Glossary for c3.4 Flow Chart (2010.05.04)

(1) LEVEL_N: the total number of energy levels in this calculation(ex: If LEVEL_N =3, then calculation will contain J = 0, 1, 2)

(2) TOTAL_N = $\frac{(\text{LEVEL\_N}+1)\times\text{LEVEL\_N}}{2}$: the total number of sublevels without considering the negative m (ex: If LEVEL_N = 2, then TOTAL_N = 3. There are (J,M) = (0,0), (1, 0), (1, 1) three sublevels.)

(3) T : the temperature of the cloud

(4) TAU : the optical depth TAU (use the 1->0 parallel as the unit, So TAU = $\tau_{1\to0,\parallel}$)

(5) TAU_START : the initial optical depth for calculation

(6) TAU_N : the number of optical depths which the code will do calculation at.
ex: If TAU_START = 0.01, TAU_N = 101, then (TAU_START)*(1.0964781)^(TAU_N-1) = 100.
So TAU will go from 0.01 to 100 with 101 points (or main loops).

(7) $n_{JM} = n\left[\frac{J(J+1)}{2} + M\right]$; n[] = {$n_{00}$, n_{10}, n_{11}, n_{20}, n_{21}, n_{22}...}: the population at J, M sublevel (M >= 0)

Since there is no circular polarization, the $n_{JM} = n_{J(-M)}$ all the time.

(8) h : Plank constant = 6.62606896E-34 (J s)

(9) c : speed of light = 299792458 (m/s)

(10) k : Boltzmann constant = 1.3806504E-23 (J/K)

(11) jp = j' : usually denote the transition j -> j'

(12) ε_j : the energy at level j

(13) $E_{j\to j'} = E\left[\frac{(j-1)j}{2} + j'\right] = \exp\left(-\frac{\varepsilon_j - \varepsilon_{j'}}{kT}\right)$: Boltzmann factor

(14) $\text{energy\_level}[j] = \varepsilon_j/100hc$: energy at level j in inverse wavelength unit (1/cm)

$\varepsilon_j = 100hc \times \text{energy\_level}[j]$

(15) T_{BB} = 2.725(K) : Cosmic blackbody radiation temperature

(16) $v_{jj'} = v[j'] = \nu_{j\to j'}/(\text{GHz})$: the frequency (GHz) of the transition j->j' (j = j'+1). Theoretically,

$\nu_{j\to j'} = \frac{\varepsilon_j - \varepsilon_{j'}}{h} = (\text{energy\_level}[j] - \text{energy\_level}[j']) \times 100c$

(17) $Br_{j+1\to j} = Br\_n[j] = 1/(\exp(\frac{h\nu_{j+1\to j}}{kT_{BB}}) - 1)$: normalized intensity of the cosmic background radiation

Originally, the intensity of the cosmic background radiation is $\left(\frac{2h\nu_{j+1\to j}^3}{c^2}\right)/(\exp(\frac{h\nu_{j+1\to j}}{kT_{BB}}) - 1)$

(18) a_matrix[i*TOTAL_N + j] = a[i][j] : a TOTAL_N by TOTAL_N matrix which stores the coefficients of rate equations. Here I use a 1D array as a 2D matrix.

$$0 = \frac{dn_i}{dt} = a[i][0]n_{00} + a[i][1]n_{10} + a[i][1]n_{11} + \cdots + a[i][j]n_j + \cdots + a[i][\text{TOTAL\_N}]n_{\text{TOTAL\_N}}$$

$$\text{where } i = (J, M) = \frac{J(J+1)}{2} + M;\ j = (J', M') = \frac{J'(J'+1)}{2} + M'$$

(19) a_matrix_i[] : similar to a_matrix[], but it does not contain the radiative transition part, which contains A[] and R[].

(20) $C_{J\text{->}J'}$ = C[(J-1)J/2+J'] : collisional excitation coefficients/rate for J->J' where J > J'

(21) $A_{J\text{->}J'} = A_{JJ'}$ = A[J']: Einstein A-coefficients for J -> J', (J = J'+1)

(22) $A_{JM\text{->}J'M'} = A_{JM\text{->}J\text{-}1,M+dM} = A^{dM}_{JM}$ = A_coeff(J, M, dM): Einstein A-coefficients for sublevel transition (J, M) -> (J-1, M+dM)

(23) $R^q_{J+1\text{->}J} = R^q_J$ = R[J][q]: normalized radiation for J+1-> J with polarization q. See Deguchi and Watson's paper (1984) equation 12

(24) q : polarization direction, 0 for parallel ∥, 1 for perpendicular ⊥

(25) b[] = {Nt, 0, 0, …}: used for solving the rate equations. Nt is total number of particle or density which does not affect the result of calculation.

(26) REL_PREC : relative precision criterion for the iteration to decide whether it converges or not.

(27) $\mathrm{k}^{\mathrm{q}}_{\mathrm{J+1,J}} = \mathrm{k}^{\mathrm{q}}_{\mathrm{J+1\rightarrow J}} = \mathrm{k\_f\_n(x, q, J)}$: normalized absorption coefficients for J+1 -> J with q polarization along the direction x.

(28) OBS_ANG : the angle between the light of sight and z axis.

(29) $\mathrm{I\_pa\_n()} = \int \mathrm{I}^{\mathrm{q}}_{\mathrm{JJ'}} \phi(\nu - \nu_{\mathrm{JJ'}}) \mathrm{d}\,\nu$: the normalized profile-averaged intensity given by the large velocity gradient (LVG) approximation. In the code, it has already been divided by $(2h\nu^3/c^2)$

(30) $\mathrm{tau}^{\mathrm{q}}_{\mathrm{j+1,j}} = \tau^{\mathrm{q}}_{\mathrm{j+1\rightarrow j}} = \mathrm{tau[j][q]}$: optical depth for transition j+1->j with polarization q. They use the optical depth of the line which is TAU_ANG from the z axis as the unit.

(31) TAU_ANG : the angle between z axis and the line which the unit of optical depth has been used. Usually we set TAU_ANG = OBS_ANG, but it can be set to be different.

(32) 1D, one-dimensional case : velocity gradient is in z axis, $\tau \propto 1/\cos^2\theta$

(33) 2D, two-dimensional case : velocity gradient is in x-y plane, $\tau \propto 1/\sin^2\theta$

(34) Mix, mix case : velocity gradient is in z axis and x-y plane, $\tau \propto 1/(\cos^2\theta + \alpha\sin^2\theta)$

(35) Isotropic case : no polarization case

(36) $\mathrm{I}^{\mathrm{q}}_{\mathrm{j+1\rightarrow j}} = \mathrm{I}^{\mathrm{q}}_{\mathrm{j+1,j}} = \mathrm{I[j][q]}$: normalized emerge specific intensity for j+1->j, polarization q. In the code, it has already been divided by $(2h\nu^3/c^2)$

(37) $\mathrm{S}^{\mathrm{q}}_{\mathrm{j+1\rightarrow j}} = \mathrm{S}^{\mathrm{q}}_{\mathrm{j+1,j}} = \mathrm{S[j][q]}$: normalized source function for j+1->j, polarization q. In the code, it has already been divided by $(2h\nu^3/c^2)$

(38) $\mathrm{beta\_f}(\tau = \mathrm{tau}) = \beta(\tau) = \frac{1-\mathrm{e}^{-\tau}}{\tau}$: the escape probability