Physics of the Interstellar and Intergalactic Medium: Errata

Updated 2013.04.30

Bruce T. Draine

PRINCETON UNIVERSITY PRESS
PRINCETON AND OXFORD

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

- §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: 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.

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

- §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: 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 $\Delta J = 0, \pm1$; $\Delta K_{-1} = \pm1, \pm3$; and $\Delta K_{+1} = \pm1, \pm3$.
to
The selection rules for electric dipole radiative transitions in H_2O are $\Delta J = 0, \pm1$; $\Delta K_{-1} = \pm1, \pm3$; and $\Delta K_{+1} = \pm1, \pm3$; 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 ($\lambda = 1215$ Å) has ... $f_{\ell u} = 0.4162$
→
H Lyman α ($\lambda = 1215.67$ Å) has ... $f_{\ell u} = 0.4164$,
and in the following sentence, change 0.4162 → 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.

- §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" → "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 "≈".
noted 2011.08.18 by K.-G. Lee.
- §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, 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
$$\nu \ll \frac{e^2(\Delta n_e)_{L,\rm rms}}{2\pi m_e c}(2LD)^{1/2} = 1{\times}10^3\,\mathrm{GHz}\frac{(\Delta n_e)_{L,\rm rms}}{10^{-3}\,\mathrm{cm}^{-3}}\left(\frac{L}{10^{14}\,\mathrm{cm}}\frac{D}{\mathrm{kpc}}\right)^{1/2}.$$
noted 2013.02.03 by W. Vlemmings.
- §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}
$T_1 = 4000\,\mathrm{K}, W_2 = 1.65\times10^{-13}$	:	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

- §13.1, p. 128, typo:
  $\sigma_{\rm pe}({\rm H}_2) = 2.8\sigma_{\rm p.i.}({\rm H}) \ \to \sigma_{\rm pe}({\rm H}_2) = 2.8\sigma_{\rm pe}({\rm H})$
  noted 2011.03.06

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

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

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

- §13.4, p. 134, typos:
  $\sigma_{\rm c.i.} \ \to \ \sigma_{\rm ci}$ (4 places), $k_{\rm c.i.} \ \to \ k_{\rm ci}$ (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 $\alpha_{n\ell}$ (cm^3 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 $n_e = 10^3\,{\rm cm}^{-3}$)

- §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

$$\alpha_A(T) \approx 4.13 \times 10^{-13} \, Z \, (T_4/Z^2)^{-0.7131-0.0115\ln(T_4/Z^2)} \, \mathrm{cm}^3 \, \mathrm{s}^{-1} \, , \qquad (14.3)$$
$$\alpha_B(T) \approx 2.54 \times 10^{-13} \, Z \, (T_4/Z^2)^{-0.8163-0.0208\ln(T_4/Z^2)} \, \mathrm{cm}^3 \, \mathrm{s}^{-1} \, . \qquad (14.4)$$

noted 2012.01.04 by E. Jenkins.

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

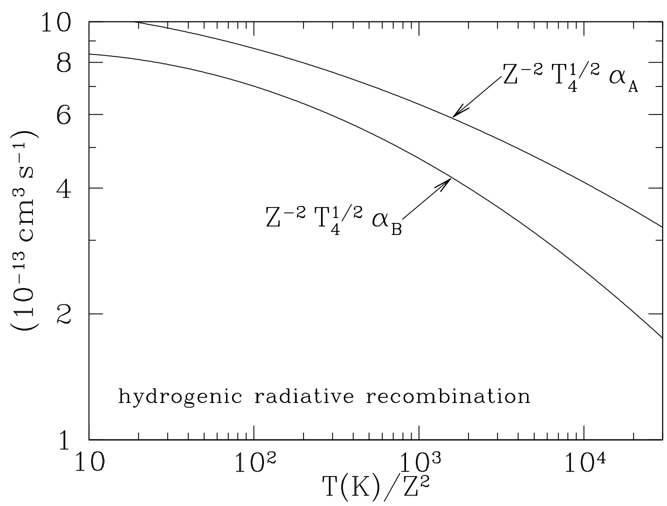

Figure 14.1 Case A and Case B rate coefficients α_A and α_B for radiative recombination of hydrogen, multiplied by $T_4^{1/2}$ (equations 14.5,14.6). Note that no single power-law fit can reproduce the T-dependence over a wide range in T.

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

- §14.5, 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
  $\mathrm{H}_3^+ + e^- \rightarrow \mathrm{H}_2 + \mathrm{H}$ $\quad 1.1 \times 10^{-7} T_2^{-0.56}$ $\quad$ McCall et al. (2004)
  with

$H_3^+ + e^- \to H + H + H$	$8.9 \times 10^{-8} T_2^{-0.48}$	McCall et al. (2004)
$H_3^+ + e^- \to H_2 + H$	$5.0 \times 10^{-8} T_2^{-0.48}$	McCall et al. (2004)

noted 2013.04.03

- §14.7.1, p. 155, typo: $I_{O(^3P_0)} = 13.6181\,\mathrm{eV}, \quad \to \quad I_{O(^3P_2)} = 13.6181\,\mathrm{eV}$), noted 2011.02.22 by Xu Huang.

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

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

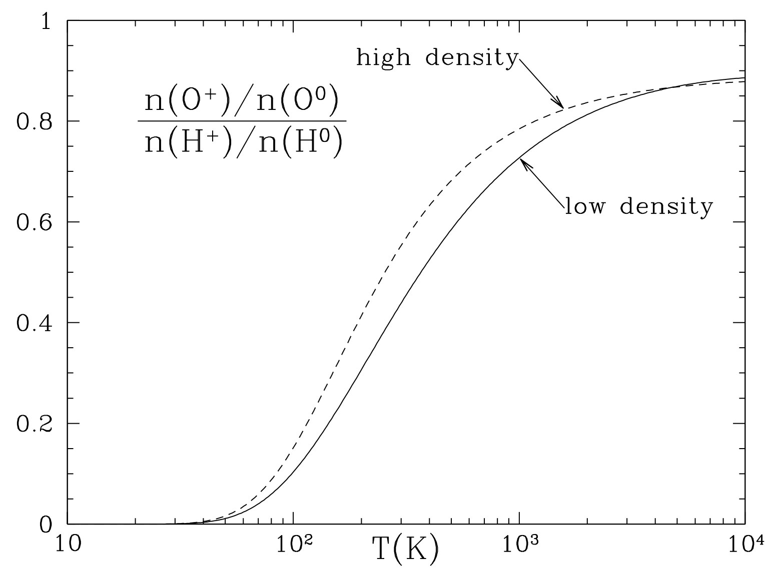

Figure 14.5 Dependence of oxygen ionization fraction on hydrogen ionization fraction due to charge exchange. The low-density limit applies for $n_{\mathrm{H}} \lesssim 10^4\,\mathrm{cm}^{-3}$.
noted 2011.05.18 by E. B. Jenkins.

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

- §15.1.2, p. 163, change
  the Case B radiative recombination rate for $\mathrm{He}^+ + e^- \to \mathrm{He}^0$ is ~ 1.9 times larger than for hydrogen.
  $\to$
  $\alpha_{\mathrm{eff}}(\mathrm{He})/\alpha_B(\mathrm{H}) \approx 1.1 - 1.7$, depending on the fraction y of $h\nu > 24.6\,\mathrm{eV}$ 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 $Q_1 < 0.18 Q_0$, $\rightarrow$ if $Q_1 \lesssim 0.14 Q_0$,
  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:
  $$3360\,(Q_{0,49})^{1/3}\,n_2^{1/3} \quad\rightarrow\quad 2880\,(Q_{0,49})^{1/3}\,n_2^{1/3} T_4^{0.28}$$
  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

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

- §15.7, p. 180, typo: substantially reduced → 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. (16.18), 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
$$\frac{n_e}{n_{\rm H}} = \frac{\left[B^2 + 4A\zeta_{\rm CR}(1+\phi_s)/n_{\rm H}\right]^{1/2} - B}{2k_{16.19}} \quad , \qquad (16.25)$$
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 $\zeta_{\rm CR} = 1 \times 10^{-17}\,{\rm s}^{-1}$:

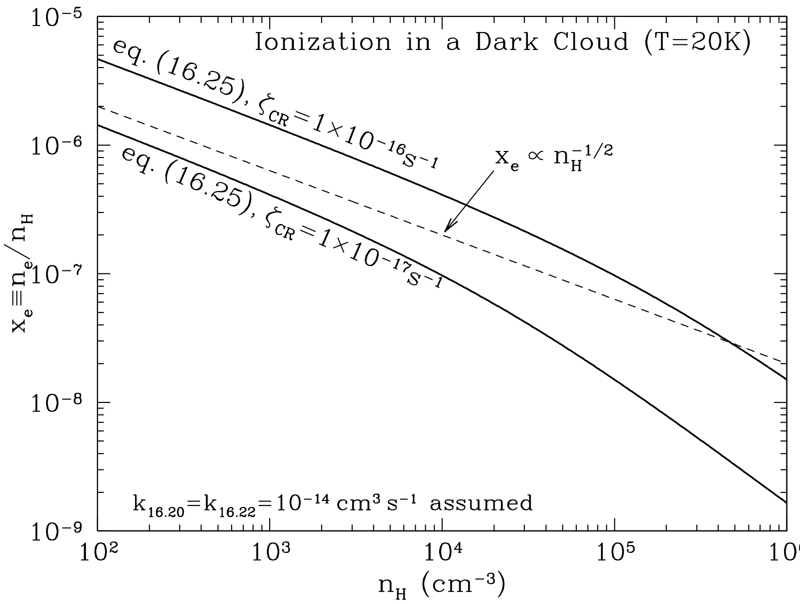

Figure 16.3 Fractional ionization in a dark cloud, estimated using Eq. (16.25), with the grain recombination rate coefficients set to $k_{16.20} = k_{16.22} = 10^{-14}\,\mathrm{cm}^3\,\mathrm{s}^{-1}$ (see Fig. 14.6). The dashed line is a simple power-law approximation $x_e \approx 2 \times 10^{-5}(n_{\rm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

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

						$n_{{\rm crit},u}$(H)		$n_{{\rm crit},u}(e^-)$	
			E_ℓ/k	E_u/k	$\lambda_{u\ell}$	$T=100$ K	$T=5000$ K	$T=100$ K	$T=5000$ K
Ion	ℓ	u	(K)	(K)	(μm)	(cm^{-3})	(cm^{-3})	(cm^{-3})	(cm^{-3})
C II	$^2P^o_{1/2}$	$^2P^o_{3/2}$	0	91.21	157.74	2.7×10^3	1.5×10^3	6.8	40.
C I	$^3P_0$	$^3P_1$	0	23.60	609.7	620	170	76.	6.4
	$^3P_1$	$^3P_2$	23.60	62.44	370.37	720	150	75.	6.3
O I	$^3P_2$	$^3P_1$	0	227.71	63.185	2.5×10^5	4.9×10^4	1.8×10^5	4.8×10^4
	$^3P_1$	$^3P_0$	227.71	326.57	145.53	2.4×10^4	8.6×10^3	2.3×10^4	5.8×10^3
Si II	$^2P^o_{1/2}$	$^2P^o_{3/2}$	0	413.28	34.814	2.5×10^5	1.2×10^5	140.	1.5×10^3
Si I	$^3P_0$	$^3P_1$	0	110.95	129.68	4.8×10^4	2.8×10^4	2.9×10^4	830.
	$^3P_1$	$^3P_2$	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

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

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

noted 2010.11.27

- §17.7, p. 199, top line, typo: $n_{\rm H,crit}$ → $n_{\rm crit}({\rm H})$
  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 → "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:
  $\lambda_{\rm BJ,red} = 3682.6$ Å → $\lambda_{\rm BJ,red} = 3682.1$ Å
  noted 2011.03.11

- §19.3, p. 222: revise value for A_{10}: replace
  $A_{10} = 6.78 \times 10^{-8}\,{\rm s}^{-1} \rightarrow A_{10} = 7.16 \times 10^{-8}\,{\rm s}^{-1}$ (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 → function
  noted 2011.03.11 by C. Petrovich

- §21.3, p. 242, typo: ...into the UV. whereas... → ...into the UV, whereas...
  noted 2011.03.21

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

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

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

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

- §23.1, p. 266, typo: ${\rm Mg}_2x{\rm Fe}_{2-2x}{\rm SiO}_4$ → ${\rm Mg}_{2x}{\rm Fe}_{2-2x}{\rm SiO}_4$
  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: totaly $\rightarrow$ total
  noted 2011.03.23
- §24.2, p. 293, typo: ...does not extend below ∼23K. $\rightarrow$ ...does not extend below ∼35K.
  noted 2011.03.24
- §24.2, p. 293, typo:
  ...corresponds the grain... $\rightarrow$ ...corresponds to the grain...
  noted 2011.03.25
- §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

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

  noted 2011.05.01 by P. Pattarakijwanich.
- §26.3.1, p. 311, after Eq. (26.25), typo: $2\pi/\Omega_L \approx 10\,\mathrm{yr}$ $\rightarrow$ $2\pi/\Omega_L \approx 500\,\mathrm{yr}$
  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... → ...form the...
  noted 2011.03.31
- §28.2, p. 327, 2nd paragraph, typo:
  $EM \approx 5\times10^6\,\mathrm{cm}^{-3}\,\mathrm{pc} \;\rightarrow\; EM \approx 5\times10^6\,\mathrm{cm}^{-6}\,\mathrm{pc}$
  noted 2011.03.31 by C. Petrovich.
- §29.1, p. 332, 1st paragraph, typo: $b=0 \rightarrow b=90°$, so that the 2nd sentence reads
  ...vary as $N(\mathrm{H\,I}, b) = N(\mathrm{H\,I}, b = 90°)/\sin|b| = N_0 \csc|b|$.
  noted 2012.11.04 by R. Simons.
- §29.4, p. 335, typo:
  ...found $nT \approx 2800\,\mathrm{cm}^{-3}\,\mathrm{K}$... → ...found $nT \approx 3800\,\mathrm{cm}^{-3}\,\mathrm{K}$...
  noted 2011.04.05
- §29.4, p. 335, typo: ...implies $n_\mathrm{H} \approx 35\,\mathrm{cm}^{-3}$. → ...implies $n_\mathrm{H} \approx 50\,\mathrm{cm}^{-3}$.
  noted 2011.04.05
- §30.2, p. 339, typo: ...near threshold are... → near-threshold yields are...
  noted 2011.04.05 by B. Hensley.
- §31.4, p. 349, Eq. (31.24), typo: on RHS, change

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

  noted 2013.04.12 by Ai-Lei Sun.
- §31.4, p. 349, Eq. (31.25), typo: $\tau_{1000} \rightarrow \tau_{d,1000}$
  noted 2012.07.10
- §32.1, p. 357, 1st paragraph, typo: ...a their... → ...their...
  noted 2012.06.22 by F. van der Tak.
- §32.1, p. 357, 2nd paragraph, typo: (see Plate 15). → (see Plate 11).
  noted 2011.06.07 by S. Lorenz Martins.
- §32.9, p. 368, typo: magntic → magnetic
  noted 2011.04.11
- §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 $\mathrm{OH}^+ + \mathrm{H}_2$
  noted 2011.04.12

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

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

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

$$= 5.1\times10^4\,{\rm yr}\left(\frac{(n_{\rm H})_c}{30\,{\rm cm}^{-3}}\right)\left(\frac{R_c}{\rm pc}\right)^2\left(\frac{T_h}{10^7\,{\rm K}}\right)^{-2.5}\left(\frac{\ln\Lambda}{30}\right) . \quad (34.18)$$

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 $B_xB_zv_x \rightarrow B_xB_zv_z$. The equation should read

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

noted 2011.04.19

- §36.2.3, p. 400, Eq. (36.10): $8\pi \rightarrow 4\pi$ (twice). The equation should read

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

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

noted 2011.04.19

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

$$\frac{\rho_1u_1^3}{2} + \frac{\gamma}{\gamma-1}u_1p_1 + \frac{u_1B_1^2}{4\pi} = \frac{\rho_2u_2^3}{2} + \frac{\gamma}{\gamma-1}u_2p_2 + \frac{u_2B_2^2}{4\pi} \quad , \quad (36.16)$$

noted 2011.04.19

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

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

  noted 2011.04.19

- §36.2.5, p. 402, Eq. (36.27), typo:

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

  noted 2011.05.17 by P. Pattarakijwanich.

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

- §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, eq. (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

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

  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. 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 $E \lesssim 10^5$ GeV have $R_{\rm gyro} < 10^{-4}\,{\rm pc}$ → protons with $E \lesssim 10^3$ GeV have $R_{\rm gyro} < 10^{-4}\,{\rm pc}$
  noted 2011.04.26

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

- §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

- §41.3.2, 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 $Q_{0,\rm MW} = (3.2 \pm 0.5) \times 10^{53}\,{\rm s}^{-1}$, after...
  noted 2011.01.04

- §42.5, p. 471, Eq. (42.9) typo: dsik $\rightarrow$ 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 E, p. 483, typo: Pfundt $\rightarrow$ 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 F, p. 501, Table F.6: 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 $1.26 \times 10^{-\mathbf{10}} T_2^{0.115+0.057 \ln T_2}$
  $k_{u\ell}$ for ℓ–u $={}^3\mathrm{P}_0$–${}^3\mathrm{P}_2$ should read $2.64 \times 10^{-\mathbf{10}} T_2^{0.231+0.046 \ln T_2}$
  noted 2012.05.02 by M.J. Wolfire

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

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

  noted 2011.02.14 by Xu Huang.