strengths and redshifts in qualitative agreement with typical values measured for Of stars; these need to be refined with a more accurate calculation. On the whole, the Castor–Abbott–Klein model appears to give a fairly satisfactory picture of the basic dynamics of Of atmospheres; but many questions remain open.

FRONTIERS

The theory of radiatively driven winds is at an early stage of its development, and many interesting (and challenging) problems remain to be attacked. Within the framework of the Castor–Abbott–Klein theory, refinements of the force law to include the complete spectrum, a more realistic ionization–excitation equilibrium, and more accurate treatment of the transfer (accounting for the fact that a photon scattered at one point in the envelope can subsequently interact with the material at some other point), should yield more precise and reliable results.

A more difficult problem is posed by the question of how to treat properly the energy equation and thereby determine the temperature structure of the flow. The observations (**533**) of O VI lines, described earlier in this section, have been interpreted (*assuming* collisional ionization *only*—an assumption that requires further consideration) as requiring temperatures of the order of 2×10^5 °K, which is much higher than can be produced radiatively. This suggests that there may be mechanical energy deposition that produces a (relatively cool) corona. Mechanisms for producing a mechanical flux (which presumably dissipates and heats the outer layers) have been proposed in (**289**; **290**; **404**), but these are not entirely satisfactory in their present form. If the flow were to become *turbulent* (see below), energy dissipation and heating could occur and, because $\rho v^2 \gg kT$, even a rather low efficiency in the conversion of flow energy to heat could have a large effect on the temperature. Nevertheless, it must be stressed that, although current models do not convincingly determine the temperature structure, the *dynamics* of the flow will remain essentially unaltered for $T \lesssim 3 \times 10^7$ °K (a value that seems completely excluded observationally), *unless* the energy deposition changes the topology of the solution [e.g., by the introduction of additional critical points (**307**)] and, thereby, even the qualitative nature of the solution. These possibilities all await further exploration.

One of the problems that will ultimately have to be faced by the "core-halo" models is that evidence has been presented for atmospheric extension effects in the *continuous* energy distribution of the *most extreme* Of stars (**367**; **466**). Unless it can be shown that there are errors in the observations or in their reduction (e.g., in the allowance for interstellar reddening), it will be necessary to find ways to construct models showing a slower outward rise of the velocity. Such models seem essential for WR stars, where a critical analysis

(**304**) of the energy distribution of HD 50896 (WN5) seems absolutely to require an extended subsonic-flow region; some models of this type have been constructed (**133**), but only with ad hoc force laws, and much further work remains to be done before they can be regarded as satisfactory.

Although all theoretical models of radiatively driven winds assume that the flow is steady, there is ample evidence that the spectrum (and hence the wind) of Of stars is time-variable. A wide range of time-scales (**176**; **536**) has been noted. It appears, in fact, that essentially all early-type supergiants that show emission lines are intrinsic spectrum variables (**537**). In a few cases, pathological spectra with transient *inverse* P-Cygni profiles (presumably indicating temporary *inflow* of the material) have been observed (**173**). If the time-scale of the variations is long compared to the time a fluid parcel requires to move from the photosphere to the critical point, then one can argue that the flow can be considered as a sequence of quasi-stationary states, each of which is well approximated by steady flow. The only problem then remaining would be to understand the mechanism leading to the variations. On the other hand, if very short time-scales are ever observed, then a fully time-dependent treatment might be required, and this would introduce staggering difficulties into the problem.

Although the assumption of spherical symmetry of the wind is a reasonable starting point, it may not adequately describe the flow for some stars. In particular, if the star is rapidly rotating, then centrifugal forces can appreciably lower the effective surface gravity, to the point where it barely exceeds even continuum radiation-forces. This may lead to enhanced mass loss from the equatorial regions of the star (**409**), in which case the flow becomes axisymmetric instead of spherically symmetric. The divergence of stream-lines away from the equatorial plane again introduces the possibility of a radical alteration of the topology of the solution (**307**). Furthermore, rotation implies that the flow has nonzero vorticity and, in the presence of rotational shear, the flow may disintegrate and become *turbulent*, as suggested by the very large Reynolds numbers mentioned earlier in this section. In this event, gross inhomogeneities may develop in the wind, and again the theoretical complexity becomes overwhelming.

Finally, there is the question of whether magnetic fields play a significant role in winds from early-type stars. The O-stars are very young, and have only recently formed from the interstellar medium. Presumably any fields present in the medium could persist as weak fields in the atmospheres of these stars. There would then be the possibility of a region of forced corotation out to an Alfvenic point, with subsequent radial expansion. Could this give rise to the profiles with broad emission wings extending beyond the short-wavelength edge of the P-Cygni absorption feature, as observed in some stars? Could such fields produce structural inhomogeneities with flow-tube divergences such as are seen in the solar corona and wind (**307**)? Could they provide structures against which shear (as a result of rotation) with consequent turbulence can develop? The present observational detection threshold for stellar magnetic fields is several hundred gauss; much weaker fields (a few tens of gauss) in the atmosphere could have major effects on the flow.

It should be clear from the points raised above that there remains much to be learned about the physics of stellar winds for early-type stars. Without doubt it is unrealistic to suppose that these issues can be decided on the basis of theoretical considerations alone. It is obvious that a thorough analysis of the spectroscopic data, at a high level of internal consistency, with the goal of *diagnosing the physical conditions in the flow semiempirically*, is required, and that such efforts will be immensely rewarding.

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Glossary of Physical Symbols

Physical symbols used in the text are listed below, along with a brief description of their meaning and the page number on which each first appears. Standard mathematical symbols, dummy variables and indices, and notations used only in one location are not included.

a	Ratio of damping width to Doppler width, $\Gamma/4\pi\,\Delta\nu_D$	279
a	Isothermal sound speed	519
a_i	Quadrature weight	65
a_{ji}	Branching ratio $j \rightarrow i$ in radiative decay of state j	142
a_R	Radiation constant in Stefan's law	7
a_s	Adiabatic sound speed	519
a_ν	Macroscopic absorption coefficient uncorrected for stimulated emission	78
a_ν	Coefficient in linear expansion of Planck function	148
a_0	Bohr radius	89
$a_j(t)$	Coefficient of eigenstate ψ_j in expansion of a general state $\psi(t)$	85
$a_\nu(\mu)$	Absorption-depth, relative to continuum, in spectrum-line intensity-profile at angle $\cos^{-1}\mu$ from disk-center, $1 - r_\nu(\mu)$	269
$\mathbf{A}$	Vector potential	7
$\mathcal{A}$	Rate matrix of statistical equilibrium equations	138
A_a	Autoionization transition probability	134
A_i	Atomic weight of chemical species i	110
A_{ji}	Einstein spontaneous-emission probability for transition $j \rightarrow i$	78
A_s	Stabilization transition probability in dielectronic recombination process	135
A_ν	Absorption-depth, relative to continuum, in spectrum line flux-profile, $1 - R_\nu$	269

A_0	Central absorption depth of an infinitely opaque line	318
$\mathbf{A}_d$	Matrix coupling depth-points $d-1$ and d in Feautrier difference-equation solution of transfer equation	155
b_i	Non-LTE departure coefficient (n_i/n_i^*) for level i	219
b_ν	Coefficient in linear expansion of Planck function	148
$b_a(\tau)$	Planck function normalized to value at surface of atmosphere $B_\nu[T(\tau)]/B_\nu(T_0)$	76
$b_\nu(\tau_\nu)$	Planck function normalized to disk-center intensity, $B_\nu[T(\tau_\nu)]/I_\nu(0, 1)$	262
$\mathbf{B}$	Magnetic induction	7
$\mathscr{B}$	Righthand-side vector of statistical equilibrium equations	138
B_{ij}	Einstein absorption probability for transition $i \rightarrow j$	77
B_{ji}	Einstein induced-emission (or stimulated-emission) probability for transition $j \rightarrow i$	78
B_0	Planck function at $T = T_0$	312
B_1	$(\partial B_\nu/\partial\bar{\tau})$ evaluated at $\bar{\tau} = 0$	312
B^*	Equivalent Planck function for recombination emission in non-LTE source function	360
$\mathbf{B}_d$	Coupling matrix at depth-point d in Feautrier difference-equation solution of transfer equation	155
$B(T)$	Frequency-integrated Planck function	52
$B_{\text{eff}}(\tau)$	Effective thermal source in line with overlapping continuum	352
$B_\nu(T)$	Planck function	7
$B_\nu^*[T(\tau)]$	Planck function for temperature distribution that gives radiative equilibrium	179
c	Velocity of light	4
C_{ij}	Collisional transition rate from level i to level j	127
$C_{i\kappa}$	Collisional ionization rate of level i to continuum	123
C_k	Interaction coefficient of kth component of hydrogen Stark pattern	295
C_p	Specific heat at constant pressure	186
C_p, C_3, C_4, C_6	Coefficient of power-law expression for perturber–radiator interaction	283
C_v	Specific heat at constant volume	186
C_0	Numerical constant in collision rate formula, $\pi a_0{}^2(8k/m\pi)^{\frac{1}{2}}$	133
$\mathbf{C}_d$	Matrix coupling depth-points d and $d+1$ in Feautrier difference equation solution of transfer equation	155
$\mathscr{C}_i$	Net collisional rate into level i	486
d	Electron-impact line shift	306
$\mathbf{d}$	Electric dipole moment	86
d_i	Departure of ratio of non-LTE to LTE population of level i from unity, $(b_i - 1)$	219

d_{mn}	Matrix element of dipole moment $\langle\phi_m^*\|\mathbf{d}\|\phi_n\rangle$	86
d^3r	Volume element	8
D	Distance from star to observer	11
D	Debye length, Debye radius	122
$\mathbf{D}$	Electric displacement	7
D_B	Balmer jump (in magnitudes)	195
D_P	Paschen jump (in magnitudes)	195
$\mathbf{D}_d$	Auxiliary matrix used in developing Feautrier difference-equation solution of transfer equation	156
(D/Dt)	Fluid-frame or Lagrangian derivative	514
$(D/Dt)_{\text{coll}}$	Time rate of change of distribution function caused by collisions	33
e	Electron charge	81
e	Specific internal energy of a fluid	517
$e(\infty)$	Residual energy per particle at infinite distance in stellar wind, E/F	531
E	Total particle energy	494
E	Total energy flux in stellar wind	526
$\mathbf{E}$	Electric field	7
$\mathbf{E}$	Matrix giving definition of $\mathbf{J}$ in terms of $\mathbf{u}_i$'s in Rybicki difference-equation solution of transfer equation	159
$\mathscr{E}$	Energy in radiation field	3
E_i	Energy of atomic state i relative to ground state	22
E_ν	Contribution to emissivity from (fixed) overlapping transitions	397
E_ν	Energy received at frequency ν from an expanding atmosphere by an external observer	474
E_0	Magnitude of electric field	8
E_0	Threshold energy of collision process	132
E_R^*	Thermodynamic equilibrium value of radiation energy-density	7
$E(\omega)$	Energy spectrum of oscillator	275
$E_c(\infty)$	Heat-conduction flux at infinite distance in stellar wind	531
$E_n(x)$	Exponential integral of order n	40
$E_R(\mathbf{r}, \nu, t)$, $E_R(\mathbf{r}, \nu)$, $E_R(\nu)$	Monochromatic energy density in radiation field	6
$E_R(\mathbf{r}, t)$, $E_R(\mathbf{r})$, E_R	Total (frequency-integrated) energy density in radiation field	6
$\mathbf{f}$	Force-per-unit-volume acting on a fluid	516

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f_b	Buoyancy force	188
f_c	Continuum oscillator strength	123
f_{ij}	Oscillator strength of transition $i \to j$	84
$\mathscr{f}_\nu$	Monochromatic flux received by observer	11
$f(n', n)$	Oscillator strength for transition between states with principal quantum numbers n' and n	88
$f(n', l'; n, l)$	Oscillator strength for transition from substate l' of state n' to substate l of state n	88
$f(t)$	Amplitude of time-variation of oscillator	274
$f(\mathbf{v})$, $f(v)$	Maxwellian velocity distribution	110
$f(\mathbf{r}, \mathbf{p}, t)$, $f(\mathbf{r}, \mathbf{v}, t)$	Particle distribution function	32
$f(\mathbf{r}, \nu, t)$, $f(z, \nu, t)$, f_ν	Variable Eddington factor K_ν/J_ν	18
$f_{jk}(n_e, T)$	Fraction of chemical species k in ionization stage j, N_{jk}/N_k	114
$f_K(n', n)$	Kramers'-formula oscillator strength for transition $n' \to n$ in hydrogen	90
$f_R(\mathbf{r}, \mathbf{n}, \nu, t)$	Photon distribution function	4
F	Perturber field-strength	291
F	Particle flux in stellar wind	525
$\mathbf{F}$	Imposed external force	32
$\mathscr{F}$, $\boldsymbol{\mathscr{F}}$	Frequency-integrated flux	44
F_c	Flux in continuum near spectrum line	269
F_{conv}	Energy flux transported by convection	188
F_{rad}	Energy flux transported by radiation	190
F^α	Four-force	541
F_0	Normal field strength	291
$\mathbf{F}_{rad}$	Radiative damping force on an oscillator	82
$\mathscr{F}_{BB}$	Frequency-integrated flux from blackbody	12
$F(v)$	Spontaneous recapture probability for electrons of velocity v	94
$F(v)$	Dawson's function	280
$F(\mathbf{r}, \nu, t)$, $F(z, \nu, t)$, F_ν	$\mathscr{F}_\nu/\pi$ Monochromatic "astrophysical" flux of radiation field	10
$F(\omega)$	Fourier transfrom	275
$F(\omega, T)$	Fourier transfrom of wavetrain of duration T	281
$\mathscr{F}(\mathbf{r}, \nu, t)$, $\mathscr{F}(z, \nu, t)$, $\mathscr{F}_\nu$	Monochromatic flux of radiation field in direction normal to atmospheric layers	10

$\boldsymbol{\mathscr{F}}(\mathbf{r}, \nu, t)$, $\boldsymbol{\mathscr{F}}(\mathbf{r}, \nu)$, $\boldsymbol{\mathscr{F}}_\nu$	Monochromatic vector flux of radiation field	9
$\mathscr{F}_{BB}(\nu)$	Flux from blackbody	12
g	Surface gravity in planar atmosphere	170
g_{crit}	Surface gravity at which radiation force exceeds gravitational force in atmosphere	170
g_{eff}	Net acceleration, gravitational minus radiative, of stellar atmospheric material	256
g_i	Statistical weight of atomic state i	77
g_{ijk}	Statistical weight of excitation state i of ionization state j of chemical species k	110
g_{nl}	Statistical weight of substate l of state n	88
g_R	Acceleration produced by radiation force	554
$g_{R,l}$	Radiative acceleration produced by all spectrum lines	558
$g_R^{\,0}$	Acceleration produced by radiation force in a single spectrum line	555
$\mathbf{g}_R$	Four-force of radiation on matter	498
$g(\mathbf{n}', \mathbf{n})$, $g(\mu', \mu, \phi')$, $g(\mu', \mu)$	Angular phase functions in scattering process	29
$g_I(n', n)$	Gaunt factor, for bound–bound transition $n' \to n$ in hydrogen	90
$g_{II}(n, k)$, $g_{II}(n, \nu)$	Gaunt factor for bound–free transition $n \to k$ in hydrogen	99
$g_{III}(k, l)$, $g_{III}(\nu, v)$, $\bar{g}_{III}(\nu, T)$	Gaunt factor for free–free transitions in hydrogen	101
G	Newtonian gravitation constant	255
$\mathbf{G}_{em}$	Momentum density in electromagnetic field	14
$\mathbf{G}_R$	Momentum density in radiation field	10
$G(v)$	Induced recapture probability for electrons of velocity v	94
$G(\nu)$, $G_{lu}(\nu)$	Generalized statistical weight ratio in stimulated emission correction	165
h	Planck's constant	4
$\hbar$	Reduced Planck's constant $h/2\pi$	85
h	Specific enthalpy of a fluid	518
h_ν	Eddington factor giving ratio $H_\nu(0)/J_\nu$ at surface of atmosphere	157
H	Frequency-integrated Eddington flux	54
H	Pressure scale height	188

$\mathbf{H}$	Magnetic field	7
$\mathscr{H}$	Nominal Eddington flux, $\sigma_R T_{\rm eff}^4/4\pi$	174
H_A	Hamiltonian for atom	85
H_P	Perturber Hamiltonian	298
H_ν^0, H^0	Current value of Eddington flux in Avrett–Krook procedure	174
H_0	Magnitude of magnetic field	8
H_0	Flux-constant in extended atmosphere, $r^2 H = L/16\pi^2$	245
$H(a, v)$	Voigt function	279
$H(q_i, p_i)$	Hamiltonian operator	85
$H(\mathbf{r}, \nu, t)$, $H(z, \nu, t)$, H_ν	Monochromatic Eddington flux, $\frac{1}{4}F_\nu = \mathscr{F}_\nu/4\pi$	10
$H(\mu)$	Limb-darkening function	70
$H_n(v)$	Expansion function in power-series expression for Voigt function	280
$\mathbf{i}$	Unit vector in x-direction	3
I	Frequency-integrated specific intensity	54
I	Moment of inertia of a star	536
I_c	Specific intensity emitted from core in expanding, extended atmosphere	478
I_k	Fractional intensity of kth component of hydrogen Stark pattern	296
I_{ul}	Total line intensity in transition $u \rightarrow l$	488
I_H	Ionization energy of hydrogen	133
$I(\mathbf{r}, \mathbf{n}, \nu, t)$, $I_\nu(T, \mu)$, $I_\nu(\mu)$, I_ν	Specific intensity of radiation	2
$I(\omega)$	Power spectrum of oscillator	275
$I_\nu(p, \infty)$	Emergent specific intensity along ray with impact parameter p in extended atmosphere	247
$I^+(\mu, \nu)$, I^+	Specific intensity traveling in $+\mu$ direction	36
$I^-(\mu, \nu)$, I^-	Specific intensity traveling in $-\mu$ direction	36
$\mathbf{j}$	Unit vector in y-direction	3
$\mathbf{j}$	Current density	7
J	Jacobian of transformation of coordinates	32
$\mathbf{J}$	Total angular momentum of atom	92
J_ν^0, J^0	Current value of mean intensity in Avrett–Krook procedure	174
$\bar{J}$, $\bar{J}_{ij}$	Mean intensity averaged over line profile, $\int \phi_\nu J_\nu \, d\nu$	129
$\bar{\mathbf{J}}$	Discrete representation of depth-variation of $\bar{J}(z)$ in Rybicki difference-equation solution of transfer equation	159

$J(\mathbf{r}, t)$, J	Frequency-integrated mean intensity, $\int_0^\infty J_\nu \, d\nu$	6
$J(\mathbf{r}, \nu, t)$, $J(\mathbf{r}, \nu)$, $J(z, \nu)$, $J_\nu(\tau)$, J_ν	Mean intensity	5
k	Boltzmann's constant	7
k	Wavenumber	8
k	Continuum-state quantum number for hydrogen	98
$\mathbf{k}$	Unit vector in z-direction	3
k_c	Continuum opacity uncorrected for stimulated emission	321
k_α	Root of characteristic equation in discrete-ordinate method	66
K	Frequency-integrated second moment of radiation field	55
$\mathscr{K}$	Numerical coefficient in hydrogen cross-section	99
$\mathbf{K}_i$	Discrete representation of depth-variation of thermal source terms at angle-frequency point i in Rybicki difference-equation solution of transfer equation	159
$K(\mathbf{r}, \nu, t)$, $K(z, \nu, t)$, K_ν	Second angular moment of monochromatic radiation field	16
$K_\beta(\tau)$	Line-formation kernel function for an expanding atmosphere	481
$K_1(\tau)$	Line-formation kernel function	339
$K_{1,r}(\tau)$	Kernel for line-formation with overlapping continuum	351
l	Azimuthal quantum number	89
l	Continuum-state quantum number for hydrogen	100
l	Convective mixing length	188
l	Correlation length in turbulent velocity field	464
l_ν	Photon mean-free-path	51
L	Stellar luminosity	49
L	Photon destruction length	333
L	Rotational angular momentum of a star	536
$\mathbf{L}$	Total orbital angular momentum of atom	92
$\mathbf{L}$, $L_\beta^{\ \alpha}$	Lorentz transformation	493
$L_{\rm crit}$	Critical luminosity at which radiation force exceeds gravitational force in atmosphere	171
L_α	Integration constant in discrete-ordinate method	67
$\mathbf{L}_d$	Source-term in Feautrier difference-equation solution of transfer equation	155
$L_{1,r}(\tau)$	Continuum kernel function	351
m	Mass of electron	83

m	Magnetic quantum number	89
m	Column mass in atmosphere	170
m_e	Mass of electron	89
m_p	Mass of proton	89
m_H	Mass of hydrogen atom	170
m_0	Rest (proper) mass of a particle	494
$\bar{m}$	Average mass per nucleus (atoms + ions)	170
M	Mach number	520
$\mathcal{M}$	Stellar mass	171
M_a	Integration constant in discrete ordinate method	67
$\dot{\mathcal{M}}$	Mass-loss rate	516
$M(t)$	Radiation force multiplier	561
n	Index of refraction	4
n	Principal quantum number	89
$\mathbf{n}$, $\mathbf{n}'$	Directions of radiation propagation	2
$\mathbf{n}$	Occupation-number solution-vector of statistical equilibrium equations	138
n_d	Number density in doubly excited state of dielectronic recombination process	135
n_e	Number density of free electrons	94
n_i	Number density of atoms in state i	78
n_i^*	LTE value of number density of atoms in state i	79
n_{ijk}	Number density of atoms in excitation state i of ionization stage j of chemical species k	110
n_p	Proton number density	138
$\mathbf{n}_0$	Propagation vector of plane wave	8
$n(\tau)$	Turbulent eddy density	464
$n_k(\mathbf{r}, t)$	Particle density of particle species k in a gas	513
$n_i(\nu)$	Number density of atoms in state i capable of absorbing radiation at frequency ν	77
$\tilde{n}_i(\nu)$	Ratio of population in substate ν of state i to line profile, $n_i(\nu)/\phi(\nu)$	436
N	Total particle density (all species)	115
N	Number density of perturbers	282
N_{jk}	Number density of atoms in all excitation states of ionization stage j of chemical species k	111
N_k	Number density of atoms of chemical species k in all excitation and ionization states	114
N_N	Number density of nuclei (atoms + ions)	115
N_ν	Third angular moment of monochromatic radiation field	502
$\mathcal{N}_{km}$	Number of transitions $k \rightarrow m$	87
p	Total pressure	170

p	Impact parameter of ray in extended atmosphere	247
p	Exponent in power-law expression for perturber–radiator interaction	283
$\mathbf{p}$	Momentum of a particle	32
p_e	Electron pressure	103
p_g	Total gas pressure	115
p_i	Generalized momentum coordinate	85
p_l	Pressure in interstellar medium	533
p_{ji}	Cascade probability of state j to state i	142
p_k	Partial pressure of particle species k in a gas	514
p_ν	Probability of photoionization at frequency ν	94
p_ν	Coefficient in linear expansion of Planck function on τ_ν scale	310
$p(x, x')$	Joint probability of absorption from substate x and return to substate x' in a line transition	277
$p(\xi', \xi)$	Redistribution probability in atom's rest frame	412
$p_R(\mathbf{r}, \nu, t)$, $p_R(z, \nu, t)$, $p_R(\nu)$	Monochromatic radiation pressure scalar	16
$p_R^*(\mathbf{r}, \nu, t)$, $p_R^*(z, \nu, t)$	Thermodynamic equilibrium value of monochromatic radiation pressure scalar	17
P	Radiation-pressure tensor	12
P_d	Photon destruction probability	333
P_{ij}	Component ij of radiation pressure tensor	12
P_{ij}	Total transition rate from level i to level j	128
P^α	Four-momentum	494
$\bar{P}$	Mean radiation pressure	13
$P(t)$	Power radiated from accelerating charge	82
$P(u_h)$	Probability distribution function for dimensionless velocity in turbulent atmosphere	464
$\langle P(\omega) \rangle$	Average power radiated at circular frequency ω by harmonic oscillator	82
$P_e(\tau)$	Photon escape probability	334
$P_{nl}(r)$	Radial charge density	89
q	Heat delivered to a gas, per unit volume	517
q_i	Generalized space coordinate	85
q_ν	Sphericality factor in extended atmosphere	251
$\mathbf{q}_c$	Conductive heat flux	517
$q(\tau)$	Hopf function	55
$q_{ij}(T)$	Collision rate $i \rightarrow j$, per atom in state i, per electron, averaged over Maxwellian velocity distribution at temperature T	132

$q_x(\tau)$	Exponential absorption factor for a turbulent atmosphere	465
$\langle q_x(\tau)\rangle_S$	Static average of $q_x(\tau)$	466
Q	Integration constant in discrete-ordinate method	67
Q	Factor correcting for ionization and radiation pressure effects on mean molecular weight of a gas	188
Q_{ij}	Collision cross-section in units of πa_0^2	132
$Q(r, \mu)$	Derivative of radial velocity along a line of sight in Sobolev method	479
$Q_x(s)$	Laplace transform of $q_x(\tau)$	466
r	Radial distance from center of a star	3
r	Distance between two test points	4
r	Ratio of continuum to line opacity χ_c/χ_l	36
r	Opacity ratio in schematic Lyman continuum problem	222
$\mathbf{r}$	Position in a stellar atmosphere	2
r_c	Core radius in extended atmosphere	251
r_c	Critical radius in transsonic wind	526
r_s	Sonic point radius	562
r_A	Alfvenic radius	535
r_0	Mean interatomic distance	111
r_0	Radial coordinate of surface of constant radial velocity, $(z_0^2 + p^2)^{1/2}$	479
$r_{2/3}$	Radius at Rosseland optical depth $\bar{\tau}_R = \frac{2}{3}$	256
r_*	Stellar radius	11
$\hat{\mathbf{r}}$	Unit vector in radial direction	3
$r_\nu(\mu)$	Residual specific intensity, relative to continuum, in spectrum line at angle $\cos^{-1}\mu$ from disk center, $1 - a_\nu(\mu)$	270
R	Stellar radius	49
$\mathscr{R}$	Rydberg constant	89
$\mathscr{R}$	Reynolds number	560
R	Stress-energy tensor of radiation field	498
R_{db}	Dielectronic recombination rate $d \rightarrow b$	135
R_{ij}	Radiative transition rate from state i to state j	77
$R_{i\kappa}$	Photoionization rate of level i to continuum	123
R_{ji}	Radiative de-excitation rate $j \rightarrow i$ scaled to equilibrium value $R_{ji} = n_j^* R'_{ji}/n_i^*$	129
R'_{ji}	Radiative de-excitation rate $j \rightarrow i$ per atom in upper state	129
$R_{\kappa i}$	Radiative recombination rate $\kappa \rightarrow i$ scaled to equilibrium value $R_{\kappa i} = n_\kappa^* R'_{\kappa i}/n_i^*$	131
$R'_{\kappa i}$	Radiative recombination rate $\kappa \rightarrow i$ per ion in ground state	130
R_ν	Residual flux, relative to continuum, in spectrum line profile, $1 - A_\nu$	269
R_0	Residual flux at center of infinitely opaque line	312

$\mathscr{R}_i$	Net radiative into level i	486
$R(x', x)$	Angle-averaged redistribution function in dimensionless frequency units	427
$R(x', \mathbf{n}'; x, \mathbf{n})$	Redistribution function in dimensionless frequency units	418
$R(\nu', \nu)$	Angle-averaged redistribution function	28
$R(\nu', \mathbf{n}'; \nu, \mathbf{n})$	Redistribution function for scattering process	27
$R_c(\nu', \mathbf{n}'; \nu, \mathbf{n})$	Redistribution function in laboratory frame for coherent scattering in atom's frame	418
$R_{nl}(r)$	Radial wavefunction	89
$R_u(\nu', \nu)$	Angle-averaged redistribution function for atom moving with (dimensionless) velocity $\mathbf{u}$	425
$R_v(\nu', \mathbf{n}'; \nu, \mathbf{n})$	Redistribution function for atom moving with velocity $\mathbf{v}$	416
s	Path length	31
s	Spin quantum number	89
s_e	Electron scattering coefficient per gram of stellar material	554
S	Surface area	3
S	Frequency-integrated source function	54
$\mathbf{S}$	Poynting vector	11
$\mathbf{S}$	Total spin angular momentum of atom	92
S_l	Line source function	80
S_{max}	Maximum source function in finite slab	347
$\mathbf{S}_d$	Discrete representation of source function at depth-point d in Feautrier difference-equation solution of transfer equation	157
$S(i, j)$	Line strength in transition $i \rightarrow j$	88
$S(\mathbf{r}, \nu)$, $S(z, \nu)$, S_ν	Source function, η_ν/χ_ν	35
$S(\alpha)$	Normalized Stark profile	296
$S(-\mu)$	Angular distribution of intensity emergent from grey atmosphere	70
$\mathscr{S}(\mathscr{L})$	Strength of line within multiplet	92
$\mathscr{S}(\mathscr{M})$	Multiplet strength	92
$S_x(s)$	Laplace transform of $\langle q_x(\tau)\rangle_S$	466
t	Time	2
t	Current optical depth scale in Avrett–Krook procedure	174
t	Equivalent electron-scattering optical depth in expanding atmosphere	561
t_c	Self-relaxation time for electrons in a plasma	122
t_r	Average recombination time	122
T	Absolute thermodynamic temperature	7
T	Stress-energy tensor of electromagnetic field	497

T_c	Color temperature	248
T_c	Radiation temperature of core in expanding atmosphere	486
T_e	Kinetic temperature of electrons	122
T_{eff}	Effective temperature	49
T_k	Kinetic temperature of atoms and ions	123
T_r	Radiation temperature	360
T_ν, T	Total optical thickness of finite slab	36
T_0	Boundary temperature of atmosphere	61
T_1	Temperature perturbation in Avrett–Krook procedure	174
$\mathbf{T}_i$	Tridiagonal matrix representing differential operator for angle-frequency point i in Rybicki difference-equation solution of transfer equation	157
$\mathbf{T}^M$	Maxwell stress tensor	14
$T(k^2)$, $T(X)$	Characteristic function in discrete ordinate method	66
$T(t, 0)$	Time development operator	298
$T_A(t, 0)$	Time-development operator for atom	301
$T_P(t, 0)$	Time-development operator for perturber	300
$T_R(\nu, \mu)$, $T_R(\nu)$, T_R	Radiation temperature	121
$T_0(t)$	Current temperature distribution in Avrett–Krook procedure	174
$\mathbf{u}$	Velocity in units of thermal velocity $(m/2kT)^{\frac{1}{2}}\,\mathbf{v}$	417
$\mathbf{u}_d$	Discrete representation of $u(z_d, \nu, \mu)$ in Feautrier difference-equation solution of transfer equation	155
$\mathbf{u}_i$	Discrete representation of depth-variation of $u(z, \nu_i, \mu_i)$ in Rybicki difference-equation solution of transfer equation	157
$u(z, \nu, \mu)$, $u_{\nu\mu}$	Symmetric angle-average of specific intensity $\frac{1}{2}[I(\nu, +\mu) + I(\nu, -\mu)]$	152
$u_h(\tau)$	Hydrodynamic velocity in turbulent atmosphere in units of local thermal velocity $v_h(\tau)/v_{\text{th}}(\tau)$	464
$\mathbf{U}_i$	Matrix giving depth-coupling to $\bar{J}$ at angle–frequency point i in Rybicki difference-equation solution of transfer equation	159
$U(t, 0)$	Time-development operator in interaction representation	302
$U_i(r, \theta, \phi;$ $n, l, m, s)$	Electron orbital	91
$U_{jk}(T)$	Partition function of ionization stage j of chemical species k	111
v	Frequency displacement from line-center measured in Doppler widths, $(\nu - \nu_0)/\Delta\nu_D$	279
v	Average relative velocity of colliding particles	282
$\mathbf{v}$	Velocity	7

v_c	Critical velocity in transsonic wind	526
v_{esc}	Escape velocity from stellar surface	550
v_r	Expansion velocity in radial direction	474
v_z	Expansion velocity along a ray with impact parameter p	474
v_0	Most probable speed	110
v_∞	Terminal velocity in stellar wind	530
v_{th}^*	Fiducial thermal velocity	449
$\bar{v}$	Average speed of convective elements	188
$\dot{\mathbf{v}}$	Acceleration	81
$v(z, \nu, \mu)$, $v_{\nu\mu}$	Antisymmetric angle-average of specific intensity $\frac{1}{2}[I(\nu, +\mu) - I(\nu, -\mu)]$	152
$\mathbf{v}(\mathbf{r})$	Expansion velocity of atmosphere	449
$v_h(\tau)$	Hydrodynamic velocity in turbulent atmosphere	464
V	Volume	6
V	Perturbation potential	86
V	Velocity of atmosphere in fiducial thermal velocity units, v/v_{th}^*	449
V_i	The ith component of total particle velocity in a gas	513
V_i'	The ith component of thermal velocity of a particle in a gas	513
$\langle V_i \rangle = v_i$	The ith component of fluid (or mean flow) velocity in a gas	513
V_{mn}	Matrix element of perturbation potential $\langle \phi_m^* \| V \| \phi_n \rangle$	86
V^α	Four-velocity	542
$\mathbf{V}_i$	Matrix containing depth-variation of quadrature weights and profile functions at angle-frequency point i in Rybicki difference-equation solution of transfer equation	159
$V_{cl}(t)$	Classical interaction potential	301
$V_{cl}'(t)$	Canonical transformation of classical interaction potential to interaction representation	302
w	Electron-impact line width	306
w	Doppler width corresponding to thermal velocity $(\nu_0/c)(2kT/m)^{\frac{1}{2}}$	417
w_k	Quadrature weight	144
w_1, w_2	Relative probabilities of line and continuum bands in picket-fence model	207
W	Dilution factor	120
$\mathbf{W}$	Matrix in final system $\mathbf{WJ} = \mathbf{Q}$ in Rybicki difference-equation solution of transfer equation	160
W_e	Electron distribution function	292
W_i	Ion distribution function	292
W_λ, W_ν	Equivalent width of spectrum line	270
W^*	Reduced equivalent width, $W/2A_0\Delta\nu_D$	318

$W(r)$	Nearest-neighbor distribution function	290
$W(t)$	Energy density in electromagnetic field	8
$W(\beta)$	Field-strength distribution function	291
$W(\beta, \delta)$	Field-strength distribution function allowing for shielding effects	293
$W(\xi)$	Distribution function for velocities along line-of-sight	279
$W_H(\beta)$	Holtsmark field-strength distribution function	294
$W_\lambda(\mu)$, $W_\nu(\mu)$	Equivalent width of spectrum line at angle $\cos^{-1}\mu$ from disk-center	270
x	Cartesian coordinate in horizontal direction	3
x	Frequency displacement from line-center measured in Doppler or damping widths	338
x_α	$1/k_\alpha$, where k_α is a characteristic root	69
$\underline{x}$	Minimum of absolute value of incident and scattered photon frequencies measured in dimensionless units from line-center	428
$\bar{x}$	Maximum of absolute value of incident and scattered photon frequencies measured in dimensionless units from line-center	428
X_α	$x_\alpha^2 = 1/k_\alpha^2$, where k_α is a characteristic root	69
X_ν	Generalized optical depth variable in spherical atmosphere	251
X_ν	Contribution to opacity from (fixed) overlapping transitions	397
X_0	$u_0/(1 - e^{-u_0})$, where $u_0 = (h\nu_0/kT)$	313
$X_t[f(t)]$	K-integral operator	41
y	Cartesian coordinate in horizontal direction	3
Y	Ratio of abundance of helium to hydrogen by number	138
Y_{ij}	Net collisional bracket	132
$Y_l^m(\theta, \phi)$	Spherical harmonic	89
z	Cartesian coordinate in vertical direction (normal to atmospheric layers)	3
z	Path-length along ray in extended atmosphere	247
$z_0(p, x)$, z_0	The z-coordinate of surface of constant radial velocity corresponding to frequency shift x	479
Z	Total geometrical thickness of finite slab	36
Z	Charge number of atomic nucleus	91
Z_i	Ionic charge	330
Z_{ji}	Net radiative bracket in transition $j \to i$	129
α	Stark shift in Å per unit normal field strength, $\Delta\lambda/F_0$	296
α_k	Relative abundance of chemical species k	115
α_ν	Energy absorption cross-section per atom	94
α_*	Stellar angular diameter	12
$\alpha(t)$	Atomic wave function	300

$\alpha_{ij}(\nu)$	Absorption cross-section at frequency ν in bound–bound transition $i \to j$	128
$\alpha_{i\kappa}(\nu)$	Absorption cross-section at frequency ν in bound–free transition $i \to \kappa$	130
$\alpha_{DR}(T)$	Dielectronic recombination coefficient	135
$\alpha_{RR}(T)$	Radiative recombination coefficient	131
$\alpha_{\kappa\kappa}(\nu)$	Free–free absorption cross-section at frequency ν	165
β	Ratio of line to continuum opacity in picket-fence model	207
β	Field strength in units of normal field strength, F/F_0	291
β	Velocity in units of speed of light	493
β_c	Probability of penetration of core radiation to test point in expanding atmosphere	478
β_ν	Fractional departure of monochromatic opacity from mean value	74
β_ν	Ratio of line opacity to continuum opacity, $\chi_l(\nu)/\chi_c = \chi_l\phi_\nu/(\kappa_c + \sigma)$	309
β_0	Ratio of line to continuum opacity for line with Voigt profile, $\beta_\nu = \beta_0 H(a, v)$, $\beta_0 = \chi_0/\chi_c$	312
$\beta(r)$	Photon escape-probability in expanding atmosphere	478
γ	Classical damping constant	82
γ	Ratio of specific heats for an ideal gas	186
γ	Convective efficiency parameter	189
γ	Ratio of radiation force to its limiting value in diffusion approximation	255
γ	Fraction of all emission that occurs coherently in atom's rest-frame	415
γ	Velocity gradient $\partial V/\partial\tau$ in uniformly expanding atmosphere	481
γ	Lorentz transformation factor $(1 - v^2/c^2)^{-\frac{1}{2}}$	493
γ_ν, γ	Ratio of monochromatic opacity to mean value or continuum value	74
γ_ν	Generalized noncoherent scattering coefficient in non-LTE source function	223
$\gamma(z, p)$	Coefficient of frequency-derivative in comoving-frame transfer equation using optical depth scale	504
$\tilde{\gamma}(z, p)$	Coefficient of frequency-derivative in comoving-frame transfer equation	504
Γ	Ratio of specific heats for non-ideal gas (i.e., including ionization and radiation pressure effects)	186
Γ	Ratio of radiation force to gravity force	256
Γ	Reciprocal lifetime of excited state	277
Γ	Total damping width of a line	278
Γ_e	Ratio of radiation force from electron scattering only to gravity	256

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Γ_C	Collisional damping width	282
Γ_L, Γ_U	Reciprocal mean lifetime of lower and upper states of transition $L \leftrightarrow U$	277
Γ_R	Radiative damping width	282
Γ_W	Collisional damping width in Weisskopf theory	283
Γ_3	Resonance damping width	287
Γ_6	Van der Waals damping width	326
$\Gamma_{ij}(T)$	Secondary temperature-dependent factor for collision rates	133
$\delta, \delta_L, \delta_U, \delta_R, \delta_C$	Reduced damping widths, $\Gamma/2$ in circular frequency units, $\Gamma/4\pi$ in ordinary frequency units	277
δ	Number of perturbers in Debye sphere	294
δ	Ratio of continuum to total opacity averaged over line profile	351
δN, δN_d	Perturbation of total number density (at depth-point d) in linearization procedure	118
δT, δT_d	Perturbation of temperature (at depth-point d) in linearization procedure	118
$\delta\mathbf{N}$	Perturbation of total number density distribution in linearization method	184
$\delta\mathbf{T}$	Perturbation of temperature distribution in linearization method	184
δ_{ij}	Kronecker δ-symbol	14
δn_e, $\delta n_{e,d}$	Perturbation of electron density (at depth-point d) in linearization procedure	117
δn_l, $\delta n_{l,d}$, $\delta\mathbf{n}_d$	Perturbation of level-populations (at depth-point d) in linearization procedure	118
δJ_ν, δJ_{dn}	Perturbation of mean intensity (at depth-point d) in linearization procedure	143
$\delta\mathbf{J}_k$	Perturbation of depth-variation of mean intensity (at frequency ν_k) in linearization procedure	184
$\delta(x)$	Dirac delta-function	8
$\delta(z)$	Ratio of Doppler width to fiducial Doppler width, $\Delta\nu_D(z)/\Delta\nu_D^*$	449
$\delta\rho$, $\delta\rho_d$	Perturbation of mass density (at depth-point d) in linearization procedure	183
$\delta\eta_\nu$, $\delta\eta_{dn}$	Perturbation of emissivity (at depth d, frequency ν_n) in linearization procedure	183
$\delta\chi_\nu$, $\delta\chi_{dn}$	Perturbation of opacity (at depth d, frequency ν_n) in linearization procedure	183
$\delta\chi_\nu$	Change in opacity produced by departures from LTE	219
$\delta\boldsymbol{\psi}_d$	Perturbation of solution vector in complete linearization method	231
$\Delta B(\tau)$	Correction to integrated Planck function at depth τ in Unsöld–Lucy procedure	63

$\Delta H(\tau)$	Error in integrated Eddington flux in Unsöld–Lucy procedure	64
$\Delta T(m)$	Temperature perturbation at depth (column mass) m	173
$\Delta\theta$	Difference in θ_{exc} between Sun and a star	327
$\Delta\nu$	Frequency shift arising from Doppler effect	279
$\Delta\chi$	Lowering of ionization potential	112
$\Delta\lambda_c$	Classical damping width in wavelength units	276
$\Delta\lambda_W$	Wavelength shift produced by perturber located at Weisskopf radius	296
$\Delta\nu_D$	Doppler width in frequency units	279
$\Delta\nu_D^*$	Fiducial Doppler width	449
$\Delta\tau_{d+\frac{1}{2}}$	Optical depth increment between mesh-points d and $d+1$ in difference-equation solution of transfer equation	154
$\Delta\omega_g$	Frequency shift from line-center at boundary between impact and statistical-broadening regimes	289
$\Delta\omega_W$	Frequency shift produced by perturber located at Weisskopf radius	289
$\Delta\omega_0$	Line shift in Lindholm theory	285
$\Delta\omega_0$	Normal frequency shift	290
$\Delta\omega(t)$	Instantaneous frequency shift induced by collision with perturber	283
ε	Electric permittivity	7
ε	Fraction of line emission that is thermal (classical theory)	35
ε, ε'	Collisional thermalization parameter in non-LTE source function	337
ε_ν	Generalized thermal emission parameter in non-LTE source function	223
$\bar{\varepsilon}$	Thermalization parameter in schematic Lyman continuum problem	224
ζ_ν, ζ_k	Non-LTE source function parameter	226
η	Photoionization coupling parameter in non-LTE source function	359
η_0	Critical phase shift in Weisskopf theory	283
η'	Phase change in time-interval ds	284
$\eta(t)$	Instantaneous phase shift induced by collision with perturber	283
$\eta(t, s)$	Change in phase in time interval $(t, t+s)$	284
$\eta(\mathbf{r}, \nu, t)$, $\eta(z, \nu, t)$, η_ν	Emission coefficient	25
$\eta(\infty)$, $\eta(\rho)$	Total phase shift produced in collision with perturber at impact parameter ρ	283
$\eta^t(\mathbf{r}, \nu, t)$, $\eta^t(\nu)$	Thermal emission coefficient	26

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$\eta^s(\mathbf{r}, \nu, t)$, $\eta^s(\nu)$	Scattering emission coefficient	28
$\eta^*(\mathbf{r}, \nu, t)$, $\eta^*(\nu)$	Thermodynamic equilibrium value of emission coefficient	26
θ	$5040/T$	322
θ	Polar angle between direction of pencil of radiation and normal to atmosphere layers	3
θ	Recombination source term in non-LTE source function	359
θ_{eff}	$5040/T_{eff}$	213
θ_{exc}	Excitation temperature parameter deduced from curve of growth, $5040/T_{exc}$	322
$\hat{\boldsymbol{\theta}}$	Unit vector in direction of change in polar angle for orthogonal spherical coordinate system	16
Θ	Polar angle of a point on a spherical surface	3
Θ	Angle between incident and scattered photons	416
κ	Thermal conductivity	517
κ_c	Continuum absorption coefficient	205
$\bar{\kappa}_J$	Absorption-mean opacity	60
$\bar{\kappa}_P$	Planck mean opacity	59
$\kappa(\mathbf{r}, \nu, t)$, $\kappa(z, \nu, t)$, κ_ν	Absorption ("true") coefficient	24
$\kappa^*(\mathbf{r}, \nu, t)$, $\kappa^*(\nu)$	Thermodynamic equilibrium value of "true" absorption coefficient	26
λ	Wavelength	8
$\bar{\lambda}$	De Broglie wavelength	300
λ_ν	Ratio of true absorption to total opacity $\kappa_\nu/(\kappa_\nu + \sigma_\nu) = (1 - \rho_\nu)$	148
λ_ν	Fraction of total emission that is thermal in classical line-formation theory $[(1 - \rho) + \varepsilon\beta_\nu]/(1 + \beta_\nu)$	309
Λ	Thermalization depth	335
Λ_i	Discrete matrix representation of Λ-operator at (ν_i, μ_i)	160
$\Lambda_t[f(t)]$	Lambda (mean-intensity) operator	41
μ, μ'	$\cos\theta$ (cosine of polar angle of pencil of radiation)	3
μ	Magnetic permeability	7
μ	Number of atomic mass units per free particle in a gas	519
μ_i	Angle-point in discrete-ordinate method	65
μ_H	Reduced mass of hydrogen atom	89
ν, ν'	Frequency	2
ν_{ij}	Frequency associated with transition $i \rightarrow j$	22
ν_n	Threshold frequency for ionization from nth state of hydrogen	99

ν_0	Threshold frequency for continuum absorption	123
ν_0	Line-center frequency	278
$\underline{\nu}$	Minimum of incident and scattered photon frequencies	426
$\bar{\nu}$	Maximum of incident and scattered photon frequencies	426
$\mathbf{v}_d$	Auxiliary vector used in developing Feautrier difference-equation solution of transfer equation	156
ξ	Line-of-sight velocity	279
ξ, ξ'	Photon frequency in atom's rest frame	412
ξ_{therm}	Most probable line-of-sight thermal speed at temperature T_{exc} deduced from curve of growth	323
ξ_{turb}	Most probable line-of-sight speed of small-scale "turbulent" mass motions in atmosphere	323
ξ_x	Photon destruction probability at frequency x from line center	350
ξ_ν, ξ_k	Non-LTE source function parameter	225
ξ_0	Most probable line-of-sight velocity	279
$\bar{\xi}$	Average photon destruction probability in a line	351
$\pi(t)$	Perturber wave function	300
$\mathbf{\Pi}$	Gas pressure tensor	516
Π_{ij}	The ijth component of gas pressure tensor	514
Π^k_{ij}	The ijth component of partial pressure tensor for particle species k in a gas	514
ρ	Charge density	7
ρ	Mass density	170
ρ	Impact parameter in collision	283
ρ_j	Density matrix element	298
ρ_A	Density matrix for atomic states	301
ρ_P	Density matrix for perturber states	301
ρ_W	Weisskopf radius	283
ρ_ν	Ratio of scattering coefficient to opacity, $\sigma_\nu/(\kappa_\nu + \sigma_\nu) = (1 - \lambda_\nu)$	43
ρ_0	Effective impact parameter for collision-broadening	283
ρ_0	Invariant mass density	542
ρ_{00}	Equivalent mass density of invariant mass density plus internal energy of fluid	542
ρ_{000}	Equivalent mass density of invariant mass density plus enthalpy of fluid	542
σ	Continuum scattering coefficient	309
σ_e	Thomson scattering cross-section for free electrons	106
σ_{tot}	Total scattering cross-section	84
σ_I	Imaginary part of collision integral	285
σ_R	Stefan–Boltzmann constant	12

σ_R	Real part of collision integral	285
$\sigma(\mathbf{r}, \nu, t)$, $\sigma(z, \nu, t)$, σ_ν	Scattering coefficient	24
$\sigma_{ij}(v)$	Cross-section for transition $i \rightarrow j$ induced by collisions with electrons of velocity v	132
τ	Mean time between collisions	282
τ	Proper time	542
τ_c	Continuum optical depth	271
τ_e	Optical thickness of convective element	189
τ_l	Static line optical depth	453
τ_s	Effective impact time	288
$\bar{\tau}_R$	Rosseland mean optical depth	58
τ_1	Optical-depth perturbation in Avrett–Krook method	174
$\bar{\tau}$	Mean optical depth	56
$\tau(\mathbf{r}, \nu)$, $\tau(z, \nu)$, τ_ν	Monochromatic optical depth	34
$\tau_0(r_0)$	Line-of-sight optical depth through uniformly expanding envelope in Sobolev theory	479
ϕ	Azimuthal angle of pencil of radiation around normal to atmospheric layers	3
ϕ	Scalar potential	7
ϕ	Ratio of Paschen jump to Balmer jump, D_p/D_B	236
$\hat{\Phi}$	Unit vector in direction of change in azimuthal angle for orthogonal spherical coordinate system	16
$\phi(s)$	Reduced autocorrelation function	284
$\phi(\nu)$, ϕ_ν	Line absorption profile	27
$\phi_i(\mathbf{r})$	Time-independent wave function of atomic state i	85
Φ	Azimuthal angle of a point on a spherical surface	3
Φ_{ab}	Matrix element describing broadening of spectrum line $a \rightarrow b$	302
Φ_ν	Continuum photon-absorption rate coefficient, $4\pi\alpha_\nu/h\nu$	223
$\Phi(s)$	Autocorrelation function	275
$\Phi(x)$	$\int_{-\infty}^{x} \phi(x)\,dx$	479
$\Phi_{ijk}(T)$	Saha–Boltzmann factor of excitation state i of ionization stage j of chemical species k relative to ground-state population of ionization stage $j+1$, $n^*_{ijk} = n_e n_{0,j+1,k}\Phi_{ijk}$	113
$\tilde{\Phi}_{ijk}(T)$	Saha–Boltzmann factor of excitation state i of ionization stage j of chemical species k relative to total number density in ionization stage $j+1$, $n^*_{ijk} = n_e N_{jk}\tilde{\Phi}_{ijk}$	113
$\Phi_\nu(\mu)$	Limb-darkening function	262

$\Phi_t[f(t)]$	Phi (flux) operator	41
χ_c	Opacity in continuum	35
χ_{lj}	Line opacity in transition $i \rightarrow j$, $\chi_l(\nu) = \chi_{lj}\phi_\nu$	316
χ_{ijk}	Excitation potential of state i, relative to ground state, of ionization stage j of chemical species k	110
χ_{ion}, χ_I	Ionization potential	94
$\bar{\chi}$	Mean opacity	56
$\bar{\chi}_C$	Chandrasekhar mean opacity	74
$\bar{\chi}_F$	Flux-weighted mean opacity	57
$\bar{\chi}_R$	Rosseland mean opacity	58
χ_0	Line opacity assuming a Voigt profile, $\chi_l(\nu) = \chi_0 H(a, v)$, $\chi_0 = \chi_{lj}/(\pi^{1/2}\Delta\nu_D)$	317
$\chi(\mathbf{r}, \nu, t)$, $\chi(z, \nu, t)$, χ_ν	Extinction coefficient, opacity, total absorption coefficient	23
$\chi_l(\nu)$, χ_l	Line opacity	35
ψ_p	Numerical factor in expression for total phase shift	283
ψ_d	Solution vector at depth-point d in complete linearization method	230
$\psi(\mathbf{r}_1, \ldots, \mathbf{r}_N)$	Wave function of N-electron atom	84
$\psi(\nu)$, ψ_ν	Line emission profile	27
$\psi_i(\mathbf{r}, t)$	Time-dependent wave function of atomic state i	85
$\psi^*(\nu)$	Natural-excitation line emission profile	29
ω	Solid angle	3
ω	Circular frequency	8
ω_{mn}	Circular frequency associated with transition $m \rightarrow n$	86
ω_ν	Ratio of line emission profile to absorption profile, ψ_ν/ϕ_ν	437
ω_0	Resonant frequency of an oscillator	82
ω_0	Line-center frequency	276
∇, ∇_E	Logarithmic temperature–pressure gradient in ambient atmosphere and convective elements	187
∇_A, ∇_R	Adiabatic and radiative logarithmic temperature–pressure gradient	186
∇_p	Gradient with respect to momentum coordinates	33
$\oplus$	Earth symbol	524
$\odot$	Sun symbol	171
$\oint$	Integral over all solid angles	5

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