

Physics of the Interstellar and Intergalactic Medium

Errata in the fourth and fifth printings.

Updated 2024.12.08

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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

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

  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

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

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

  noted 2019.02.06

- §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.

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

- §10.2, sentence preceding Eq. (10.5): change
  ...the Gaunt factor from quantum-mechanical calculations is approximately
  $\rightarrow$
  ...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

$$j_{\mathrm{fb},\nu} = \frac{g_{\mathrm{b}}}{g_e g_i} \frac{2\,h^4\nu^3}{(2\pi m_e kT)^{3/2} c^2}\, \mathrm{e}^{(I_{\mathrm{b}}-h\nu)/kT}\, \sigma_{\mathrm{b,pi}}(\nu) n_e n_i$$

  noted 2021.02.14 by Shigenobu Hirose.

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

$$= 6.53 \times 10^{-5}\,\mathrm{arcsec} \left(\frac{D/\,\mathrm{kpc}}{L/10^{14}\,\mathrm{cm}}\right)^{1/2} \frac{(\Delta n_e)_{L,\mathrm{rms}}}{10^{-3}\,\mathrm{cm}^{-3}} \nu_9^{-2}$$

  noted 2021.10.25 by I. Wasserman.

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

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

- §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.

- §14.7.1, 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.

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

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

  noted 2015.06.01 by E. B. Jenkins.

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

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

  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.

- §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

- §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

- §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

- §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

- §23.3.2, 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... → ...charge $Z_{\rm gr} = Ua/e$ can...
noted 2021.06.25 by Yu Fung Wong.

- §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: $\sim 7.8\times10^{18}$ cm $\rightarrow$ $\sim 7.8\times10^{17}$ cm
  noted 2020.10.26
- §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.
- §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

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

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

- §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):
  $Jh\nu/c = \rho_1u_1h\nu/\mu_ic \ll \rho_1(u_1^2+c_1^2+B_1^2/8\pi)$.
  $\rightarrow$
  $Jh\nu/c = \rho_1u_1h\nu/\mu_ic \ll \rho_1(u_1^2+c_1^2)+B_1^2/8\pi$.
  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:

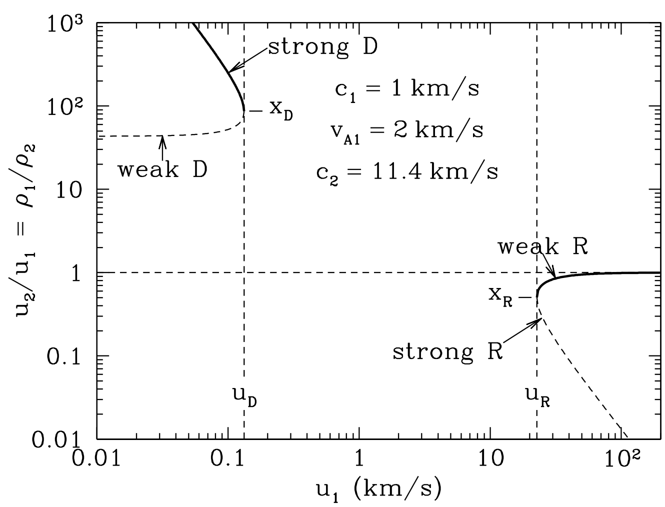


Figure 37.1 $u_2/u_1 = \rho_1/\rho_2$, as a function of the velocity u_1 of the I-front relative to the neutral gas just ahead of the I-front, for D-type and R-type ionization front

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 $u_{\rm D}$ and $u_{\rm R}$.

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

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

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

noted 2024.07.09 by Zhang Zhijun.

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

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

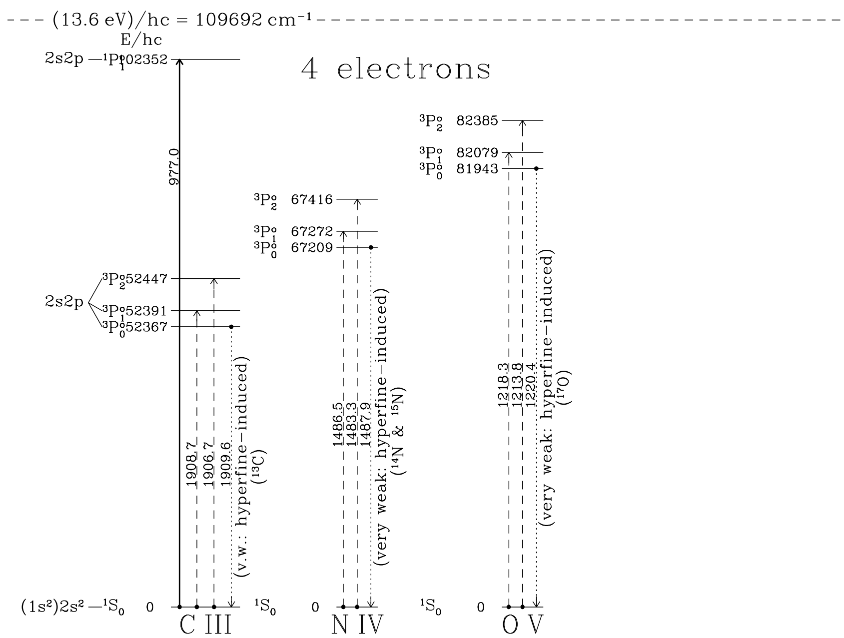
noted 2015.04.30 by J. Greco.

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

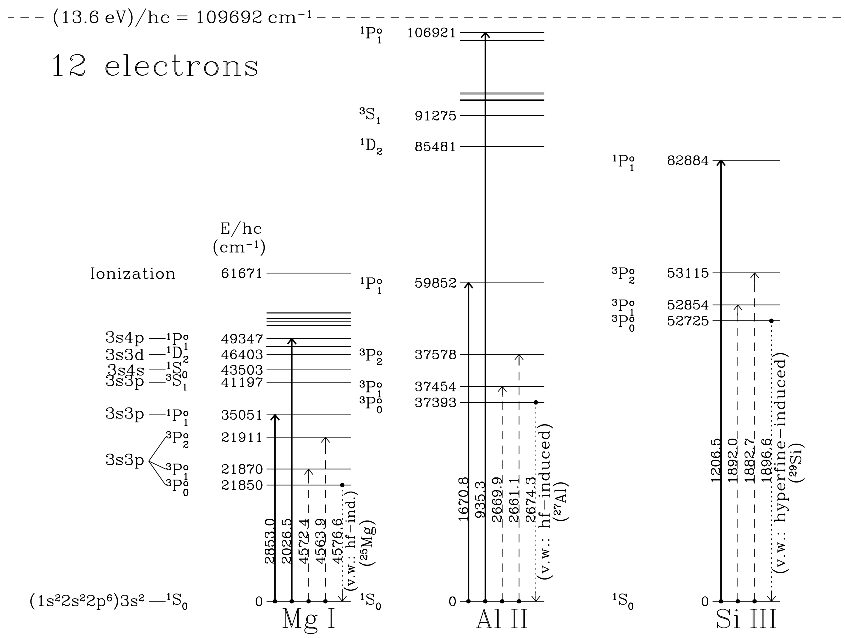
- Appendix E, p. 485: diagrams for N IV and O V: the levels shown as $^2\mathrm{P}^o_1$ and $^2\mathrm{P}^o_2$ should be $^3\mathrm{P}^o_1$ and $^3\mathrm{P}^o_2$, respectively.
  noted 2023.05.23

- 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:



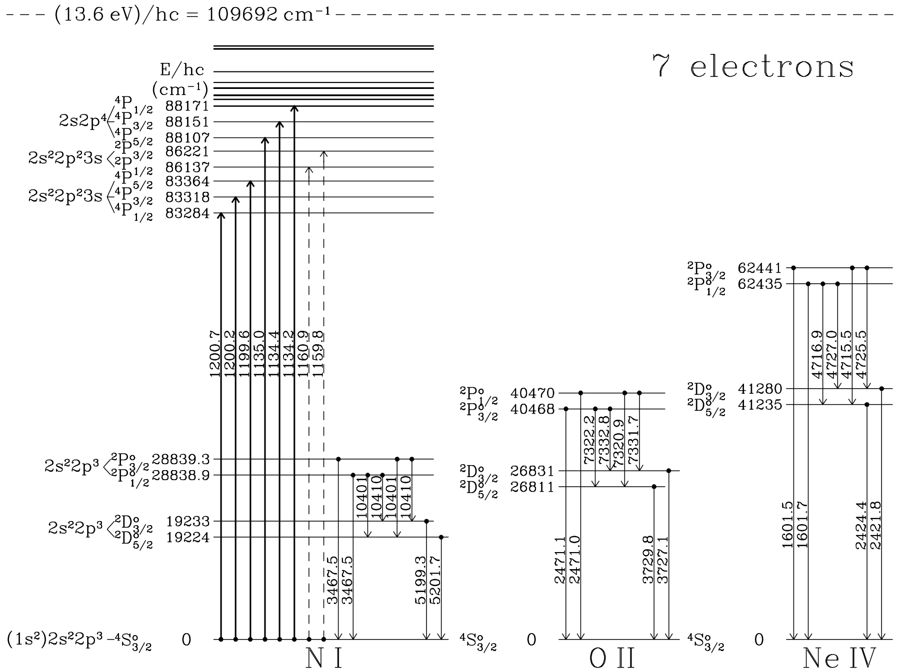
noted 2024.12.06 by S.R. Kulkarni

- Appendix E., p. 486: 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 can occur if hyperfine-induced by nuclei with nonzero spin (now noted in figure). Corrected figure:



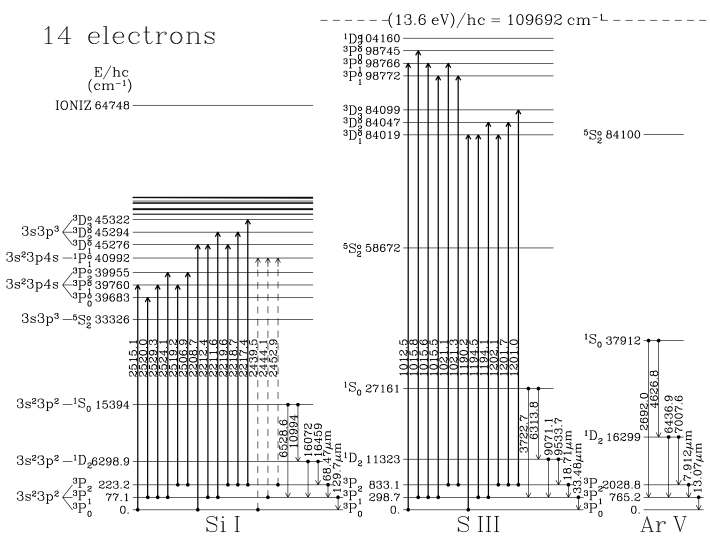
noted 2024.12.08

- 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 F, Table F.2, p. 497, typo: the first transition listed for S III: change ^{3}P$_0$–^{1}P$_0$ $\rightarrow$ ^{3}P$_0$–^{3}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 $^2\mathrm{P}^o_{3/2}$ 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: 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. 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:

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

  $\rightarrow$

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

  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.