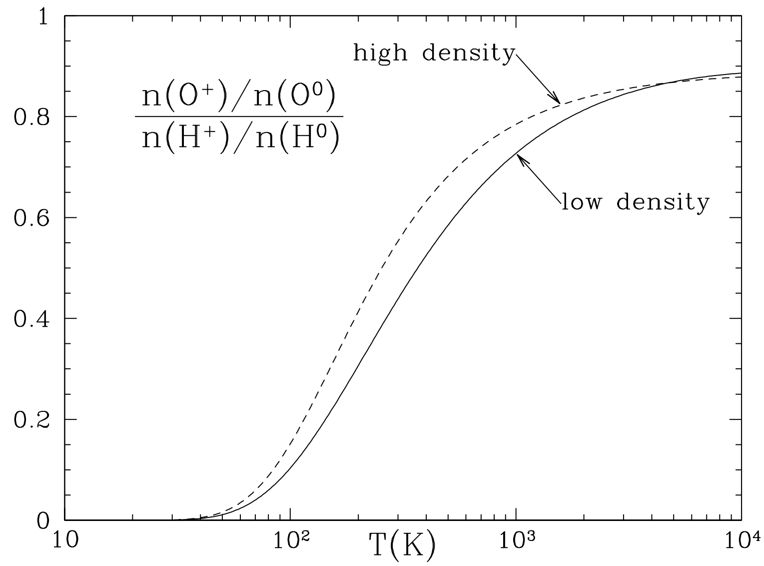


Figure 14.5 Dependence of oxygen ionization fraction on hydrogen ionization fraction due to charge exchange. The low-density limit applies for $n_{\rm H} \lesssim 10^4\,{\rm cm}^{-3}$.
noted 2011.05.18 by E. B. Jenkins.

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

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

  noted 2015.06.01 by E. B. Jenkins.

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

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

  noted 2015.06.01 by E. B. Jenkins.

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

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

  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.

- §15.1, p. 163, typo: $\sigma_{\rm p.i.} \;\rightarrow\; \sigma_{\rm pi}$ (two places)
  noted 2011.03.05

- §15.1.2, p. 163, change
  the Case B radiative recombination rate for ${\rm He}^+ + e^- \rightarrow {\rm He}^0$ is ~ 1.9 times

larger than for hydrogen.
$\rightarrow$
$\alpha_{\rm eff}({\rm He})/\alpha_B({\rm H}) \approx 1.1 - 1.7$, depending on the fraction y of $h\nu > 24.6\,{\rm eV}$ photons that are absorbed by H.
noted 2011.03.17

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

- §15.1.2, p. 165, change
will be $\sim 18\%$ $\rightarrow$ will be $\sim 14\%$
noted 2011.03.17

- §15.1.2, p. 165, change
if $Q_1 < 0.18Q_0$, $\rightarrow$ if $Q_1 \lesssim 0.14Q_0$,
noted 2011.03.17

- §15.1.2, p. 165, change
$Q_1/Q_0 \geq 0.18$, $\rightarrow$ $Q_1/Q_0 \gtrsim 0.14$,
noted 2011.03.17

- §15.1.2, p. 165, change
O6.1 V and earlier, O5.3 III and earlier, and O4 I and earlier – have $Q_1/Q_0 \gtrsim 0.18$.
$\rightarrow$
O6.9 V and earlier, O6.5 III and earlier, and O6 I and earlier – have $Q_1/Q_0 \gtrsim 0.14$.
noted 2011.03.17

- §15.4, p. 168, Eq. (15.19), typo: $\sigma_d \rightarrow \sigma_{\rm dust}$
noted 2011.02.24 by Xu Huang.

- §15.3, p. 166, Eqs. (15.10, 15.11), typo: $\sigma_{\rm p.i.} \rightarrow \sigma_{\rm pi}$
noted 2011.03.06

- §15.3, p. 167, Eq. (15.12), typo: $\sigma_{\rm p.i.} \rightarrow \sigma_{\rm pi}$
noted 2011.03.06

- §15.3, p. 167, Eq. (15.13), typo:
$$3360\,(Q_{0,49})^{1/3}\,n_2^{1/3} \;\rightarrow\; 2880\,(Q_{0,49})^{1/3}\,n_2^{1/3}T_4^{0.28}$$
where we have taken $\sigma_{\rm pi} = 2.95 \times 10^{-18}\,{\rm cm}^2$.
noted 2011.03.17

- §15.4, p. 169, Eq. (15.27) (twice) and following paragraph (twice): typo:
$\sigma_d \rightarrow \sigma_{\rm dust}$
noted 2011.03.05 by B. Hensley.

- §15.4, p. 170, Eq. (15.30), typo: $\sigma_d \rightarrow \sigma_{\rm dust}$
noted 2011.03.05 by B. Hensley.

- §15.4, p. 170, following Eq. (15.30), add:
  where $\sigma_{d,-21} \equiv \sigma_{\rm dust}/10^{-21}\,{\rm cm}^2$.
  noted 2011.03.05

- §15.5, p. 172, line 4, typo: ... about the He ... $\rightarrow$ ... above the He ...
  noted 2011.03.06 by S. Ferraro

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

- §15.7.1, p. 179, Eq. (15.53), typo: $\sigma_d \rightarrow \sigma_{\rm dust}$
  noted 2011.03.05

- §15.7, p. 180, typo: substantially reduced $\rightarrow$ substantially increased
  noted 2011.02.24

- §15.8, p. 180, Eq. (15.59), typo: there is a spurious factor of c in the denominator. It should read
  $$U \equiv \frac{1}{n_{\rm H}} \int_{\nu_0}^{\infty} \frac{u_\nu d\nu}{h\nu}$$
  noted 2011.03.06 by S. Ferraro.

- §16.4, p. 186, Eq. (16.9, 16.10), update: change
  $$\begin{aligned} &{\rm H}_3^+ + e^- \rightarrow {\rm H}_2 + {\rm H} \quad , \quad k_{16.9} = 4.1 \times 10^{-8} T_2^{-0.52}\,{\rm cm}^3\,{\rm s}^{-1} \ , \\ &{\rm H}_3^+ + e^- \rightarrow {\rm H} + {\rm H} + {\rm H} \quad , \quad k_{16.10} = 7.7 \times 10^{-8} T_2^{-0.52}\,{\rm cm}^3\,{\rm s}^{-1} \ , \end{aligned}$$
  to
  $$\begin{aligned} &{\rm H}_3^+ + e^- \rightarrow {\rm H}_2 + {\rm H} \quad , \quad k_{16.9} = 5.0 \times 10^{-8} T_2^{-0.48}\,{\rm cm}^3\,{\rm s}^{-1} \ , \\ &{\rm H}_3^+ + e^- \rightarrow {\rm H} + {\rm H} + {\rm H} \quad , \quad k_{16.10} = 8.9 \times 10^{-8} T_2^{-0.48}\,{\rm cm}^3\,{\rm s}^{-1} \ , \end{aligned}$$
  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
  $x_e \approx x_M \approx 1.9 \times 10^{-4} \quad \rightarrow \quad x_e \approx x_M \approx 1.1 \times 10^{-4}$ (see Eq. 16.3)
  noted 2013.04.04

- §16.5, p. 188, Eq. (16.16), typo: should read
  $${\rm H}_2 + {\rm CR} \rightarrow {\rm H}_2^+ + e^- + {\rm CR}$$
  noted 2020.09.29 by R. Córdova

- §16.5, p. 188, Eq. (16.18), added information:
  $${\rm H}_3^+ + M \rightarrow M{\rm H}^+ + {\rm H}_2 \ : \quad k_{16.18} \approx 2 \times 10^{-9}\,{\rm cm}^3\,{\rm s}^{-1} \qquad (16.18)$$
  noted 2011.04.03

- §16.5, p. 189, Eq. (16.25), typo: in numerator of RHS, replace $k_{16.19} \rightarrow A$, so that it reads

$$\frac{n_e}{n_{\rm H}} = \frac{\left[B^2 + 4A\zeta_{\rm CR}(1+\phi_s)/n_{\rm H}\right]^{1/2} - B}{2k_{16.19}} \quad , \tag{16.25}$$

noted 2011.03.30 by C. Hill.

- §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 $\zeta_{\rm CR} = 1\times10^{-17}\,{\rm s}^{-1}$:

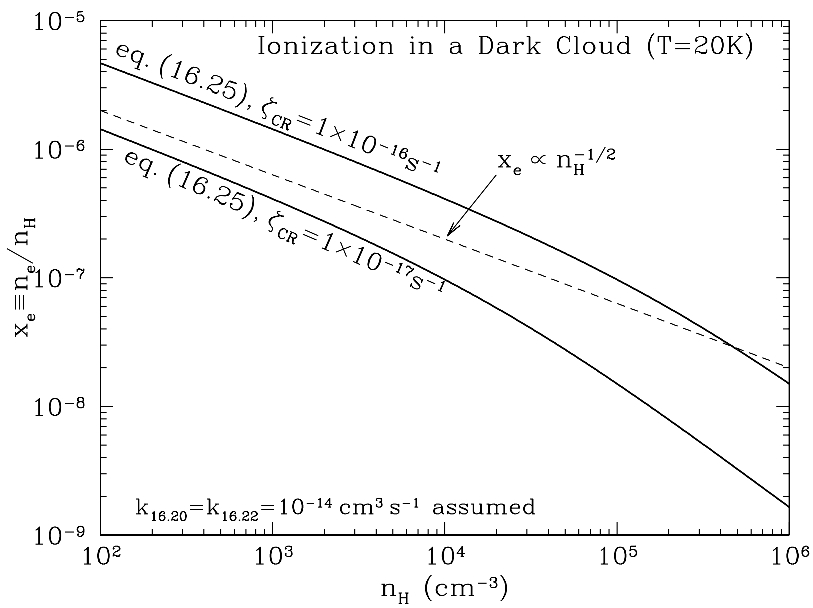


Figure 16.3 Fractional ionization in a dark cloud, estimated using Eq. (16.25), with the grain recombination rate coefficients set to $k_{16.20} = k_{16.22} = 10^{-14}\,{\rm cm}^3\,{\rm s}^{-1}$ (see Fig. 14.6). The dashed line is a simple power-law approximation $x_e \approx 2\times 10^{-5}(n_{\rm H}/\,{\rm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

noted 2013.03.05.

- §17.2, p. 192, Table 17.1. This has been revised to include critical densities for both H and e^-:

Table 17.1 Critical Densities for Fine-Structure Excitation in H I Regions

						$n_{\mathrm{crit},u}(\mathrm{H})$		$n_{\mathrm{crit},u}(e^-)$	
			E_ℓ/k	E_u/k	$\lambda_{u\ell}$	$T=100\,\mathrm{K}$	$T=5000\,\mathrm{K}$	$T=100\,\mathrm{K}$	$T=5000\,\mathrm{K}$
Ion	ℓ	u	(K)	(K)	(μm)	(cm^{-3})	(cm^{-3})	(cm^{-3})	(cm^{-3})
C II	$^2\mathrm{P}^o_{1/2}$	$^2\mathrm{P}^o_{3/2}$	0	91.21	157.74	2.7×10^3	1.5×10^3	6.8	40.
C I	$^3\mathrm{P}_0$	$^3\mathrm{P}_1$	0	23.60	609.7	620	170	76.	6.4
	$^3\mathrm{P}_1$	$^3\mathrm{P}_2$	23.60	62.44	370.37	720	150	75.	6.3
O I	$^3\mathrm{P}_2$	$^3\mathrm{P}_1$	0	227.71	63.185	2.5×10^5	4.9×10^4	1.8×10^5	4.8×10^4
	$^3\mathrm{P}_1$	$^3\mathrm{P}_0$	227.71	326.57	145.53	2.4×10^4	8.6×10^3	2.3×10^4	5.8×10^3
Si II	$^2\mathrm{P}^o_{1/2}$	$^2\mathrm{P}^o_{3/2}$	0	413.28	34.814	2.5×10^5	1.2×10^5	140.	1.5×10^3
Si I	$^3\mathrm{P}_0$	$^3\mathrm{P}_1$	0	110.95	129.68	4.8×10^4	2.8×10^4	2.9×10^4	830.
	$^3\mathrm{P}_1$	$^3\mathrm{P}_2$	110.95	321.07	68.473	9.9×10^4	3.6×10^4	4.4×10^4	1.9×10^3

noted 2011.03.06

- §17.3, p. 195, footnote 3, typos:
  ...frequency $\sim 8\times10^{10}$ Hz... $\rightarrow$ ...frequency $\sim 1.1\times10^{10}$ Hz...
  ...$\sim 10^2$ precession periods. $\rightarrow$ ...~ 18 precession periods.
  noted 2020.10.02

- §17.5, p. 197, Eq. (17.27) should read

$$R_{12} = (g_2/g_1)\left[C_{21}e^{-E_{21}/kT} + n_{\gamma,21}A_{21}\right] . \tag{17.27}$$

  noted 2010.11.27

- §17.7, p. 199, top line, typo: $n_{\mathrm{H,crit}} \rightarrow n_{\mathrm{crit}}(\mathrm{H})$
  noted 2011.03.10

- §18.1.2, Fig. 18.3, p. 208, two typos: The ground states of S II and Ar IV should both have degeneracy $g_0 = 4$
  noted 2012.11.12 by A. Natta

- §18.4.1, p. 212: Replace wavelength in air with wavelength *in vacuo*:
  "Balmer jump" at $\lambda = 3645.1$ Å $\rightarrow$ "Balmer jump" at $\lambda = 3647.0$ Å
  noted 2011.03.11

- §18.4.1, p. 212: Refine wavelength midway between H 20 and H 21 lines:
  $\lambda_{\mathrm{BJ,red}} = 3682.6$ Å $\rightarrow$ $\lambda_{\mathrm{BJ,red}} = 3682.1$ Å
  noted 2011.03.11

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

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

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

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

  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

- §19.4, p. 224, typo: functon $\rightarrow$ function
noted 2011.03.11 by C. Petrovich

- §20.1, p. 229, typo just below Eq. (20.2): replace
...unit time that level x will... $\rightarrow$ ...unit time the level u will...
noted 2020.10.12 by Yan Liang

- §21.3, p. 242, typo: ...into the UV. whereas... $\rightarrow$ ...into the UV, whereas...
noted 2011.03.21

- §21.6.1, p. 244, typo: $k^2 = \epsilon_{\rm ISM}\omega^2 c^2 \quad\rightarrow\quad k^2 = \epsilon_{\rm ISM}\omega^2/c^2$
noted 2011.03.28

- §21.6.1, p. 244, Eq. (21.12), typo:
$$n_{\rm gr}C_{\rm ext}(\omega) = 2{\rm Im}(k) = 2\omega c{\rm Im}(\sqrt{\epsilon_{\rm ISM}}) \approx \omega c\,{\rm Im}(\epsilon_{\rm ISM}) \tag{21.12}$$
$\rightarrow$
$$n_{\rm gr}C_{\rm ext}(\omega) = 2{\rm Im}(k) = 2(\omega/c){\rm Im}(\sqrt{\epsilon_{\rm ISM}}) \approx (\omega/c)\,{\rm Im}(\epsilon_{\rm ISM}) \tag{21.12}$$
noted 2011.03.28

- §22.4.2, p. 252, Eq. (22.27), typo: $4\pi \rightarrow 9\pi$.
noted 2012.06.26

- §22.6, p. 256, footnote 6: the DDSCAT website has moved. Change
http://code.google.com/p/ddscat $\rightarrow$ http://www.ddscat.org
noted 2019.03.25

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

- §23.1, p. 266, typo: $\mathrm{Mg}_2x\mathrm{Fe}_{2-2x}\mathrm{SiO}_4 \rightarrow \mathrm{Mg}_{2x}\mathrm{Fe}_{2-2x}\mathrm{SiO}_4$
noted 2011.03.24 by C. Petrovich

- §23.3.2, p. 268, typo: Si-O-Si bending mode $\rightarrow$ O-Si-O bending mode
noted 2020.10.12

- §23.3, p. 269, typo: ...that the *at most*... $\rightarrow$ ...that *at most*...
noted 2011.03.23

- §23.4, p. 272, Fig. 23.5 caption, typo: Lowe panels:... $\rightarrow$ Lower panels:...
  noted 2011.03.23

- §23.10, p. 280, typo: varyies $\rightarrow$ varies
  noted 2011.03.23

- §23.10, p. 283, typo: totaly $\rightarrow$ total
  noted 2011.03.23

- §24.2, p. 293, typo: ...does not extend below $\sim$23K. $\rightarrow$ ...does not extend below $\sim$35K.
  noted 2011.03.24

- §24.2, p. 293, typo:
  ...corresponds the grain... $\rightarrow$ ...corresponds to the grain...
  noted 2011.03.25

- §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

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

  noted 2014.06.27 by B. Jiang.

- §26.2.2, p. 309, Fig. 26.2: the rightmost abscissa label should read "100", not "10".
  noted 2011.03.29 by B. Hensley.

- §26.3.1, p. 311, Eq. (26.24), typo:

$$\mu = \frac{Qa^2\omega}{3} \quad \rightarrow \mu = \frac{Qa^2\omega}{3c}$$

  noted 2011.05.01 by P. Pattarakijwanich.

- §26.3.1, p. 311, Eq. (26.25), typos: The equation should read

$$\Omega_L = \frac{5UB}{8\pi\rho a^2 c} = 3.7\times10^{-10}\left(\frac{3\,{\rm g\,cm^{-3}}}{\rho}\right)\left(\frac{U}{\rm Volt}\right)\left(\frac{B}{5\,\mu{\rm G}}\right)\left(\frac{0.1\,\mu{\rm m}}{a}\right)^2{\rm s}^{-1}. \qquad (26.25)$$

  noted 2011.05.01 by P. Pattarakijwanich.

- §26.3.1, p. 311, after Eq. (26.25), typo: $2\pi/\Omega_L \approx 10\,{\rm yr}$ $\rightarrow$ $2\pi/\Omega_L \approx 500\,{\rm yr}$
  noted 2011.05.01 by P. Pattarakijwanich.

- §27.1, p. 315, 2nd paragraph, typo:
...resulting photoelectron will... $\rightarrow$ ...resulting photoelectrons will...
noted 2011.03.31

- §27.1, p. 317, typo: ...injection of photoelectron energy rate... $\rightarrow$ ...injection of photoelectron energy...
noted 2012.06.22 by F. van der Tak.

- §27.1, p. 317, typo: ...nebulae dust are dusty,... $\rightarrow$ ...nebulae are dusty,...
noted 2011.03.31

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

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

  and (27.22) and (27.23) should read

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

  noted 2023.01.29 by S. R. Kulkarni.

- §28.1, p. 326, 2nd paragraph, typo: ...form the the... $\rightarrow$ ...form the...
noted 2011.03.31

- §28.2, p. 327, 2nd paragraph, typo:
$EM \approx 5\times10^6\,{\rm cm}^{-3}\,{\rm pc} \rightarrow EM \approx 5\times10^6\,{\rm cm}^{-6}\,{\rm pc}$
noted 2011.03.31 by C. Petrovich.

- §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.

- §29.4, p. 335, typo:
...found $nT \approx 2800\,{\rm cm}^{-3}\,{\rm K}$... $\rightarrow$ ...found $nT \approx 3800\,{\rm cm}^{-3}\,{\rm K}$...
noted 2011.04.05

- §29.4, p. 335, typo: ...implies $n_{\rm H} \approx 35\,{\rm cm}^{-3}$. $\rightarrow$ ...implies $n_{\rm H} \approx 50\,{\rm cm}^{-3}$.
noted 2011.04.05

- §30.2, p. 339, typo: ...near threshold are... $\rightarrow$ near-threshold yields are...
noted 2011.04.05 by B. Hensley.

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

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

  noted 2013.04.12 by Ai-Lei Sun.

- §31.4, p. 349, Eq. (31.25), typo: $\tau_{1000} \to \tau_{d,1000}$
  noted 2012.07.10

- §32.1, p. 357, 1st paragraph, typo: ...a their... $\to$ ...their...
  noted 2012.06.22 by F. van der Tak.

- §32.1, p. 357, 2nd paragraph, typo: (see Plate 15). $\to$ (see Plate 11).
  noted 2011.06.07 by S. Lorenz Martins.

- §32.9, p. 368, typo: magntic $\to$ magnetic
  noted 2011.04.11

- §32.9, p. 368, just before eq. (32.11), typo: change
  $A_V/N_{\mathrm{H}} = 1.87 \times 10^{21}\,\mathrm{cm}^2 \;\to\; A_V/N_{\mathrm{H}} = 5.3 \times 10^{-22}\mathrm{mag\,cm}^2$.
  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

- §33.1, p. 375, typo: photodisociation $\to$ photodissociation
  noted 2011.04.11

- §33.1, p. 375, typo: occuring $\to$ occurring
  noted 2011.04.25 by B. Hensley.

- §33.2.2, p. 378, typo: reaction products should be $\mathrm{OH}^+ + \mathrm{H}_2$
  noted 2011.04.12

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

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

  noted 2019.04.18 by G. Halevi.

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

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

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

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

noted 2013.01.05 by B. Hensley.

- §35.3, p. 392, typo: rate-of-change $\mathbf{v}$ of... $\rightarrow$ rate-of-change of $\mathbf{v}$...
  noted 2011.04.14

- §36.1, p. 397, typo: occuring $\rightarrow$ occurring
  noted 2011.04.26

- §36.2.2, p. 399, Eq. (36.8), two corrections: $8\pi \rightarrow 4\pi$ and $B_x B_z v_x \rightarrow B_x B_z v_z$. The equation should read

$$\frac{\partial}{\partial x}\left[\frac{1}{2}\rho v_x v^2 + U v_x + p v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x - \frac{B_x B_y v_y}{4\pi} - \frac{B_x B_z v_z}{4\pi} \right.$$
$$\left. - v_j \sigma_{jx} - \kappa \frac{dT}{dx} + \rho v_x \Phi_{\rm grav}\right] = \Gamma - \Lambda\ . \quad (36.8)$$

  noted 2011.04.19

- §36.2.3, p. 400, Eq. (36.10): $8\pi \rightarrow 4\pi$ (twice)
  noted 2011.04.19
  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

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

$$\left\{\left[\frac{\rho v^2}{2} + \frac{\gamma p}{(\gamma-1)}\right] v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x - \frac{(B_x B_y v_y + B_x B_z v_z)}{4\pi} - \kappa \frac{dT}{dx}\right\}_2 . \quad (36.10)$$

- §36.2.5, p. 401, Eq. (36.16): $8\pi \rightarrow 4\pi$ (twice). The equation should read

$$\frac{\rho_1 u_1^3}{2} + \frac{\gamma}{\gamma - 1} u_1 p_1 + \frac{u_1 B_1^2}{4\pi} = \frac{\rho_2 u_2^3}{2} + \frac{\gamma}{\gamma - 1} u_2 p_2 + \frac{u_2 B_2^2}{4\pi} \quad , \quad (36.16)$$

  noted 2011.04.19

- §36.2.5, p. 401, Eq. (36.19): $8\pi \rightarrow 4\pi$ (twice). The equation should read

$$\frac{1}{2}\rho_1 v_s^3 + \frac{\gamma}{\gamma - 1} p_1 v_s + \frac{B_1^2}{4\pi} v_s = \frac{1}{2}\frac{\rho_1 v_s^3}{x^2} + \frac{\gamma}{\gamma - 1}\frac{p_2 v_s}{x} + \frac{B_1^2}{4\pi} v_s x \quad . \quad (1)$$

  noted 2011.04.19

- §36.2.5, p. 402, Eq. (36.27), typo:

$$\frac{3}{16}\mu v_s^2 \;\rightarrow\; \frac{3}{16}\frac{\mu v_s^2}{k}$$

  noted 2011.05.17 by P. Pattarakijwanich.

- §36.6, p. 409, typo: occuring $\rightarrow$ occurring
  noted 2011.04.25 by B. Hensley.

- §37.1, p. 413, 2nd paragraph: Change
  Cases of astrophysical interest will normally have..
  $\rightarrow$
  Many cases of astrophysical interest will have...
  noted 2018.04.09.

- §37.1, p. 413, typo just above Eq. (37.3):
  $Jh\nu/c = \rho_1 u_1 h\nu/\mu_i c \ll \rho_1(u_1^2 + c_1^2 + B_1^2/8\pi)$.
  $\rightarrow$
  $Jh\nu/c = \rho_1 u_1 h\nu/\mu_i c \ll \rho_1(u_1^2 + c_1^2) + B_1^2/8\pi$.
  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...
    $\rightarrow$
    ...are called **weak R-type**. Weak R-type solutions...
  - §37.1.1, p. 414, second paragraph:
    ...referred to as **weak R-type**,... $\rightarrow$ ...referred to as **strong R-type**,...

- §37.1.1, p. 414, second paragraph:
  Hence, only strong R-type I-fronts are physically relevant.
  $\rightarrow$
  Hence, only weak R-type I-fronts are physically relevant.
- §37.1.2, p. 414, first paragraph:
  ...is termed **weak D-type**. $\rightarrow$ ...is termed **strong D-type**.
- §37.1.2, p. 414, second paragraph:
  ...is termed **strong D-type**. $\rightarrow$ ...is termed **weak D-type**.
- Fig. 37.1 and caption should be:

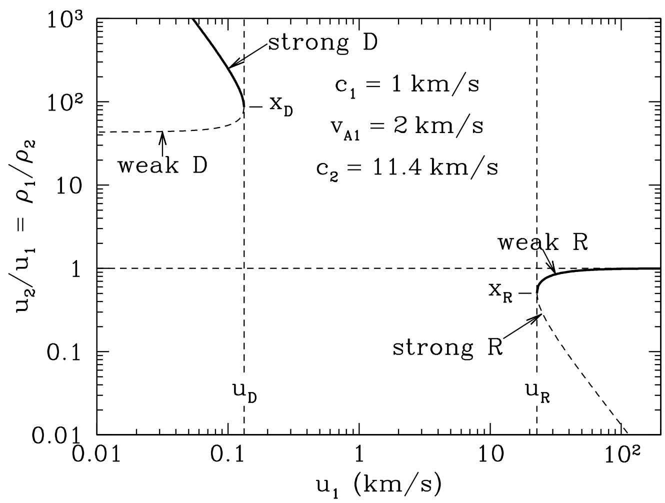


Figure 37.1 $u_2/u_1 = \rho_1/\rho_2$, as a function of the velocity u_1 of the I-front relative to the neutral gas just ahead of the I-front, for D-type and R-type ionization front solutions (see text) for an example with $c_1 = 1\,\mathrm{km\,s^{-1}}$, $v_{A1} = 2\,\mathrm{km\,s^{-1}}$, and $c_2 = 11.4\,\mathrm{km\,s^{-1}}$. 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, ... $\rightarrow$ ...will be weak R-type, ...
- §37.1, p. 417, fourth line:
  ...will now be weak D-type, ... $\rightarrow$ ...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:
  $$v_s \approx V_i \quad . \qquad (37.21)$$
  $\rightarrow$
  ...moving at a speed V_s that will be close to (just slightly larger than) the speed of the I-front:
  $$V_s \approx V_i \quad . \qquad (37.21)$$

noted 2016.12.08 by Ryohei Nakatani.

- §38.3, p. 428, last paragraph, typo:
  $\dot{M}_w \approx 2 \times 10^{-5}\,\mathrm{km\,s^{-1}} \rightarrow \dot{M}_w \approx 2 \times 10^{-5}\,M_\odot\,\mathrm{yr}^{-1}$
  noted 2015.12.17 by J. Miralda-Escudé.

- §39.1.1, p. 430, typo: case of Type II supernova → case of Type II supernovae
  noted 2011.04.21

- §39.1.1, p. 430, typo: relative dense → relatively dense
  noted 2011.04.21

- §39.1.1, p. 430, typo: Plate 11 → Plate 12
  noted 2011.04.21 by C. Petrovich.

- §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

$$v_s(t_{\rm rad}) = 188\,\mathrm{km\,s^{-1}}(E_{51}n_0^2)^{0.07} \quad , \tag{39.22}$$

$$T_s(t_{\rm rad}) = 4.86 \times 10^5\,\mathrm{K}(E_{51}n_0^2)^{0.13} \quad , \tag{39.23}$$

$$kT_s(t_{\rm rad}) = 41\,\mathrm{eV}(E_{51}n_0^2)^{0.13} \quad . \tag{39.24}$$

  noted 2012.10.02 by G.B. Field.

- §39.2, p. 435, footnote 1, typo (twice): occuring → occurring
  noted 2011.04.12 by B. Hensley.

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

$$N_{\rm SN} = 0.24 S_{-13} E_{51}^{1.26} n_0^{-1.47} c_{s,6}^{-13/5} \tag{39.35}$$

$$= 0.48 S_{-13} E_{51}^{1.26} n_0^{-0.17} p_4^{-1.30} \quad , \quad p_4 \equiv \frac{p/k}{10^4\,\mathrm{cm^{-3}\,K}} \tag{39.36}$$

  noted 2014.06.27 by B. Jiang.

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

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

  noted 2014.06.27 by B. Jiang.

- §39.4, p. 439, typo: neighboorhood → neighborhood
  noted 2011.04.14

- §40.2, p. 442, typo: with a increased energy → with an increased energy
  noted 2011.04.26

- §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

- §40.9, p. 450, typo: $e^+\mathrm{H} \rightarrow \mathrm{H}^+ + 2\gamma \ \rightarrow\ e^+ + \mathrm{H} \rightarrow \mathrm{H}^+ + 2\gamma$
  noted 2011.04.27

- §41.1, p. 453, typos: Eq. (41.17) should read

$$
\begin{aligned}
M_{\rm J} &\equiv \frac{4\pi}{3}\rho_0\left(\frac{\lambda_{\rm J}}{2}\right)^3 = \frac{\pi}{6}\left(\frac{\pi kT}{G\mu}\right)^{3/2}\frac{1}{\rho_0^{1/2}} \\
&= 1.34\,M_\odot\left(\frac{T}{10\,\mathrm{K}}\right)^{3/2}\left(\frac{m_{\rm H}}{\mu}\right)^{3/2}\left(\frac{10^6\,\mathrm{cm}^{-3}}{n_{\rm H}}\right)^{1/2} \quad . \qquad (41.17)
\end{aligned}
$$

  noted 2024.07.09 by Zhang Zhijun.

- §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: $\langle\sigma v\rangle \rightarrow \langle\sigma v\rangle_{\rm mt}$
  noted 2012.04.16

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

- §41.4, p. 461, Eq. (41.56), typo: $\langle\sigma v\rangle \rightarrow \langle\sigma v\rangle_{\rm mt}$
  noted 2012.04.16

- §41.6, p. 463, typo: ... the allows the $\rightarrow$ ... this allows the
  noted 2011.04.28 by B. Hensley

- §41.6, p. 463, typo: magenetic $\rightarrow$ magnetic
  noted 2011.01.10

- §42, p. 465, typo: Stahler & Palla (2005) $\rightarrow$ Stahler & Palla (2004)
  (also corrected in Bibliography)
  noted 2012.06.22 by F. van der Tak.

- §42.2, p. 467, last paragraph, typo: ...face-on it, may... $\rightarrow$ ...face-on, it may...
  noted 2012.06.22 by F. van der Tak.

- §42.4, p. 470, 3rd paragraph should read
  ... to be $Q_{0,\mathrm{MW}} = (3.2 \pm 0.5) \times 10^{53}\,\mathrm{s}^{-1}$, after...
  noted 2011.01.04

- §42.5, p. 471, Eq. (42.9) typo: dsik → disk
  noted 2011.01.04

- Plate 5 caption: 2nd sentence should read
  ... synchrotron emission seen in Plate 4.
  noted 2011.01.12

- 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 A, p. 475: entry for RM should read
  RM ... see Eq. (11.23)
  noted 2011.01.05

- 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.

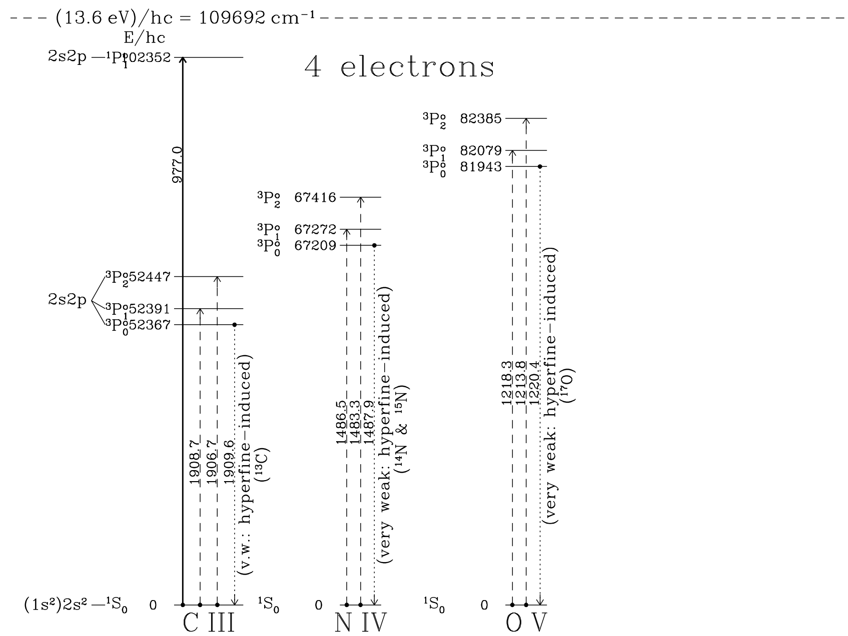
- Appendix D, p. 481: corrected typos:
  F VI → VII: $I = 147.163 \rightarrow 157.163$
  Ne VI → VII: $I = 154.214 \rightarrow 157.934$
  Ti III → IV: $I = 24.492 \rightarrow 27.492$
  Ti V → VI: $I = 123.7 \rightarrow 99.299$
  Zn VI → VII: $I = 133.903 \rightarrow 108.0$
  noted 2015.07.10 by Guangtun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

- Appendix E, p. 483, typo: Pfundt → Pfund
  noted 2011.04.28 by B. Hensley.

- Appendix E, p. 484: diagram for C IV: the wavelength labels 1548.2 and 1550.8 should be interchanged.
  noted 2011.03.11

- Appendix E, p. 485: diagrams for N IV and O V: the levels shown as ${}^2\mathrm{P}^o_1$ and ${}^2\mathrm{P}^o_2$ should be ${}^3\mathrm{P}^o_1$ and ${}^3\mathrm{P}^o_2$, respectively.
  noted 2023.05.23

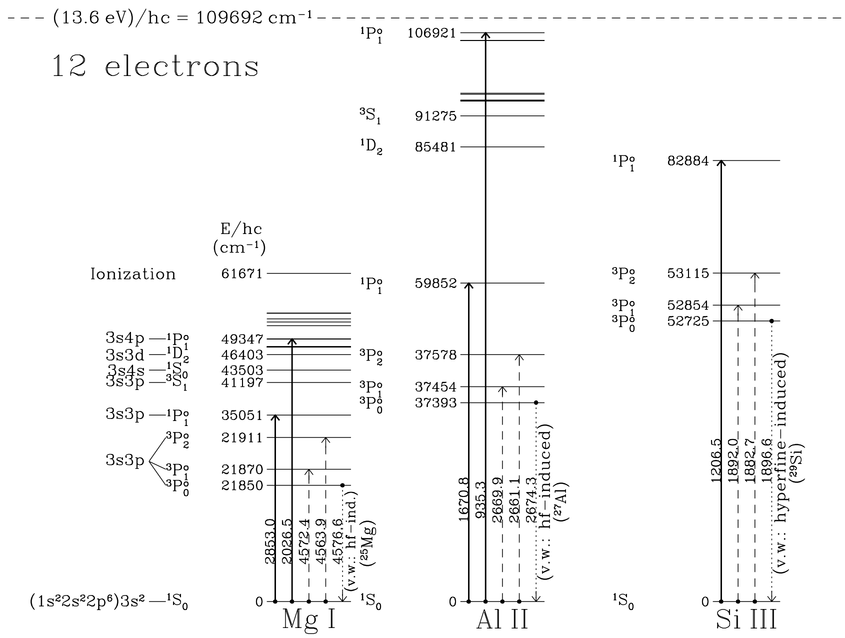
- Appendix E, p. 485, diagrams for C III, N IV, and O V: The weak (spin-forbidden magnetic dipole) ${}^1\mathrm{S}_0$-${}^3\mathrm{P}_2$ transitions were inadvertently omitted. Very weak ${}^1\mathrm{S}_0$-${}^3\mathrm{P}_0$ transitions occur only if hyperfine-induced by nucleus with nonzero spin (now noted in figure). Corrected figure:



noted 2024.12.06 by S.R. Kulkarni

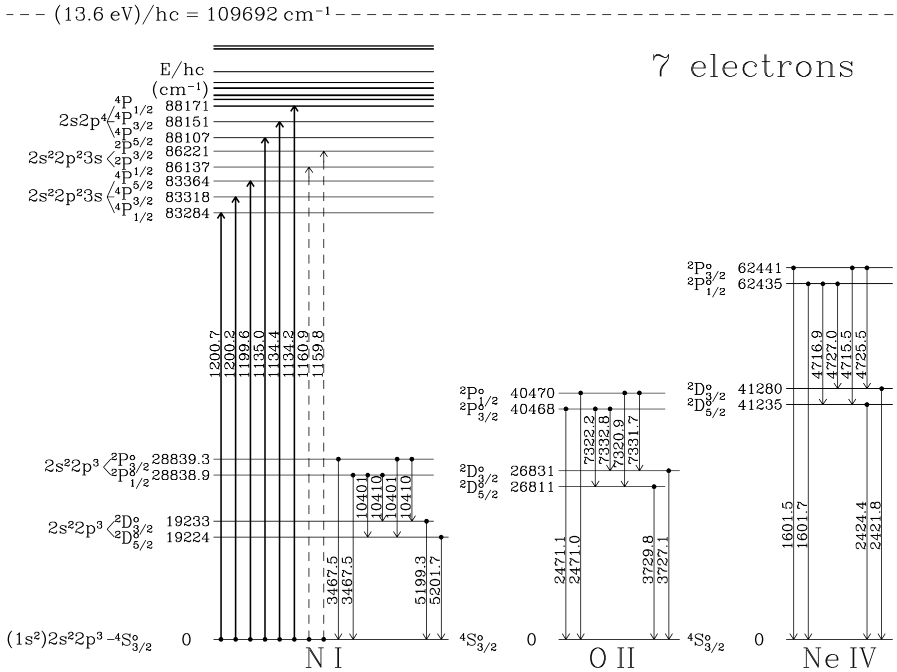
- Appendix E, p. 486: labelling of the fine-structure excited state for C II, N III, and O IV should have $J = 3/2$ (not $J = 1/2$).
  noted 2012.01.29 by E.B. Jenkins.

- Appendix E., p. 486: The weak (spin-forbidden magnetic dipole) $^1S_0$-$^3P_2$ transitions were inadvertently omitted. Very weak $^1S_0$-$^3P_0$ transitions can occur if hyperfine-induced by nuclei with nonzero spin (now noted in figure). Corrected figure:



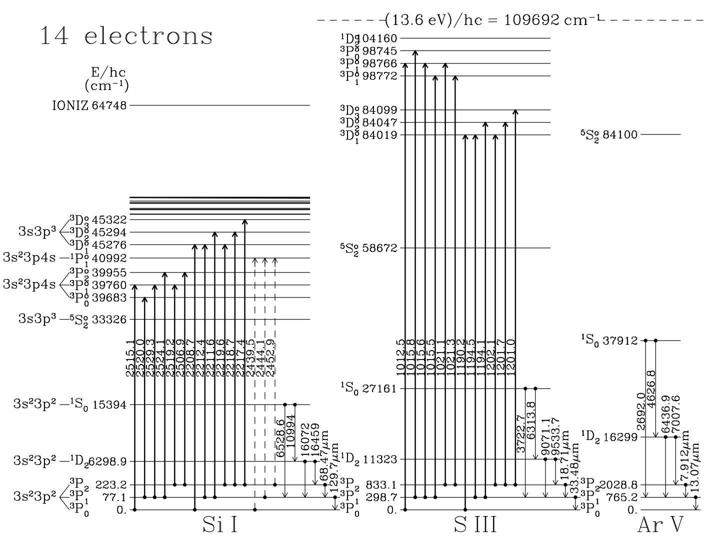
noted 2024.12.08

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



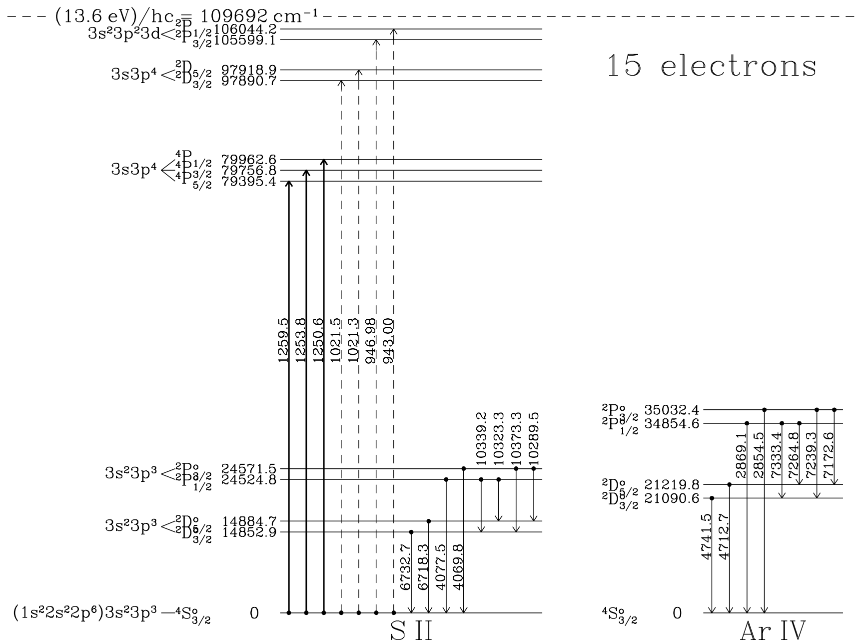
noted 2023.04.16 by S.R. Kulkarni.

- 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: $^2\mathrm{D}^o_{3/2,5/2}$ 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 $^3\mathrm{P}_0$–$^1\mathrm{P}_0 \rightarrow {}^3\mathrm{P}_0$–$^3\mathrm{P}_1$
  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	$^3\mathrm{P}_2$–$^3\mathrm{P}_1$	$0.0105\, T_4^{0.4861+0.0054\ln T_4}$	*a*
”	$^3\mathrm{P}_2$–$^3\mathrm{P}_0$	$0.00459\, T_4^{0.4507-0.0066\ln T_4}$	*a*
”	$^3\mathrm{P}_1$–$^3\mathrm{P}_0$	$0.00015\, T_4^{0.4709-0.1396\ln T_4}$	*a*
”	$^3\mathrm{P}_J$–$^1\mathrm{D}_2$	$0.0312(2J+1)\, T_4^{0.945-0.001\ln T_4}$	*b*
”	$^3\mathrm{P}_J$–$^1\mathrm{S}_0$	$0.00353(2J+1)\, T_4^{1.000-0.135\ln T_4}$	*b*
”	$^1\mathrm{D}_2$–$^1\mathrm{S}_0$	$0.0893\, T_4^{0.662-0.089\ln T_4}$	*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 $^2\mathrm{P}^o_{3/2}$ rather than $^2\mathrm{P}^o_{5/2}$.

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: incorrect powers of 10 in lines 5 and 6:
  $k_{u\ell}$ for ℓ–u $={}^3\mathrm{P}_0$–${}^3\mathrm{P}_1$ should read $1.26\times10^{-\mathbf{10}}T_2^{0.115+0.057\ln T_2}$
  $k_{u\ell}$ for ℓ–u $={}^3\mathrm{P}_0$–${}^3\mathrm{P}_2$ should read $2.64\times10^{-\mathbf{10}}T_2^{0.231+0.046\ln T_2}$
  NB!: See also erratum below on inadvertent interchange of ${}^3\mathrm{P}_0$–${}^3\mathrm{P}_2$ and ${}^3\mathrm{P}_1$–${}^3\mathrm{P}_2$ deexcitation rates.
  noted 2012.05.02 by M.J. Wolfire

- 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	${}^3\mathrm{P}_0 - {}^3\mathrm{P}_1$	$1.26\times10^{-10}T_2^{0.115+0.057\ln T_2}$	*b*
H	C I	${}^3\mathrm{P}_0 - {}^3\mathrm{P}_2$	$8.90\times10^{-11}T_2^{0.228+0.046\ln T_2}$	*b*
H	C I	${}^3\mathrm{P}_1 - {}^3\mathrm{P}_2$	$2.64\times10^{-10}T_2^{0.231+0.046\ln T_2}$	*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	${}^3\mathrm{P}_2 - {}^3\mathrm{P}_1$	$1.49\times10^{-10}T_2^{0.369-0.026\ln T_2}$	*h*
H_2(ortho)	O I	${}^3\mathrm{P}_2 - {}^3\mathrm{P}_1$	$1.37\times10^{-10}T_2^{0.395-0.005\ln T_2}$	*h*
H_2(para)	O I	${}^3\mathrm{P}_2 - {}^3\mathrm{P}_0$	$2.37\times10^{-10}T_2^{0.255+0.016\ln T_2}$	*h*
H_2(ortho)	O I	${}^3\mathrm{P}_2 - {}^3\mathrm{P}_0$	$2.23\times10^{-10}T_2^{0.284+0.035\ln T_2}$	*h*
H_2(para)	O I	${}^3\mathrm{P}_1 - {}^3\mathrm{P}_0$	$2.10\times10^{-12}T_2^{1.117+0.070\ln T_2}$	*h*
H_2(ortho)	O I	${}^3\mathrm{P}_1 - {}^3\mathrm{P}_0$	$3.00\times10^{-12}T_2^{0.792+0.188\ln T_2}$	*h*

  noted 2015.08.24 by E.B. Jenkins.

- Appendix G, p. 503, typo just before Eq. (G.7): change
  ...solution $x_0 = e^{-i\omega t}$ $\rightarrow$ ...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 (missing $^{1/2}$): Eq. (I.4) should read

$$b_{\rm crit}(v) = Wa_0\left[1+\frac{Ze^2/Wa_0}{m_e v^2/2}\right]^{1/2} \quad . \tag{I.4}$$

  noted 2011.02.08 by B. Hensley.

- 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. 508, Eq. (J.3), typo in line 3:

$$... + \int dV \frac{\partial}{\partial j}\left(v_j \rho v_i x_i\right) \;\rightarrow\; ... + \int dV \frac{\partial}{\partial x_j}\left(v_j \rho v_i x_i\right)$$

  noted 2011.02.14 by Xu Huang.

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

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

  $\rightarrow$

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

  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.