Physics of the Interstellar and Intergalactic Medium

Errata in the first printing.

Updated 2019.03.25

Bruce T. Draine

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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 π⁰ decays. → nuclear transitions, π⁰ 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 – 10⁴ cm⁻³ to 0.2 – 10⁴ cm⁻³.
  noted 2011.09.22 by B. Ménard.

• §1.2, p. 8, Table 1.4: change abundance of P from \( N_P/N_H = 3.23 \times 10^{-7} \pm 0.03 \), \( M_P/M_H = 1.00 \times 10^{-5} \) to \( N_P/N_H = 2.82 \times 10^{-7} \pm 0.03 \), \( M_P/M_H = 8.73 \times 10^{-6} \).
  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
  \[
  \sigma_{rr,ul}(E) = \frac{1}{2} \frac{g(X_\ell)}{g(X_u^+)} \left( I_{X,\ell u} + E \right)^2 \frac{1}{E m_e c^2} \sigma_{pi,\ell u}(h\nu = I_{X,\ell u} + E) \quad , \quad (3.31)
  \]
  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
  \[ I_{n\alpha} \propto A_{n\alpha} h\nu_{\alpha} \int n[H(n)] ds \propto n^{-6} b_{n} \int n_e n(H^+) ds \]
\[ \rightarrow J_{n\alpha} \propto A_{n\alpha} h\nu_{n\alpha} \int n[H(n+1)]ds \propto n^{-6} b_{n+1} \int n_e n(H^+)ds \]

noted 2019.02.06

- §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-H₂O must have \( K_{-1} + K_{+1} \) odd \( \rightarrow \) para-H₂O must have \( K_{-1} + K_{+1} \) even

and

ortho-H₂O must have \( K_{-1} + K_{+1} \) even \( \rightarrow \) ortho-H₂O 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 H₂O: 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 H₂O 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 \( 7618 \text{ cm s}^{-1} \rightarrow 7616 \text{ cm s}^{-1} \)

and in the following line change \( 7618 \text{ cm s}^{-1} \rightarrow 7616 \text{ cm s}^{-1}. \)

noted 2011.08.18 by K.-G. Lee.

- §6.4, p. 58, typos: change

H Lyman \( \alpha (\lambda = 1215 \text{ Å}) \) has ... \( f_{\ell u} = 0.4162 \)

\( \rightarrow \)

H Lyman \( \alpha (\lambda = 1215.67 \text{ Å}) \) 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

\[ 2924 \left( \frac{7618 \text{ cm s}^{-1}}{\gamma_{ul} \lambda_{ul} b_0} \right) \rightarrow 2925 \left( \frac{7616 \text{ cm s}^{-1}}{\gamma_{ul} \lambda_{ul} b_0} \right) \]

and in Eq. (6.42) change \( 7618 \text{ cm s}^{-1} \rightarrow 7616 \text{ cm s}^{-1}. \)

noted 2011.08.18 by K.-G. Lee.

- §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 \( n(\text{HI}) \). Should read:

\[
\kappa_\nu = \frac{3}{32\pi} \frac{1}{\sqrt{2\pi}} \frac{A_{ul}n_{ul}^2}{\sigma_\nu} \frac{h c}{k T_{\text{spin}}} n(\text{HI}) e^{-u^2 / 2\sigma^2_\nu} \tag{8.9}
\]

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: \( T_{\text{sky}}(v) \rightarrow T_{\text{sky}} \) (two occurrences).

noted 2011.02.10

• §8.3, p. 74, Eq. (8.26), typos: \( T_{\text{off}}A(v) \rightarrow T_{\text{off}}A(v) \) (two occurrences).

noted 2013.02.14 by Munan Gong.

• §9.4, p. 79, Eq. (9.21), the second “=” should be changed to “≈”.

noted 2011.08.18 by K.-G. Lee.

• §9.10, Table 9.4, p. 88, typos: for C II and N III, change \( ^2D_0^J \rightarrow ^2D_J \) 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 \( \text{cm}^{-5} \)):

\[
...\nu_{g^{-2.118}} \frac{EM}{10^{25} \text{cm}^{-5}} \rightarrow ...\nu_{g^{-2.118}} \left( \frac{n_i}{n_p} \right) \frac{EM}{10^{25} \text{cm}^{-5}}
\]

noted 2011.03.05 by B. Hensley and P. Pattarakijwanich.

• §10.5, p. 97, footnote 3, typo: \( 5 \times 10^6 \text{ cm}^{-3} \text{ pc} \rightarrow 5 \times 10^6 \text{ cm}^{-6} \text{ pc} \).

noted 2011.02.15 by C. Petrovich.

• §11.4, p. 110, Eq. (11.35) should read

\[
\nu \ll \frac{e^2 (\Delta n_e)_{L,\text{rms}}}{2\pi n_e c} (2L D)^{1/2} = 1 \times 10^3 \text{ GHz} \frac{(\Delta n_e)_{L,\text{rms}}}{10^{-3} \text{ cm}^{-3}} \left( \frac{L}{10^{14} \text{cm kpc}} \right)^{1/2}.
\]

noted 2013.02.03 by W. Vlemmings.
• §12.1, p. 120, Eq. (12.1), add: where $\nu_9 \equiv \nu / \text{GHz}$
noted 2012.06.22 by F. van der Tak.

• §12, p. 121, Table 12.1, typos:
  CMB, $T = 2.725$ K : $4.19 \times 10^{-13} \rightarrow 4.17 \times 10^{-13}$
  $T_2 = 4000$ K, $W_2 = 1.65 \times 10^{-13}$ : $3.19 \times 10^{-13} \rightarrow 3.20 \times 10^{-13}$
  $T_3 = 7500$ 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 $W_1 = 5 \times 10^{-13}$ to $7 \times 10^{-13}$, ... →
  ...$W_1$ by 75%, from $W_1 = 4 \times 10^{-13}$ to $7 \times 10^{-13}$, and raised $W_2$ from
  $1.0 \times 10^{-13}$ to $1.65 \times 10^{-13}$.
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 $\sigma_{pe} \rightarrow \sigma_{pi}$
noted 2018.01.07 by L. Bouma.

• §13.1, p. 128, typo:
  $\sigma_{pe}(H_2) = 2.8\sigma_{p.i.}(H) \rightarrow \sigma_{pe}(H_2) = 2.8\sigma_{pe}(H)$
noted 2011.03.06

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

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

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

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

• §13.4, p. 134, typos:
  $\sigma_{c.i.} \rightarrow \sigma_{ci}$ (4 places), $k_{c.i.} \rightarrow k_{ci}$ (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 \( \alpha_{nl} \) (cm\(^3\) s\(^{-1}\)) for H.\(^n\). 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).

<table>
<thead>
<tr>
<th>( \alpha_{nl}(L) )</th>
<th>( 5 \times 10^3 ) K</th>
<th>( 1 \times 10^4 ) K</th>
<th>( 2 \times 10^4 ) K</th>
<th>approximation</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \alpha_{1s} )</td>
<td>( 2.28 \times 10^{-13} )</td>
<td>( 1.58 \times 10^{-13} )</td>
<td>( 1.08 \times 10^{-13} )</td>
<td>( 1.58 \times 10^{-13} T_4^{-0.540-0.017 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{2s} )</td>
<td>( 3.37 \times 10^{-14} )</td>
<td>( 2.34 \times 10^{-14} )</td>
<td>( 1.60 \times 10^{-14} )</td>
<td>( 2.34 \times 10^{-14} T_4^{-0.537-0.019 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{2p} )</td>
<td>( 8.33 \times 10^{-14} )</td>
<td>( 5.36 \times 10^{-14} )</td>
<td>( 3.24 \times 10^{-14} )</td>
<td>( 5.36 \times 10^{-14} T_4^{-0.681-0.061 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{2} )</td>
<td>( 1.17 \times 10^{-13} )</td>
<td>( 7.70 \times 10^{-14} )</td>
<td>( 4.84 \times 10^{-14} )</td>
<td>( 7.70 \times 10^{-14} T_4^{-0.636-0.046 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{3s} )</td>
<td>( 1.13 \times 10^{-14} )</td>
<td>( 7.82 \times 10^{-15} )</td>
<td>( 5.29 \times 10^{-15} )</td>
<td>( 7.82 \times 10^{-15} T_4^{-0.547-0.024 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{3p} )</td>
<td>( 3.17 \times 10^{-14} )</td>
<td>( 2.04 \times 10^{-14} )</td>
<td>( 1.23 \times 10^{-14} )</td>
<td>( 2.04 \times 10^{-15} T_4^{-0.683-0.062 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{3d} )</td>
<td>( 3.03 \times 10^{-14} )</td>
<td>( 1.73 \times 10^{-14} )</td>
<td>( 9.09 \times 10^{-15} )</td>
<td>( 1.73 \times 10^{-14} T_4^{-0.868-0.093 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{3} )</td>
<td>( 7.33 \times 10^{-14} )</td>
<td>( 4.55 \times 10^{-14} )</td>
<td>( 2.67 \times 10^{-14} )</td>
<td>( 4.55 \times 10^{-14} T_4^{-0.729-0.060 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{4s} )</td>
<td>( 5.23 \times 10^{-15} )</td>
<td>( 3.59 \times 10^{-15} )</td>
<td>( 2.40 \times 10^{-15} )</td>
<td>( 3.59 \times 10^{-15} T_4^{-0.562-0.026 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{4p} )</td>
<td>( 1.51 \times 10^{-14} )</td>
<td>( 9.66 \times 10^{-15} )</td>
<td>( 5.80 \times 10^{-15} )</td>
<td>( 9.66 \times 10^{-15} T_4^{-0.691-0.064 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{4d} )</td>
<td>( 1.90 \times 10^{-14} )</td>
<td>( 1.08 \times 10^{-14} )</td>
<td>( 5.67 \times 10^{-15} )</td>
<td>( 1.08 \times 10^{-14} T_4^{-0.870-0.094 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{4f} )</td>
<td>( 1.09 \times 10^{-14} )</td>
<td>( 5.54 \times 10^{-15} )</td>
<td>( 2.57 \times 10^{-15} )</td>
<td>( 5.54 \times 10^{-15} T_4^{-1.041-0.100 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{4} )</td>
<td>( 5.02 \times 10^{-14} )</td>
<td>( 2.96 \times 10^{-14} )</td>
<td>( 1.64 \times 10^{-14} )</td>
<td>( 2.96 \times 10^{-14} T_4^{-0.805-0.065 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{A} )</td>
<td>( 6.81 \times 10^{-13} )</td>
<td>( 4.17 \times 10^{-13} )</td>
<td>( 2.51 \times 10^{-13} )</td>
<td>( 4.17 \times 10^{-13} T_4^{-0.721-0.018 \ln T_4} )</td>
</tr>
<tr>
<td>( \alpha_{B} )</td>
<td>( 4.53 \times 10^{-13} )</td>
<td>( 2.59 \times 10^{-13} )</td>
<td>( 1.43 \times 10^{-13} )</td>
<td>( 2.59 \times 10^{-13} T_4^{-0.833-0.035 \ln T_4} )</td>
</tr>
</tbody>
</table>

\( \alpha_{nl} \) from Burgess (1965); \( \alpha_{B} \) from Hummer & Storey (1987) (for \( n_e = 10^4 \) 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

\[
\alpha_A(T) \approx 4.13 \times 10^{-13} Z \left( T_4/Z^2 \right)^{-0.7131-0.0115 \ln(T_4/Z^2)} \text{ cm}^3 \text{s}^{-1}, \quad (14.3)
\]

\[
\alpha_B(T) \approx 2.54 \times 10^{-13} Z \left( T_4/Z^2 \right)^{-0.8163-0.0208 \ln(T_4/Z^2)} \text{ cm}^3 \text{s}^{-1}. \quad (14.4)
\]

noted 2012.01.04 by E. Jenkins.

- Fig. 14.1, p. 140, typos: the quantities plotted should be labelled \( Z^{-2} T_4^{1/2} \alpha_A \) and \( Z^{-2} T_4^{1/2} \alpha_B \) (rather than \( Z^{-3} T_4^{1/2} \alpha_A \) and \( Z^{-3} T_4^{1/2} \alpha_B \)).
Figure 14.1 Case A and Case B rate coefficients $\alpha_A$ and $\alpha_B$ 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 → Pfund noted 2011.03.05 by B. Hensley.

- §14.2.4, p. 144, Eq. (14.11), typo: $1880 \text{ cm}^{-3}$ → $1.55 \times 10^4 \text{ cm}^{-3}$ noted 2011.03.17

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

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

- §14.6, p. 154, Table 14.8 update: replace $\text{H}_3^+ + e^- \rightarrow \text{H}_2 + \text{H} \quad 1.1 \times 10^{-7} T_2^{-0.56} \quad \text{McCall et al. (2004)}$ with $\text{H}_3^+ + e^- \rightarrow \text{H} + \text{H} + \text{H} \quad 8.9 \times 10^{-8} T_2^{-0.48} \quad \text{McCall et al. (2004)}$ $\text{H}_3^+ + e^- \rightarrow \text{H}_2 + \text{H} \quad 5.0 \times 10^{-8} T_2^{-0.48} \quad \text{McCall et al. (2004)}$ noted 2013.04.03

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

- §14.7.1, p. 156, Eq. (14.31), for notational consistency: $n(\text{H}) \rightarrow n(\text{H}^0)$ noted 2011.05.15 by E. B. Jenkins.
8

- §14.7.1, p. 156, just before Eq. (14.35), typo:
  In the low density limit... → 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:

  ![Graph](image)

  **Figure 14.5** Dependence of oxygen ionization fraction on hydrogen ionization fraction due to charge exchange. The low-density limit applies for \( n_\text{H} < \sim 10^4 \text{ cm}^{-3} \).
  noted 2011.05.18 by E. B. Jenkins.

- §14.9, p. 159, typo: factor of 2 error. Eq. (14.41) should read
  \[
  \sigma_{rr}(E) = \frac{g_{\ell}}{2g_u} \frac{(I + E)^2}{E m_e c^2} \sigma_{pi}(h\nu = I + E).
  \] (14.41)
  noted 2015.06.01 by E. B. Jenkins.

- §14.9, p. 160, typo: factor of 2 error. Eq. (14.43) should read
  \[
  \frac{\langle \sigma v \rangle_{rr}}{\langle \sigma v \rangle_{ci}} \approx 2\pi \alpha^3 f_{pi} \frac{I}{C/kT} e^{I/kT}.
  \] (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
  \[
  \frac{I}{kT} e^{I/kT} = \frac{C}{2\pi^3 f_{pi}} \frac{1}{\alpha^3}.
  \] (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.
• §15.1, p. 163, typo: \( \sigma_{p,i} \rightarrow \sigma_{pi} \) (two places)
  noted 2011.03.05

• §15.1.2, p. 163, change
  the Case B radiative recombination rate for \( \text{He}^+ + e^- \rightarrow \text{He}^0 \) is \( \sim 1.9 \) times
greater than for hydrogen.
  \[
  \alpha_{\text{eff}}(\text{He})/\alpha_B(\text{H}) \approx 1.1 - 1.7, \text{ depending on the fraction } y \text{ of } h\nu > 24.6 \text{ eV}
  \]
  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 \( Q_1/Q_0 \gtrsim 0.18 \).
  \[
  \rightarrow \quad \text{O6.9 V and earlier, O6.5 III and earlier, and O6 I and earlier – have } Q_1/Q_0 \gtrsim 0.14.
  \]
  noted 2011.03.17

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

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

• §15.3, p. 167, Eq. (15.12), typo:
  \( \sigma_{p,i} \rightarrow \sigma_{pi} \)
  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 \( \sigma_{pi} = 2.95 \times 10^{-18} \text{ cm}^2 \).
  noted 2011.03.17


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

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

- §15.4, p. 170, following Eq. (15.30), add:
  where \[ \sigma_d, -21 = \sigma_{dust}/10^{-21} \text{ cm}^2. \]
  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

- §15.7.1, p. 179, Eq. (15.53), typo: \[ \sigma \rightarrow \sigma_{dust} \]
  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
  \[ U \equiv \frac{1}{n_H} \int_{\nu_0}^{\infty} \frac{u_\nu d\nu}{h\nu} \]
  noted 2011.03.06 by S. Ferraro.

- §16.4, p. 186, Eq. (16.9, 16.10), update: change
  \[ \begin{align*}
  H_3^+ + e^- & \rightarrow H_2 + H , \quad k_{16.9} = 4.1 \times 10^{-8} T_2^{-0.52} \text{ cm}^3 \text{s}^{-1} , \\
  H_3^+ + e^- & \rightarrow H + H + H , \quad k_{16.10} = 7.7 \times 10^{-8} T_2^{-0.52} \text{ cm}^3 \text{s}^{-1} ,
  \end{align*} \]
  to
  \[ \begin{align*}
  H_3^+ + e^- & \rightarrow H_2 + H , \quad k_{16.9} = 5.0 \times 10^{-8} T_2^{-0.48} \text{ cm}^3 \text{s}^{-1} , \\
  H_3^+ + e^- & \rightarrow H + H + H , \quad k_{16.10} = 8.9 \times 10^{-8} T_2^{-0.48} \text{ cm}^3 \text{s}^{-1} ,
  \end{align*} \]
  and cite McCall et al. (2004) for \( k_{16.9} \) and \( k_{16.10} \).

- §16.4, p. 187, typo: in paragraph below Eq. (16.15), change
  \[ x_c \approx x_M \approx 1.9 \times 10^{-4} \quad \rightarrow \quad x_c \approx x_M \approx 1.1 \times 10^{-4} \text{ (see Eq. 16.3)} \]
  noted 2013.04.03

- §16.5, p. 188, Eq. (16.18), added information:
  \[ \begin{align*}
  H_3^+ + M & \rightarrow MH^+ + H_2 \quad k_{16.18} \approx 2 \times 10^{-9} \text{ cm}^3 \text{s}^{-1} \quad (16.18)
  \end{align*} \]
  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

\[
\frac{n_e}{n_H} = \frac{[B^2 + 4A\zeta_{CR}(1 + \phi_s)/n_H]^{1/2} - B}{2k_{16.19}},
\]

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 \( \zeta_{CR} = 1 \times 10^{-17} \text{ s}^{-1} \):

![Fractional ionization in a dark cloud (T=20K)](image)

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

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

\[ \text{Eq. (17.27)} \]

\[ n_{\text{crit},u}(H) \]

\[ n_{\text{crit},u}(e^-) \]

\begin{tabular}{|c|c|c|c|c|c|c|c|c|}
\hline
Ion & \ell & u & \( E_{\ell}/k \) (K) & \( E_u/k \) (K) & \( \lambda_{ul} \) (\( \mu \)m) & \( T_{100}\text{K} \) & \( T_{5000}\text{K} \) & \( T_{100\text{K}} \) \\
\hline
C II & \(^3\)P\(_{1/2}\) & \(^3\)P\(_{3/2}\) & 0 & 91.21 & 157.74 & 2.7 \times 10^5 & 1.5 \times 10^5 & 6.8 & 40. \text{ } T = 100 \text{ K} \\
C I & \(^3\)P\(_0\) & \(^3\)P\(_1\) & 0 & 23.60 & 690.7 & 620 & 170 & 76. & 6.4 \text{ } T = 5000 \text{ K} \\
C I & \(^3\)P\(_1\) & \(^3\)P\(_2\) & 23.60 & 62.44 & 370.37 & 720 & 150 & 75. & 6.3 \\
O I & \(^3\)P\(_2\) & \(^3\)P\(_1\) & 0 & 227.71 & 63.185 & 4.9 \times 10^3 & 1.8 \times 10^5 & 4.8 \times 10^4 & 4.8 \times 10^4 \\
Si II & \(^3\)P\(_0\) & \(^3\)P\(_1\) & 0 & 227.71 & 63.185 & 4.9 \times 10^3 & 1.8 \times 10^5 & 4.8 \times 10^4 & 4.8 \times 10^4 \\
Si I & \(^3\)P\(_0\) & \(^3\)P\(_1\) & 110.95 & 327.01 & 68.473 & 9.9 \times 10^4 & 3.6 \times 10^4 & 4.4 \times 10^4 & 1.9 \times 10^4 \\
\hline
\end{tabular}

noted 2011.03.06

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

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

\[ \text{Eq. (17.27)} \]

noted 2010.11.27

• §17.7, p. 199, top line, typo: \( n_{\text{H, crit}} \rightarrow n_{\text{crit}}(H) \)

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 \( \lambda = 3645.1 \text{ Å} \) → “Balmer jump” at \( \lambda = 3647.0 \text{ Å} \)

noted 2011.03.11

• §18.4.1, p. 212: Refine wavelength midway between H 20 and H 21 lines:

\[ \lambda_{\text{BJ, red}} = 3682.6 \text{ Å} \rightarrow \lambda_{\text{BJ, red}} = 3682.1 \text{ Å} \]

noted 2011.03.11

• §18.5, p. 214, Eq. (18.11): Change

... \( \Omega_{03} \) is approximately independent of \( T_e \), we have

\[ n(O III) \]

\[ n(H^+) \]

\[ C \frac{I([O III]5008)}{I(H\beta)} T_4^{-0.37} e^{2.917/T_4}, \]

\[ (18.11) \]

to

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

\[ n(O III) \]

\[ n(H^+) \]

\[ C \frac{I([O III]5008)}{I(H\beta)} T_4^{-0.49} e^{2.917/T_4}, \]

\[ (18.11) \]

noted 2015.02.27

• §19.3, p. 222: revise value for \( A_{10} \): replace

\[ A_{10} = 6.78 \times 10^{-8} \text{ s}^{-1} \rightarrow A_{10} = 7.16 \times 10^{-8} \text{ s}^{-1} \] (see Eq. 5.7).

noted 2013.04.17
• §19.3, p. 223: revised numbers according to revised value for $A_{10}$:
  noted 2013.04.17

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

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

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

• §21.6.1, p. 244, Eq. (21.12), typo:
  \[
  n_{g7} C_{\text{ext}}(\omega) = 2 \text{Im}(k) = 2 \omega c \text{Im}( \sqrt{\epsilon_{\text{ISM}}}) \approx \omega c \text{Im}(\epsilon_{\text{ISM}}) \quad (21.12)
  \]
  $\rightarrow$
  \[
  n_{g7} C_{\text{ext}}(\omega) = 2 \text{Im}(k) = 2(\omega/c) \text{Im}( \sqrt{\epsilon_{\text{ISM}}}) \approx (\omega/c) \text{Im}(\epsilon_{\text{ISM}}) \quad (21.12)
  \]
  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: $\text{Mg}_{2x}\text{Fe}_{2-2x}\text{SiO}_4 \rightarrow \text{Mg}_{2x}\text{Fe}_{2-2x}\text{SiO}_4$
  noted 2011.03.24 by C. Petrovich

• §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: totally $\rightarrow$ total
  noted 2011.03.23
• §24.2, p. 293, typo: ...does not extend below \( \sim 23 \text{K} \). \( \rightarrow \) ...does not extend below \( \sim 35 \text{K} \).
noted 2011.03.24

• §24.2, p. 293, typo:
...corresponds the grain... \( \rightarrow \) ...corresponds to the grain...
noted 2011.03.25

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

\[
\frac{\omega}{2\pi} = 4.6 \text{ GHz} \left( \frac{T_{\text{tot}}}{100 \text{ K}} \right)^{1/2} \left( \frac{0.001 \mu \text{m}}{a} \right)^{5/2} \tag{26.23}
\]

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:
\[
\mu = \frac{Qa^2 \omega}{3} \rightarrow \mu = \frac{Qa^2 \omega}{3c}
\]

noted 2011.05.01 by P. Pattarakijwanich.

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

\[
\Omega_L = \frac{5UB}{8\pi \rho a^2 c} = 3.7 \times 10^{-10} \left( \frac{3 \text{ g cm}^{-3}}{\rho} \right) \left( \frac{U}{\text{Volt}} \right) \left( \frac{B}{5 \mu \text{G}} \right) \left( \frac{0.1 \mu \text{m}}{a} \right)^2 \text{s}^{-1} \tag{26.25}
\]

noted 2011.05.01 by P. Pattarakijwanich.

• §26.3.1, p. 311, after Eq. (26.25), typo: \( 2\pi /\Omega_L \approx 10 \text{ yr} \) \( \rightarrow \) \( 2\pi /\Omega_L \approx 500 \text{ yr} \)
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

• §28.1, p. 326, 2nd paragraph, typo: ...form the the... \( \rightarrow \) ...form the...
noted 2011.03.31
• §28.2, p. 327, 2nd paragraph, typo:

\[ EM \approx 5 \times 10^6 \text{ cm}^{-3} \text{ pc} \rightarrow EM \approx 5 \times 10^6 \text{ cm}^{-6} \text{ pc} \]

noted 2011.03.31 by C. Petrovich.

• §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 2015.04.07

• §29.1, p. 332, 1st paragraph, typo:

\[ b = 0 \rightarrow b = 90^\circ, \text{ so that the 2nd sentence reads...} \]

\[ \ldots \text{vary as } N(\text{HI}, b) = N(\text{HI}, b = 90^\circ) / \sin |b| = N_0 \csc |b|. \]

noted 2012.11.04 by R. Simons.

• §29.4, p. 335, typo:

\[ \ldots \text{found } nT \approx 2800 \text{ cm}^{-3} \text{ K} \ldots \rightarrow \ldots \text{found } nT \approx 3800 \text{ cm}^{-3} \text{ K} \ldots \]

noted 2011.04.05

• §30.2, p. 339, typo: \( \ldots \text{near threshold are...} \rightarrow \ldots \text{near-threshold yields are...} \)

noted 2011.04.05 by B. Hensley.

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

\[ \frac{\pi e^2}{m_e c^2 h} \sum_{\ell u} f_{\ell u} \lambda_{\ell u}^3 u\lambda f_{\text{shield}, \ell u} \rightarrow \frac{\pi e^2}{m_e c^2 h} \sum_{\ell u} f_{\ell u} \lambda_{\ell u}^3 u\lambda f_{\text{shield}, \ell u} p_{\text{diss}, \ell u} \]

noted 2013.04.12 by Ai-Lei Sun.

• §31.4, p. 349, Eq. (31.25), typo: \( \tau_{1000} \rightarrow \tau_{d,1000} \)

noted 2012.07.10

• §32.1, p. 357, 1st paragraph, typo: \( \ldots \text{a their...} \rightarrow \ldots \text{their...} \)

noted 2012.06.22 by F. van der Tak.

• §32.1, p. 357, 2nd paragraph, typo: (see Plate 15). \( \rightarrow \) (see Plate 11).

noted 2011.06.07 by S. Lorenz Martins.

• §32.9, p. 368, typo: magnetic \( \rightarrow \) magnetic

noted 2011.04.11

• §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, prepenulement paragraph: terminological correction. Change “core” to “clump” (three occurrences).

noted 2015.04.16
• §33.1, p. 375, typo: photodisociation → photodissociation
  noted 2011.04.11

• §33.1, p. 375, typo: occuring → occurring
  noted 2011.04.25 by B. Hensley.

• §33.2.2, p. 378, typo: reaction products should be \( \text{OH}^+ + \text{H}_2 \)
  noted 2011.04.12

• §34.4, p. 387, typo: Eq. (34.17) is off by a factor 3, and should read
  \[
  t_{\text{evap}} = \frac{3M}{2M} = \frac{25 \times 2.3(n_\text{H})_e R_e^2 m_e^{1/2} e^4 \ln \Lambda}{8 \times 0.87(kT_h)^{2.5}}
  \]  
  (34.17)

  Eq. (34.18) is numerically correct, but should have shown the dependence on \( \ln \Lambda \):
  \[
  = 5.1 \times 10^4 \text{yr} \left( \frac{(n_\text{H})_e}{30 \text{ cm}^{-3}} \right) \left( \frac{R_e}{10^4 \text{ pc}} \right)^2 \left( \frac{T_h}{10^7 \text{ K}} \right)^{-2.5} \left( \frac{\ln \Lambda}{30} \right). 
  \]  
  (34.18)
  noted 2013.01.05 by B. Hensley.

• §35.3, p. 392, typo: rate-of-change \( v \) of... → rate-of-change of \( v \)
  noted 2011.04.14

• §36.1, p. 397, typo: occuring → occurring
  noted 2011.04.26

• §36.2.2, p. 399, Eq. (36.8), two corrections: \( 8\pi \rightarrow 4\pi \) and \( B_x B_y v_x \rightarrow B_z B_x v_z \). The equation should read
  \[
  \frac{\partial}{\partial x} \left[ \frac{1}{2} \rho v_x^2 + U v_x + \rho v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x - \frac{B_x B_y v_y}{4\pi} - \frac{B_x B_z v_z}{4\pi} 
  \right.
  \]
  \[
  \left. - v_j \sigma_{jx} - \kappa \frac{dT}{dx} + \rho v_x \Phi_{\text{grav}} \right] = \Gamma - \Lambda. 
  \]  
  (36.8)
  noted 2011.04.19

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

  \( v_z \) 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
  \[
  \left\{ \left[ \frac{\rho v_x^2 + \gamma p}{2} \frac{B_y^2 + B_z^2}{(\gamma - 1)} \right] v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x - \frac{B_x B_y v_y + B_x B_z v_z}{4\pi} - \kappa \frac{dT}{dx} \right\}_1 = 
  \]
  \[
  \left\{ \left[ \frac{\rho v_x^2 + \gamma p}{2} \frac{B_y^2 + B_z^2}{(\gamma - 1)} \right] v_x + \frac{(B_y^2 + B_z^2)}{4\pi} v_x - \frac{B_x B_y v_y + B_x B_z v_z}{4\pi} - \kappa \frac{dT}{dx} \right\}_2. 
  \]  
  (36.10)
• §36.2.5, p. 401, Eq. (36.16): $8\pi \rightarrow 4\pi$ (twice). The equation should read
\[
\frac{\rho_1 u_1^3}{2} + \frac{\gamma}{\gamma - 1} u_1 p_1 + \frac{u_1 B_1^2}{4\pi} \rightarrow \frac{1}{2} \frac{\rho_1 v_1^3}{\gamma - 1} u_1 v_1 \frac{B_1^2}{4\pi} .
\]

noted 2011.04.19

• §36.2.5, p. 401, Eq. (36.19): $8\pi \rightarrow 4\pi$ (twice). The equation should read
\[
\frac{1}{2} \frac{\rho_1 v_1^3}{\gamma - 1} + \frac{\gamma}{\gamma - 1} p_1 v_1 + \frac{B_1^2}{4\pi} v_1 = \frac{1}{2} \frac{\rho_1 v_1^3}{\gamma - 1} + \frac{\gamma}{\gamma - 1} p_2 v_2 + \frac{B_2^2}{4\pi} v_2 .
\]

(1)

noted 2011.04.19

• §36.2.5, p. 402, Eq. (36.27), typo:
\[
\frac{3}{16} \mu v_1^2 \rightarrow \frac{3}{16} \mu v_2^2
\]

noted 2011.05.17 by P. Pattarakijwanich.

• §36.6, p. 409, typo: occurring \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):
\[
J h \nu / c = \rho_1 u_1 h \nu / \mu_1 c \ll \rho_1 (u_1^2 + c_1^2 + B_1^2 / 8\pi).
\]

\rightarrow

\[
J h \nu / c = \rho_1 u_1 h \nu / \mu_1 c \ll \rho_1 (u_1^2 + c_1^2) + B_1^2 / 8\pi.
\]

noted 2016.12.08 by Ryohei Nakatani.

• §37.1, Eq. (37.8): The correction terms for $u_R$, $x_R$, $u_D$, and $x_D$ can be improved by analyzing the full cubic equation (37.3): change
\[
u_R \approx 2 c_2 \rightarrow u_R \approx 2 c_2 \left[ 1 - \frac{2 c_1^2 - 3 v_2^2}{8 c_2^2} \right]
\]
\[
x_R \approx \frac{1}{2} + \frac{2 c_1^2 + v_2^2}{16 c_2^2} \rightarrow x_R \approx \frac{1}{2} \left[ 1 + \frac{2 c_1^2 + v_2^2}{8 c_2^2} \right]
\]
\[
u_D \approx \frac{2 c_2^2 + v_2^2}{4 c_2} \rightarrow \frac{2 c_2^2 + v_2^2}{4 c_2} \left[ 1 + \frac{2 c_1^2 + v_2^2}{8 c_2^2} \right]
\]
\[
x_D \approx \frac{4 c_2^2}{2 c_1^2 + v_2^2} \rightarrow x_D \approx \frac{4 c_2^2}{2 c_1^2 + v_2^2} \left[ 1 + \frac{2 c_1^2 + v_2^2}{8 c_2^2} \right]
\]

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](image)

*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 \( c_1 = 1 \text{ km s}^{-1}, v_{A1} = 2 \text{ km s}^{-1}, \) and \( c_2 = 11.4 \text{ km s}^{-1} \). 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:

$$v_s \approx V_i.$$  \hfill (37.21)

→

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

$$V_s \approx V_i.$$  \hfill (37.21)

noted 2016.12.08 by Ryohei Nakatani.

• §38.3, p. 428, last paragraph, typo:
$M_w \approx 2 \times 10^{-5} \text{ km s}^{-1} \rightarrow M_w \approx 2 \times 10^{-5} M_\odot \text{ yr}^{-1}$
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

$$v_s(t_{\text{rad}}) = 188 \text{ km s}^{-1}(E_{51}/n_0^2)^{0.07},$$  \hfill (39.22)

$$T_s(t_{\text{rad}}) = 4.86 \times 10^5 K(E_{51}/n_0^2)^{0.13},$$  \hfill (39.23)

$$kT_s(t_{\text{rad}}) = 41 \text{ eV}(E_{51}/n_0^2)^{0.13}. $$  \hfill (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

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

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

noted 2014.06.27 by B. Jiang.
\[ \frac{P}{k} = S^{0.77}_{-1.13} E^{0.97}_{51} n^{-0.13}_0 \times 5700 \text{ cm}^{-3} \text{ K} \]
• §42.2, p. 467, last paragraph, typo: ...face-on it, may... → ...face-on, it may...
  noted 2012.06.22 by F. van der Tak.

• §42.4, p. 470, 3rd paragraph should read
  ... to be $Q_{0,MW} = (3.2 \pm 0.5) \times 10^{53} \text{s}^{-1}$, 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 D, p. 481: corrected typos:
  $\text{F VI} \rightarrow \text{VII}: I = 147.163 \rightarrow 157.163$
  $\text{Ne VI} \rightarrow \text{VII}: I = 154.214 \rightarrow 157.934$
  $\text{Ti III} \rightarrow \text{IV}: I = 24.492 \rightarrow 27.492$
  $\text{Ti V} \rightarrow \text{VI}: I = 123.7 \rightarrow 99.299$
  $\text{Zn VI} \rightarrow \text{VII}: I = 133.903 \rightarrow 108.0$
  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. 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. 495: $^2D_{3/2,5/2}^0$ 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 $3^3\text{P}_0 - 3^3\text{P}_0 \rightarrow 3^3\text{P}_0 - 3^3\text{P}_1$
  noted 2016.10.03 by C.D. Kreisch.

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

<table>
<thead>
<tr>
<th>Ion</th>
<th>$\ell - u$</th>
<th>$\Omega_{\ell u}$</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>O I</td>
<td>$3^3\text{P}_2 - 3^3\text{P}_1$</td>
<td>0.0105 $T_4^{0.4861 + 0.0051 \ln T_4}$</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>$3^3\text{P}_2 - 3^3\text{P}_0$</td>
<td>0.00459 $T_4^{0.4507 - 0.0066 \ln T_4}$</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>$3^3\text{P}_1 - 3^3\text{P}_0$</td>
<td>0.00015 $T_4^{0.4709 - 0.1396 \ln T_4}$</td>
<td>a</td>
</tr>
<tr>
<td></td>
<td>$3^3\text{P}_J - 1^1\text{D}_2$</td>
<td>0.0312 $(2J+1) T_4^{0.945 - 0.001 \ln T_4}$</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>$3^3\text{P}_J - 1^1\text{S}_0$</td>
<td>0.00353 $(2J+1) T_4^{0.999 - 0.135 \ln T_4}$</td>
<td>b</td>
</tr>
<tr>
<td></td>
<td>$1^1\text{D}_2 - 1^1\text{S}_0$</td>
<td>0.0893 $T_4^{0.662 - 0.089 \ln T_4}$</td>
<td>b</td>
</tr>
</tbody>
</table>

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

- 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: $k_{\ell u}$ for $\ell - u = 3^3\text{P}_0 - 3^3\text{P}_1$ should read $1.26 \times 10^{-10} T_2^{0.115 + 0.057 \ln T_2}$

- Appendix F, Table F.6, p. 501: The table title should be “Rate Coefficients for ... Deexcitation...” rather than “... Excitation...”. noted 2015.02.27
\( k_{\ell u} \) for \( \ell - u = ^3P_0 - ^3P_2 \) should read \( 2.64 \times 10^{-10} T_2^{0.231+0.046} \ln T_2 \).

NB! See also erratum below on inadvertent interchange of \( ^3P_0 - ^3P_2 \) and \( ^3P_1 - ^3P_2 \) 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

  \( H \quad CI \quad ^3P_0 - ^3P_1 \quad 1.26 \times 10^{-10} T_2^{0.115+0.057} \ln T_2 \quad b \)
  \( H \quad CI \quad ^3P_0 - ^3P_2 \quad 8.90 \times 10^{-11} T_2^{0.228+0.046} \ln T_2 \quad b \)
  \( H \quad CI \quad ^3P_1 - ^3P_2 \quad 2.64 \times 10^{-10} T_2^{0.231+0.046} \ln T_2 \quad b \)

  noted 2015.07.03 by Munan Gong.

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

  \( H_2 \quad (para) \quad O I \quad ^3P_2 - ^3P_1 \quad 1.49 \times 10^{-10} T_2^{0.369+0.026} \ln T_2 \quad h \)
  \( H_2 \quad (ortho) \quad O I \quad ^3P_2 - ^3P_1 \quad 1.37 \times 10^{-10} T_2^{0.395+0.005} \ln T_2 \quad h \)
  \( H_2 \quad (para) \quad O I \quad ^3P_2 - ^3P_0 \quad 2.37 \times 10^{-10} T_2^{0.255+0.016} \ln T_2 \quad h \)
  \( H_2 \quad (ortho) \quad O I \quad ^3P_2 - ^3P_0 \quad 2.23 \times 10^{-10} T_2^{0.284+0.035} \ln T_2 \quad h \)
  \( H_2 \quad (para) \quad O I \quad ^3P_1 - ^3P_0 \quad 2.10 \times 10^{-12} T_2^{0.117+0.070} \ln T_2 \quad h \)
  \( H_2 \quad (ortho) \quad O I \quad ^3P_1 - ^3P_0 \quad 3.00 \times 10^{-12} T_2^{0.792+0.188} \ln T_2 \quad h \)

  noted 2015.08.24 by E.B. Jenkins.

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

  \( \ldots \text{solution } x_0 = e^{-i\omega t} \rightarrow \ldots \text{solution } x_0 e^{-i\omega t} \).

  noted 2019.02.11

- **Appendix I, p. 506, typo:** ...

  \( \sim E_u / h \rightarrow \ldots \text{a time } \sim h / E_u \)

  noted 2013.02.07 by Munan Gong.

- **Appendix I, p. 507, typo (missing \( 1/2 \)):** Eq. (I.4) should read

  \[
  b_{\text{crit}}(v) = W a_0 \left[ 1 + \frac{Ze^2 / W a_0}{m_e v^2 / 2} \right]^{1/2}.
  \]

  noted 2011.02.08 by B. Hensley.

- **Appendix I, p. 507, typo (15.78 \( \rightarrow \) 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:**

  \[
  \ldots + \int dV \frac{\partial}{\partial j} (v_j \rho v_i) \rightarrow \ldots + \int dV \frac{\partial}{\partial x_j} (v_j \rho v_i)
  \]

  noted 2011.02.14 by Xu Huang.
Appendix J, p. 510, Eq. (J.13), typo:

\[ \Pi_0 \equiv \oint dS \cdot r_p \rightarrow \Pi_0 \equiv \frac{1}{3} \oint dS \cdot r_p \]

noted 2017.03.08.