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## Option Behavior

Options are ordered under subject. Associated with each option are requested inputs. Some inputs are not prompted for, and can only be changed from their default values by specifying them in the call. eg.

CJBB (JONS=T)

In this documentation, such input are placed in [ ]. If you see a hidden option which is not described, check \$cmfdist/disp/maingen.f. The option use should be obvious.

Many options, e.g., DC (departure coefficients) operate on many species. The species is specified by direct attachment to the option call. For example to plot departure coefficient for C2, issue the command

DC\_C2

Options that require species addenda are specified by a \* --- eg DC\_\*.

All logs are base 10, unless specifically noted otherwise.

#### SVE and BOX file

Default is to write file MAIN\_OPT\_STR.sve

Append sve=filename to write a new .sve file (no brackets)

Type box=filename to write a .box file containing several .sve files

Type .filename to read .sve file

Type #filename to read .box file

Options fall into different classes: X-axis options, Y-axis options, and output. X-axis options simply set the default X-axis for subsequent plots, although users should be aware that not all plot options use the default X-axis. Y-axis options set the Y-axis. Generally multiple Y-axis options can be executed before a call to the plotting routine (PGPLOT subroutines). Some Y-axis options initiate a call to the plot routine immediately.

## X Axis options

XLOGR	Set X axis to $\log(r/R^*)$ .
XLINR	Set X axis to $r/R^*$ .
XARC	Set X axis to arcseconds [LIN=T] gives linear axis
XAU	Set X axis to units of AU [LIN=T] give linear axis
XRSUN	Set X axis to units of R <sub>sun</sub> [LIN=T] gives linear axis
XED	Set X axis to $\log(N_e)$ .
XROSS	Set X axis to $\log(\text{Tau}(\text{Ross}))$ .
SXROSS	Set X axis to spherical Rosseland optical depth scale.
XCOLD	Set X axis to $\log(\text{column density})$ .
XATOM	Set X axis to $\log(N_i)$ where $N_i$ is the atom/ion density.
XMASS	Set X axis to mass exterior to grid point.
XN	Set X axis to vector index I
XTEMP	Set X axis to Temperature (units $10^4$ K).
XVEL	Set X axis to vector index Vel(km/s)
XLOGV	Set X axis to vector index $\text{Log}(\text{Vel}(\text{km/s}))$
XTAUC	Set X axis to $\text{Log}(\text{Tau})$ [Continuum wavelength requested]
XCAKT	Set X axis to CAK (Castor, Abbott, & Kelin 1975) "t". The default Doppler velocity is 10km/s. Note that the CAK "t" parameter is generally not a monotonic function of r. [VTH] : hidden --- sets the Doppler velocity.

## Graphing options

TIT	Allows title (or revised) TITLE to be set. Note that inputting "" will generally set the string to blanks.
GR	General purpose Graphing routine.
GRNL	General purpose Graphing routine. As for GR but ignores labels.
GRED	Plots electron density on top axis. Assumes default X-axis. Ne is matched to X-axis using monotonic interpolation.
GROSS	Plots Rosseland optical depth on top axis. Assumes default X-axis. The Rosseland optical depth is matched to X-axis using monotonic interpolation.

## Parameter options

SET-ATM	Sets atmosphere to wind or exponential. For use in calculating Tau at outer boundary.
SET-METH	Sets the method for evaluating derivatives for use when computing the optical depth scale. Options LOGMON, LOGLOG, and ZERO.
SET-IBC	Sets inner boundary condition: DIFFUSION, SCHUSTER, ZERO_FLUX, HOLLOW. Default is DIFFUSION approximation for stars, and ZERO_FLUX for SN.

## Model info options

WRFREQ	Output frequencies (in units of $10^{15}$ Hz), corresponding to the bound-free edges of all levels, to EDGE_FREQ.
WRN	Output summary of model atoms to screen (species & number of levels).
WRID_*	Output summary of levels to screen [LIMS] --- from level LIM(1) to level LIM(2) Lists level and level name.
WRTRANS	Outputs a summary of all bound-bound wavelengths between 2 wavelength limits (format as in CMFGEN).
LNID	Creates a line ID file for stars with weak winds. Option selects line for which the optical depth exceeds some limiting values at $\tau_{\text{auc}}=2/3$ . Can be read in by PLT_SPEC to identify spectral lines.

## Y Axis options

YLOGR	Plots $\log(r/R^*)$
CLUMP	Plots clumping factor or reciprocal of the clumping factor. [RECIP=T]
DIFFT	Plots an estimate of the diffusion time to the outer boundary (DB=T), or the diffusion time between grid points (DB=F).
ED	Plots $\log(\text{Electron density})$ .
T	Plots $T(10^4 \text{ K})$ .
LOGT	Plots $\log(T[10^4 \text{ K}])$ .
THOP	Compute and plot T computed using the spheric Hopf function.
DTDP	Plots $d\ln T/d\ln P$
PGONP	Plots $P(\text{gas})/P(\text{Radiation})$ as a function of depth (optically thick approximation).
DPDR	Computes $1/\rho \text{ d}P(\text{gas})/\text{d}R$ .
DERAD	Plots integrated nuclear decay energy as a function of depth.
VEL	Plots $V(\text{km/s})$ .
LOGV	Plots $\text{Log}(V(\text{km/s}))$ .
SIGMA	Plots $\text{Log}(d\ln v/d\ln r)$ [ $\log(\text{sigma}+1)$ ].
YDEN	Plots density ( $\text{gm/cm}^3$ )
YCOLD	Plots $\log(\text{column density})$ .
YATOM	Plots $\log(N)$ where N is the (total) atom density.
YION	Plots $\log(N_i)$ where $N_i$ is the (total) ion density.
YROSS	Plot $\log(\text{Tau}(\text{Ross}))$ .
SYROsS	Plot spherical Rosseland optical depth scale.
ROP	Plots the Rosseland mass absorption coefficient against $\rho/T^3$ . Scaling often used with opacity tables.
TGREY	Plot grey temperature scale (if already computed by GREY option).
TCMF	Plot grey temperature scale computed by CMFGEN *(useful for SN models).
GREY	Evaluate grey temperature structure after first computing Rosseland mean opacity. X-axis setting is ignored, and T(grey) is plotted against $\log(\text{Tau}_{\text{ross}})$ . You will generally need to reset the default X-axis after using this option. [ELEC] Plots $\log(T[\text{grey}])$ .
TRAT	Plots $T/\text{TGREY}$ (assumes grey temperature distribution has been created).
ISOC	Plots the isothermal sound speed.
EK	Computes kinetic energy of outflow (in $L_{\text{sun}}$ ).
EI	Computed internal energy of outflow (in $L_{\text{sun}}$ ).
FONR	Plots Flux mean opacity / Rosseland mean opacity.
CAKT	Plots the Castor, Abbott, Klein (1975) "t" parameter.
MT	Plots the force multiplier. By definition it does not include the force contribution by electron scattering. However, in the implementation here the contributions by bound-free and free-free opacities (important at depth), are included.

## Control Options

These options were more useful in an earlier version, and are generally no longer used.

HZ IN	Switches frequency input units to $10^{15}$ Hz (def)
KEV IN	Switches frequency input units to KeV
ANG IN	Switches frequency input units to Angstrom

## Switches for testing

XRAY	Switches on/off K-shell X ray opacities.
DIS	Switches on/off level dissolution. This option is only for experimenting and testing --- it generally does not need to be used. Default is set when model is read in.
METHOD	Allows you to change the method for computing the derivatives (ZERO, LOGLOG, LOGMON) for use with Euler-McLaurin summation formula.

## Continuum options

LAM	Wavelength (Ang) or if neg in units of $10^{15}$ Hz.
ELEC	Include electron scattering opacity?
OP	Plots the continuum opacity [ $\text{cm}^{-1}$ ] [NOT program units].
KAPPA	Plots the mass absorption coefficient ( $\text{cm}^2/\text{g}$ )
ETA	Plots the continuum emissivity [ $\text{ergs}/\text{cm}^3/\text{s}/\text{Hz}$ ].
TAUC	Plots the continuum optical depth.
DTAUC	Plots the continuum optical depth increments ( $\Delta\text{Tau}$ ).
MEANOPAC	Outputs opacities, optical depth scales and optical depth increments to file in an identical format to MEANOPAC created by CMFGEN.
RAY	Plots the Rayleigh scattering opacity due to Hydrogen as a function of depth.
RAYL	Plots the Rayleigh scattering cross section as a function of wavelength. It is normalized by $N(\text{g.s.})$ times the Thompson electron scattering cross-section.
CJBB	Plots J/BB for continuum against current X axis (def). [TPLT] Set X axis to $\log(\text{Tau}[\text{continuum}])$ - X label corrupted. [JONS] Plot J/S for continuum (F). [JONLY] Plot J
JEXT	Allows comparison between J computed using ray-by-ray solution (NEWJSOLD) on ND grid, and J computed using Eddington factors (JFEAUNEW) on a more refined depth grid: $(\text{ND}-1)+1$ if $\text{ND} < 50$ $2(\text{ND}-1)+1$ if $\text{ND} < 80$ ND otherwise. The error is defined by:

$$200(J[E]-J([R]))/(J[e]+J[R]).$$

[LOGE] - Plots log of absolute value of the error.

### Multi-frequency continuum options

RTAU	Computes R at the given continuum TAU value for a set of user provided frequencies. [LINX] : Determines whether to plot a linear X axis. [LINY] : Determines whether to plot a linear Y axis
VTAU	Computes V at the given continuum TAU value for a set of user provided frequencies
ALBEDO	Plots the albedo at given continuum TAU.
TAUR	Computes TAU at the given R value for a set of user provided frequencies. [LINX] : Determines whether to plot a linear X axis. [LINY] : Determines whether to plot a linear Y axis.
CHIR	Computes CHI ( $\text{cm}^{-1}$ ) at a given value of R for a set of user provided frequencies.
KAPR	Computes KAPPA ( $\text{cm}^2/\text{g}$ ) at a given value of R for a set of user provided frequencies.
ETAR	Computes ETA ( $\text{ergs}/\text{cm}^2/\text{s}/\text{Hz}$ ) at a given value of R for a set of user provided frequencies.

### Output options

WRDC	Output departure coefficients in CMFGEN format for all species present. These files may be used as input for CMFGEN. [OWIN] Indicates depths at which populations are not output. Up to 5 pairs (S1,E1,S2,E2 etc) may be input at once. Depths between S1 and E1 inclusive, will be omitted, etc. [EXT] Indicates file extension. For example, EXT=_IN will yield HI_IN, C2_IN etc. The output files must not exist.
WRTX	Output populations for all species present. Same file format and options as for WRDC. Outputs excitation temperature (relative to ion) for all species. Same file format and options as for WRDC. Can be read by WR_F_TO_S to create an input departure file for a new, higher, ionization stage.
WRLTE	Writes LTE populations for all species present in the model. Same file format and options as for WRDC.
WRC	Output R, T, SIGMA, V, ETA, CHI_TH, ESEC to old format file (i.e. column format). CHIL and ETAL are set to 1.0E-10.
WRL_*	Output line data for computation of line profiles by other programs. R, T, V, SIGMA, ETA, CHI, ESEC, ETAL and CHIL are output. Two data formats are available: A column format for single lines, and a row format for multiple lines.

### Ionization stage specifiers

I	2	III	IV	V	SIX	SEV	VIII
IX	X	XI	XII	XIII	XIV	XV	XSIX

### Species and ion specifiers

H : HYD	He : HE	C : CARB	N : NIT	O : OXY	F : FLU	Ne : NEON	
Na : SOD	Mg : MAG	Al : ALUM	Sx : SIL	P : PHOS	S : SUL	Cl : CHL	Ar : ARG
K : POT	Ca : CAL	Sc : SCAN	Tx : TIT	V : VAN	Cr : CHRO	Mn : MAN	Fe : IRON
Co : COB	Nk : NICK						

### Example ionization state specifiers (i.e., \*)

HI	H2	HeI	He2	HeIII							
CI	C2	CIII	CIV	CV							
NI	N2	NIII	NIV	NV	NSIX						
OI	O2	OIII	OIV	OV	OSIX	OSEV					
FeI	Fe2	FeIII	FeIV	FeV	FeSIX	FeSEV	FeVIII	FeIX	FeX	FeXI	FeXII

## Species options

IF_*	Plots the ratio of the population relative to total ion population for each ionization state. [SPEC FRAC=T] Plots relative to total species abundance.
SCL_*	Scales a given population by a set factor for all depths beyond some depth K (i.e. for depths 1 to K). NB: Scale factor should generally be less than unity. To scale populations between depths L and K only do the following: SCL(SCL_FAX=X,Depth=K) SCL(SCL_FAX=1/X,Depth=L) Option available to adjust populations for input to CMFGEN. An LTE option should be issued before calling WRDC.
YSPEC	Plots species population, or log (species_pop/atom_pop). The latter requires [ELEC]=T.
IMASS	Plots mass of a given species, exterior to depth I, against current X coordinate.

## Level Options

DC_*	Plots departure coefficients for specified levels. Levels specified as 1,2,3,4,6 or 1:4,6. A maximum of 10 levels can be input.
DCS	Plots departure coefficients of each level as a function of depth. Departure coefficients at each depth make a single curve --- use symbol option in gramon_pplot.
LDC	Plots departure coefficient as a function of level at a given depth.
LPOP	Plots population as a function of level at a given depth.
TPOP	Plots radial Sobolev optical depth as function of level at a given depth (assuming f=1 and no correction for stimulated emission).
POP_*	Plots populations for specified levels.
RAT_*	Plots summed population of species. Can also be used for highest ionization state. Then Equivalent to D*. Can be used to indicate in which region a particular ion is dominant.
ION_*	Plots ionization ratio. Population for any species is summed over all levels in that species. ION* refers to the * species, and the next ionization stage.
QF_*	Computes the column density for all ionization stages belonging, to a species and for the atom. If XV is the column density for species XzV, the program returns XV/X where X is the species column density. Inserted for comparison with SETI results.
DION_*	Plots the population of highest ionization stage. e.g., DION He2 plots He++
RR_*	Computes integrated recombination coefficient, which can be plotted. Units are such that the line flux is $RR * \alpha / d^2 / \lambda$ ergs/cm <sup>2</sup> /sec. Alpha ( $\alpha$ ) is the effective recombination rate in units of $10^{-12}$ , $d$ is the distance in kpc, and $\lambda$ is the transition wavelength in $\mu$ m. [TVAR] Assume recombination rate varies with T (F). Computed recombination rate is normalized to $10^4$ K. [EXP] Exponent for T variation (Recombination assumed to vary as $T^{-0.8}$ ).
WLD_*	Plots occupation probabilities as a function of depth.

## Line options

SOBR *	Computes net rate using Sobolev approximation.
NETR_*	Computes net rate using full CMF solution. If the FORM method is adopted (see below) J, H, CHI{L}. H, and M {force multiplier} can be plotted at selected depths. [COL_OPT] Solution method: FORM, FG, HAM. The FORM method has a large number of options designed for testing the radiative transfer. [HAM] Use second order frequency differencing (F) [SKIPEW] Skip Equivalent Width computation (F). [EWACC] Required % accuracy of WE computation (0.05%). If the FG or HAM option is specified, the atomic mass is taken as 4 for all species.
MOMR_*	Similar to NETR* but use Eddington factors for solution. [HAM] Use second order frequency differencing (F). [FULESS] Include line photons scattered in resonance zone? (T) [EWACC] Required % accuracy of WE computation (0.05%).
BETA *	Computes Sobolev Escape Probability.
EW_*	Computes the line EW, and plots line formation region or the force multiplier, M(t). EW and line formation region. Options are only useful for W-R stars and LBVs. EW takes into account absorption of continuum radiation by the line when indicating the line formation region -- EP* (an older option) does not. The parameter plotted on the y-axis is normalized such that "Y.dlogr" is the relative contribution to the EW by the interval dlogr. Thus the formation zone /EW should generally be plotted against "log r". Other x-axis variables will cause distortion.
EP_*	Plots line formation region.[ELEC] Ignores electron scattering opacity (T). Preferred option as electron scattering does not destroy photons. [NEW] Includes continuum absorption of line photons (T). [LINV] Plot against linear R scale ? (F)
DIE *	Computes EW for a dielectronic line (parameters input)
SRCE *	Plots log(SL) --- SL is the line source function.
SRCEBB *	Plots log(SL/BB) where BB is black body.
SRCEJC *	Plots log(SL/Jc) where Jc is mean continuum intensity.

## Line Options (thickness)

CHIL *	Line opacity at line core. Assume a Doppler velocity of 10km/s.
TAUL_*	Plots the Sobolev optical line depth. [STAT] Computes stationary line optical depth (assuming a Doppler velocity of 10km/s and that the macroscopic velocity field is zero).
CAKT	Plots the CAK (Castor, Abbot, and Klein) parameter.
TAUSOB	Plots the Sobolev optical depth scale. Assumes $f_g=1$ , and uses the atom density for the level population.
GF *	Plots gf values in a fixed wavelength interval as a function of wavelength.
DIST_*	Plots the logarithmic Sobolev optical depth (radial or angle averaged) for every line in a given wavelength interval as a function of the line wavelength. Lines with a negative optical depth are set to -20.
NV_	Plot the number of lines with optical depth > TAU_MIN in a given velocity interval at a specified depth.
LTAU_*	Computes the optical depth of lines of a given ionization stage and species at a given depth in the atmosphere. Either the radial or tangential Sobolev optical depth is used. When plotting, use the V mode with the C(onnect) option. Alternatively it is possible to plot a line strength defined by $10^{-15} \cdot \text{CHI}\{\text{Line}\} \cdot (10 \text{ kms/C}) / (\text{sigma Ne})$ . This is a "mean" line opacity normalized by the electron scattering opacity.
VLTAU	Plots a vertical line, at each line frequency, showing the rang of velocities over which a line has an optical depth larger than unity. Currently plots for all species.
POW_*	Plots the number of lines in Log $\tau$ or Log (Line strength) space at a given depth. Each uniform logarithmic bin is 0.25 wide in LOG10 space. For Log $\tau$ space, the line optical depth is normalized by the electron scattering opacity.
DCHI	Creates an image of the partial opacities (i.e., the opacities due to each ionization stage) at a given frequency as a function of depth. The images are scaled by the TOTAL opacity at that depth.
LCHI	Creates an image of the fractional contribution to the opacity as a function of species and wavelength.
MCHI_*	Does one of two things: 1. Creates an image of the fractional contribution to the opacity and emissivity of a single species as a function of depth and wavelength. 2. When no species is specified, the maximum fractional contribution of each species at ANY depth is output to the terminal.

## Model correction options

Designed to fudge populations and temperatures. These fudged values can be output, and used to restart a model which is failing to converge.

AV *	Replaces population at a given depth by average population at adjacent depths.
REP *	Replaces population at a given depth by population at another depth.
FIXT2	Computes new T distribution based on GREY temperature distribution. GREY option must be called first. Populations are adjusted under the assumption that the departure coefficients are constant. The electron density is self-consistently estimated. Needs to be iterated. [SCALE] - Optical depth below T remains approximately fixed.
FIXT	Old temperature correction procedure. No adjustment to ED. Must do GREY, FIXT, and finally LTE option. [SCALE] - Optical depth below T remains approximately fixed.
EXTRAP	Set $T(I:J)=T(I:J+1)$ . Over the same range, the populations are determined assuming the ionization is constant. The LTE populations are updated.
LTE	Re-computes LTE populations.
NEWRG	Creates a new R grid, equally spaced on some Log $\tau$ scale.
WRRVSIG	Creates an RVSIG_COL file.
SCL_#	Scales the populations of all levels belonging to a species below some depth (see under species options).
TST	Allows velocity law to be plotted for different input parameters (e.g, $\beta$ , $V_{core}$ etc). Useful for checking effect of parameters, smoothness of velocity law etc.
CHKV	Estimates V at some inner radius ( $r < R_*$ ) for the current V(r).
SM	Smooths the level populations (or departure coefficients) over depth. Not very sophisticated.
MODSUM	Corrects the MOD_SUM file for CMFGEN which was corrupted in versions prior to 01-Sep-199?

## Atomic data options

GNTFF	Computes free-free gaunt factor for Hydrogenic ion.
GNTBF	Computes bound-free gaunt factor for Hydrogenic ion.
COL *	Computes and outputs average collision strength, OMEGA(I,J)
COLR_*	Computes collision rates at a specified depth. Net rates, downward rate, of cooling rate can be output.
PHOT_*	Outputs the photoionization cross-sections at a given frequency, or at the ionization edge ( $\nu=0$ ).
PLTPHOT_*	Plots the photoionization cross-section for a given level, as a function of $\lambda$ , frequency ( $\nu$ ), or normalized frequency ( $\nu/\nu_0$ ). The differential recombination rate can also be plotted. It can also plot all cross-sections for the ground state of a given species (e.g., CARB) as a function of Hz or EV.
RDDIE_*	Read in dielectronic lines for resonances not included in the photoionization cross-section. These will then be included with the photoionization cross-sections. [DIE_REG] Includes dielectronic lines from levels permitted to autoionize in LS coupling? [DIE_WI] Includes dielectronic lines from levels NOT permitted to autoionize in LS coupling? [VSM] Smoothing width in km/s.
NRR_*	Compute recombination rate for a given species. [PHOT_ID] Photoionization route (1 is normal default) [EXC_EN] Excitation energy of final state ( $\text{cm}^{-1}$ ) [GION] Statistical weight of lower level.
RR_*	Computes approximate integrated recombination rate (i.e., an emission measure). $d=1\text{kpc}$ , and $\alpha = 10^{-12}$ is assumed. Units are $\text{ergs/cm}^2/\text{s}$ . [TVAR] Allow for variation of T [EXP] Exponent for T variation (generally +ve). ( $\alpha$ varies as $1/T^{\text{EXP}}$ )

## Miscellaneous options

LAM	Computes Lambda for current line frequency. In vacuum for $\lambda < 2000\text{\AA}$ , otherwise in air. [FREQ]: Frequency for which lambda required.
INTERP	Routine interpolates and sets Y axis for the last plotted variable against R (crude).
CHKV	Determines radius (and velocity) where Rosseland optical depth is $\tau$ . [TAU] : Rosseland optical depth at which R and V are to be determined (default=100).
EXIT	Exit from display package
EX	Exit from display package