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About PANDORA

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Pandora *('all gifts'):* According to Hesiod, Pandora was the first woman, and was created by Zeus to punish man after Prometheus had created and helped the human race. She came with a box or storage-jar in which all evils and diseases were stored, and when Prometheus's guileless brother Epimetheus married her and opened the box, all these escaped, leaving only Hope at the bottom to be some alleviation of the troubles let loose upon the world. 'Pandora's box' became proverbial ...

from: "Who's Who in the Ancient World"
by Betty Radice (Penguin Books)

Sections

Section 1: **Input Language**

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PANDORA uses free-field self-identified input. The basic input unit is the vector or one-dimensioned array; single variables, on the one hand, and multiply-dimensioned arrays, on the other, are treated as special cases of the vector. A PANDORA input statement specifies the name of the array, and the values to be stored in consecutive locations of it. Several control facilities are provided, to make specifying input statements less tedious.

The general input statement is: **NAME** j **(** Q **)** .

Each component of that statement (including '**(**' or '**)**') is a separate 'field' or a set of fields. PANDORA's input routines use `NUDEAL`, whose conventions require that every 'field' be preceded by at least one blank, and followed by at least one blank; (*i.e.* blank is the required 'separator' between fields). In the example above, **NAME** is the name of the input quantity (array) whose values follow; j is none or several auxiliary indices; and Q is the sequence of fields and control parameters that specify the values to be stored in memory.

PANDORA's input routines maintain an internal pointer, initially set to 1 and subsequently incremented or set as specified or implied by Q, which identifies that member of the array that will be affected by the next input specification in Q. Therefore, when in the remainder of this section I use phrases like 'the array member currently being read into,' I mean the array member identified by that internal pointer.

The remainder of this section deals with: 1) field format basics; 2) **(** Q **)**; and 3) examples. The various types of input statements (*i.e.*, combinations of **NAME** and j) are discussed in Section 2; the many **NAME**s recognized by

PANDORA are treated in Section 5.

1.2

1. Format Basics

PANDORA reads input file(s) line by line; only the first 80 characters of each line are read. Each line is scanned, character-by-character, from left to right, beginning with the first character, until end-of-line (which normally occurs after the 80. character). Five types of input fields are recognized: 1) null field, 2) excessive field, 3) integer field, 4) floating point field, and 5) alphanumeric field. Only integer, floating point and alphanumeric fields are legal PANDORA input fields, the other two are considered errors.

1) Null field: the scan encountered more than 159 successive blanks, without a non-blank character turning up.

2) Excessive field: the scan encountered more than 60 successive non-blank characters, without a blank (*i.e.* break character) turning up.

3) Integer field: like an integer constant in FORTRAN, containing up to 9 significant digits. An integer field may contain: digits, and at most a single sign.

4) Floating point field: like a real constant in FORTRAN, containing up 16 significant digits, with an exponent value not exceeding 300. A floating point field may contain: digits, at most a single sign for the mantissa, at most a single decimal point for the mantissa, at most a single exponent flag, at most a single sign for the exponent.

5) Alphanumeric field: anything that is not one of the field types (1) – (4), above.

Digits: [0 1 2 3 4 5 6 7 8 9]

Signs: [+ −]

Decimal point: [.]

Exponent flags: [E e D d]

2. Q

Q may contain the following fields: *n*, **M**, **m**, *m*, **I**, **i**, *i*, **R**, **r**, *r*, **S**, **s**, **F** and **f**. Here the **boldface** fields are names (identifiers) of control parameters, and the *italic* fields are numerical values, either of input quantities, or of the control parameters whose names precede them.

n is the quantity (an integer, a floating point number, or an alphanumeric quantity) to be stored in the array member currently being read into; before being stored in memory, the value of *n* (if an integer or a floating point number) will be multiplied by *m*.

M or **m** signal that a value of *m* will follow.

m is either a floating point number, by which all floating point *n's* following *m* will be multiplied before being stored in memory; or is an integer, by which all integer *n's* will be multiplied before being stored in memory. The modes of *m* and *n* must agree (*i.e.* both integer or both floating point). The default value of *m* is 1; this value will be used if a different value of *m* is not specified explicitly in *Q*. Successive values of *m* are not multiplied together; it is always the latest value encountered that will be used.

I or **i** signal that a value of *i* will follow.

i is an integer which explicitly specifies the next array member to be read into (*i.e.* it is used to reset the internal array pointer). Any *n* not preceeded by an *i* will be stored in the array member specified by the internal array pointer. If the first *n* in *Q* is not preceeded by an *i*, it will be stored as the first array member.

R or **r** signal that a value of *r* will follow.

r is an integer specifying the value of the 'repeat' counter. The repeat counter specifies that the next *n* should be 'used' *r* times. For example: **R** 3 1.7 means that the next array member to be read into, and the two succeeding ones as well, will all be set equal to 1.7; also: **I** 7 **r** 3 1.0 (which is equivalent to **R** 3 **i** 7 1.0) means that array members 7 – 9 will all be set equal to 1.0. If the specified value of *r* implies members beyond the high end of the array, then such 'excess' will be ignored. The default value of *r* is 1.

S or **s** signal that the next array member to be read into should be skipped (*i.e.* no value will be specified for it, and its current contents should be left unchanged). The sequence **R** *r* **S** means that the next *r* array members to be read into should be skipped.

F or **f** signal that the *n* following **F** should be stored in the current array member to be read into and all succeeding ones as well (*i.e.* the sequence **F** *n* 'fills' the remainder of the array, or indeed the entire array, with *n*).

The sequence [*A*] constitutes a comment or remark. The occurrence of opening square bracket (followed by a blank) signals the beginning of a comment, *A*, which may comprise any number of fields consisting of any characters, except closing square bracket. The occurrence of closing square bracket (preceeded and followed by blank) signals the end of the comment. PANDORA ignores the entire comment (including the delimiting brackets).

The field > ('greater than' sign) indicates end-of-line (*i.e.* the remainder of the input line on which it occurs should be skipped).

Note: only UPPERCASE alphabetic characters were recognized originally; the generalization to mixeD-CAse was implemented later.

3. Examples

Here are some sample lines of input:

```
0001    N ( 34 )
0002    KK ( 13 ) >
0003    IOMX ( 2 ) > STUFF AFTER 'GREATER THAN' IS IGNORED
0004    [ THIS IS A REMARK ]
0005    XK ( I 13 5.5 ) DLU ( 0.1 ) >
0006    TE ( F 10000. )
0007    NE ( 0. M 1.E1 1. 2. 3. 4. 5.
0008    R 5 6. F 7. )
0009    [THIS STUFF IS NOT A COMMENT ]
0010    [ THIS ALSO IS NOT A R E M A R K]
0011    A 2 1 ( 1.E8 ) [ ESTIMATE > ]
0012    CRD 2 1 ( 1.E-5 ) [ ESTIMATE ] >
```

— Lines 1, 4, 6, 7, 8, 9 and 10 are scanned in their entirety (*i.e.*, all 80 characters); the others up to > only.

— Line 3 shows an alternate form of comment.

— In Line 5, the 13. value of XK is set to 5.5, and DLU is set to 0.1; showing that there may be more than one input statement in a line.

— Lines 7 and 8 show that one input statement may extend over several lines; it is the final ')' that indicates the end of the NE statement. The values in memory of NE will be: 0, 10, 20, 30, 40, 50, 60, 60, 60, 60, 60, 70 ... 70.

— Line 9 would be a valid comment if there were a blank after [, Line 10 likewise if there were a blank before] .

— Line 12 illustrates a pernicious error: it is ignored since it is considered part of the comment begun on Line 11. To get the intended effect, interchange > and] on Line 11.

Note: line numbers are not allowed in PANDORA input.

(Section 1 – last revised: 2003 Aug 01)

Section 2: **Input Statements**

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PANDORA's input routines distinguish among several types of input statements, according to their format.

1) Input of single quatities:

NAME (*q*)

where *q* can be a single integer, floating point or alphanumeric variable.

1*) Input of single quatities with one Z index:

NAME *z* (*q*)

where *z* (integer) is a Z index, and *q* can be a single integer or floating point variable.

2) Input of simple arrays:

NAME (*q*)

where *q* can be an array of integer elements or of floating point elements.

2*) Input of simple arrays with one Z index:

NAME Z *z* (*q*)

where z (integer) is a Z index, and q can be an array of integer elements or of floating point elements.

3) Input of simple arrays with one level index or one Z index:

NAME k (q)

where k (integer) is either a level index or a Z index, and q can be an array of integer elements or of floating point elements.

3*) Input of simple arrays with one level index and one Z index:

NAME k Z z (q)

where k (integer) is a level index, z (integer) is a Z index, and q can be an array of integer elements or of floating point elements.

4) Input of single quantities with two level indices:

NAME u l (q)

where u (integer) and l (integer) are two indices specifying a particular transition, $(u > l)$, and q can be a single integer, floating point or alphanumeric variable.

5) Input of simple arrays with two level indices:

NAME u l (q)

where u (integer) and l (integer) are two indices specifying a particular transition, $(u > l)$, and q can be an array of integer elements or of floating point elements.

5*) Input of simple arrays with two level indices and one Z index:

NAME u l Z z (q)

where u (integer) and l (integer) are two indices specifying a particular transition, $(u > l)$, z (integer) is a Z index, and q can be an array of integer elements or of floating point elements.

6) Input of **WEIGHT**:

WEIGHT u l (m n w)

where u (integer) and l (integer) are two indices specifying a particular transition, $(u > l)$, m (integer) and n (integer) are two indices specifying a particular term, $(m > n)$, and w (floating point) is the weight itself.

7) Input of single quatities with two level indices and one μ index:

NAME u l k (q)

where u (integer) and l (integer) are two indices specifying a particular transition, $(u > l)$, k (integer) is an index specifying a particular value of **MU**, and q can be a single integer, floating point or alphanumeric variable.

8) Input of simple arrays with two level indices and one μ index:

NAME u l k (q)

where u (integer) and l (integer) are two indices specifying a particular transition, $(u > l)$, k (integer) is an index specifying a particular value of **MU**, and q can be an array of integer elements or of floating point elements.

NOTE

"NAME," "Z," and "**WEIGHT**," can be UPPER-, lower-, or MIxed-CasE.

Section 3: **Input Files Set-Up**

***

Years ago I thought it would be ideal if input statements could appear in PANDORA's input files in any order whatever; it seemed to me that this was almost required in the interest of consistency with self-identified free-field input. It became clear, however, that in order to do this I would have to use a two-pass input reading procedure instead of the current single-pass one; since, for programming purposes, certain parameters must already have been specified before others can be accepted. I have not yet been persuaded that the extra complication of a two-pass procedure is worth it. Thus input statements may not appear in whatever order a user might like best, but must conform to the structure described here. (Don't overlook the small number of rather detailed special requirements noted below.)

The set of input statements for a run is divided into nine parts, A – I. Their contents are sketched below. All these nine parts must appear, and in that order. The input statements in parts B, D, F and H may appear in any order (except as noted below). However any of B, D, F and/or H may be empty. Further information about input reading and processing appears in Section 4.

The following subsections describe: 1) overall input file structure; 2) special requirements (concerning maximum array sizes, and specific statement order); and 3) input error handling.

1. Input File Structure

Part A must contain: **HEADING**.

Part B contains mainly table lengths and option settings, as well as other control parameters.

Part C must contain: **GO**.

Part D contains all the input parameters for the basic calculations, except that populations data appear in part H.

Part E must contain: **GO**.

Part F contains input parameters for the "spectrum" calculations.

Part G must contain: **GO**.

Part H contains populations data and related parameters.

Part I must contain: **GO**.

The **HEADING** is a single comment line, which will be printed on the 'banner' pages at the start of the printed output, and will be inserted at various places in the restart file(s) (see Section 8).

The **GO** lines must appear as shown; they indicate the ends of parts B, D, F and H, respectively. The input statement after **GO** must begin on a new line.

The complete list of all input parameters is given in Section 5. That list specifies which of the parts B, D, F, or H each parameter may appear in. The names of input parameters may be given in UPPER-, lower-, or MixEd-case. The complete set of input statements need not occur in just one file, but may be distributed over several files that are coordinated by **USE** statements (see Section 5, note 44).

2. Special Requirements

In Part B:

- **NT** must occur before **INPAIR**;
- **NSL** must be less than 51;
- **NSL** must occur before **MR** and/or **LR**;
- **NL** must be less than **NSL**;
- **NMT** must be less than 51;
- **NCL** must be less than 100;
- **NAB** must be less than 100;
- **NAB** must occur before **BANDL**, **BANDU**, or **BANDE**;
- **NVX** must be less than 100.

In Part D:

- $\mathbf{LDL}_{i,j}^{u,\ell}$ must not exceed **LDLMAX**;
- $\mathbf{LDL}_{i,j}^{u,\ell}$ must occur before $\mathbf{DDL}_{i,j}^{u,\ell}$, $\mathbf{CDL}_{i,j}^{u,\ell}$, and the broadening halfwidths for transition (u, ℓ);
- $\mathbf{KST}^{u,\ell}$ must not exceed **KSTMAX**;
- $\mathbf{KST}^{u,\ell}$ must occur before $\mathbf{XISYMT}^{u,\ell}$;
- $\mathbf{KBT}^{u,\ell}$ must not exceed **KBTMAX**;
- $\mathbf{KBT}^{u,\ell}$ must occur before $\mathbf{XIBLUT}^{u,\ell}$;
- $\mathbf{KRT}^{u,\ell}$ must not exceed **KRTMAX**;
- $\mathbf{KRT}^{u,\ell}$ must occur before $\mathbf{XIREDT}^{u,\ell}$.

Also:

- the total number of Composite Line Opacity wavelengths, from all bands, must be less than 20001 (see also Section 9);
- **MAUX** must be less than 51 (see also Section 13).

3. Input Errors

Several types of errors commonly occur: violations of input language syntax; violations of prescribed structure; typos in field names and control character names; logical inconsistencies (*i.e.*, specifying undefined transitions, giving more array members than the stated size); diddly errors related to comments or field separators (too few or too many blanks).

It can be frustratingly time-consuming to correct all errors in a newly-typed input file. Many extensive, detailed error diagnostics have been provided to help with this. Most input error notifications provided by PANDORA display the image of the current input line, and then a single asterisk on the printout line immediately below that input line. This asterisk is positioned beneath the terminating blank (break character) of the input field which triggered the error notification.

When option DELABORT is on, PANDORA attempts to ignore an erroneous input statement (by attempting to find its closing ")") in order to read all the input (perhaps encountering additonal errors and attempting to ignore them as well) before stopping. This does not always work well, but when it does work, it saves time.

(Option DELABORT is on by default; turning it off [`OMIT ( DELABORT )`] will affect the reading of the remaining input statements only.)

Note the input parameter **JSTIN** (also, equivalently, available as an option) which stops the run after all input has been read and most of the preprocessing leading up to the first iteration has been done. Such an "input-only" run typically takes little time and provides an efficient means of checking the input for a run starting from scratch.

Since most PANDORA runs are restarts of preceding runs, the input files for a given run are usually obtained through only minor incremental changes to the files of preceding runs. Thus, in practice, only few input errors tend to occur once a new series of runs (restarts) has been launched successfully.

(Section 3 – last revised: 2007 Apr 11)

Section 4: **Remarks on the Input Process**

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PANDORA's input phase must establish all the input data for the subsequent computations. The major activities of the input phase comprise: initialization, setting defaults, reading all input statements, expanding shorthand input notations (*e.g.* for **KPC** or **TR**), establishing defaults that cannot be pre-set (*e.g.* for **NP** or **ABD**), extra(inter)polating to **Z** if necessary (see Section 13), and printing out most of the input values.

There are two kinds of defaults: pre-read defaults, which can be set before any input statements are read (*e.g.* **M** or **TS** or **TBAR**), and post-read defaults, which can only be established by referring to other input, and thus cannot be set until after all the input statements (of a given Part, *i.e.* B, D, F or H) have been read.

The processing in the input phase proceeds as follows:

- Read, print and write the **HEADING**.
- Set pre-read defaults for Part B, as specified in Section 5 of this writeup.
- Read Part B of the input.
- Read Part C of the input. After C (= **GO**) has been read, only those of the input parameters in Part B that were explicitly mentioned in input statements will have had new values given them. (These explicit values need not necessarily be different from the defaults.) If any of these parameters were mentioned more than once, they will have the values given them by the respective input state-

ments that were read last.

• Digest the Part B input.

• Set up storage for all the parameters in Parts D and F of the input, and set all this storage to zero (*i.e.* zero is the basic default).

• Set pre-read defaults for Parts D and H, as specified in Section 5. Pre-read defaults for tables are potential defaults only; they will actually be set according to the current values of their respective lengths. (This makes it easy to shorten or lengthen tables *vis-a-vis* their default states. For example, consider the table **MUF** of length **LF**. The pre-read defaults are **LF** = 2 and **MUF** = 1.0, 0.3. If **LF** = 1 resulted from Part B of the input, then the pre-read default is **MUF** = 1.0. If **LF** = 4 resulted from part B of the input, then the pre-read default is **MUF** = 1.0, 0.3, 0.0, 0.0. To replace the two zeroes in this **MUF**-table, a statement in Part F of the form: "**muf** (**I** 3 0.2 0.1) " would be sufficient.

• Read Part D of the input.

• Read Part E of the input. After E (= **go**) has been read, only those input parameters of Part D that were explicitly mentioned in input statements will have had new values given them. (These explicit values need not necessarily be different from the defaults.) If any of these input parameters were mentioned more than once, they will have the values given them by the respective input statements that were read last. Provisional input tables of depth-dependent variables will have been inter(extra)polated to **Z** (see Section 13); the actual provisional values will have been discarded.

• Digest the Part D input.

• Read Part F of the input.

• Read Part G of the input. After G (= **go**) has been read, only those input parameters of Part F that were explicitly mentioned in input statements will have had new values given them. (These explicit values need not necessarily be different from the defaults.) If any of these input parameters were mentioned more than once, they will have the values given them by the respective input statements that were read last. Provisional input tables of depth-dependent variables will have been inter(extra)polated to **Z** (see Section 13); the actual provisional values will have been discarded.

• Digest the Part F input.

• Set up storage, in memory and in the random-access scratch file, for the population data of Part H of the input.

• Set pre-read defaults for Part H, as specified in Section 5.

• Read Part H of the input.

• Read Part I of the input. After I (= **GO**) has been read, only those input parameters of Part H that were explicitly mentioned in input statements will have had new values given them. (These explicit values need not necessarily be different from the defaults.) If any of these input parameters were mentioned more than once, they will have the values given them by the respective input statements that were read last. Provisional input tables of depth-dependent variables will have been inter(extra)polated to **Z** (see Section 13); the actual provisional values, and the auxiliary Z tables as well, will have been discarded.

• Print the input (see Section 11 for more details about this).

Note: default values for unspecified populations and departure coefficients of Part H will be calculated later as part of the various precalculations done before the first iteration. Tables of data for the various population ions are printed, also later, if requested with the corresponding options.

Section 5: **Input Parameters**

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This section contains the complete list of input parameter specifications, in alphabetical order by name, followed by a set of explanatory notes, and finally by an alphabetized listing of keywords and descriptive phrases for each parameter — this last list should be used when a parameter's significance or function are vaguely known and its name is sought. After the parameter name has been located in the keywords list, the complete specification can then be consulted in the first part of this section.

The list of input parameter specifications has two or more lines of information for each parameter.

Line 1 has the following format: first the parameter **NAME**, in boldface type; then an optional reference, ***note**, to one of the notes collected at the end of the spefications list; then, if the parameter is a table, the [length] of the table, in square brackets, (if no length is given, then the parameter is a single item; if [@Z] appears, this signifies that the parameter must have as many elements as the associated depth table (**Z** or **ZAUX**) – *see Section 13*); and then a final group of codes:

• first the letter designating the Part(s) of the input file the parameter may appear in (*see Section 3*),

• then the number specifying the Statement Form to be used with this parameter (*see Section 2*), and

• finally the required mode of the parameter.

Line 2 contains a brief description of the function or significance of the input parameter. More information can be found in the ***note** specified (if any).

Beginning on Line 3 there appears an optional specification of the default

value(s) of the parameter.

If no default(s) are specified, then the default(s) equal(s) zero.

A ***31, *93** D, 4, floating point
Einstein A value

ABD ***1** D, 1, floating point
abundance of the ion of the run

ACE [NSL] D, 2, floating point
CE (default) addend

ACI [NSL] D, 2, floating point
CI (default) addend

ADMAS D, 1, floating point
angular diameter (milliarcseconds)
Default: as implied by ADS

ADS D, 1, floating point
star/Sun angular diameter ratio
Default: 1.0

ADT [NDT] D, 2, floating point
Type-2 dust opacity function
Default: (5.1, 4.7, 4.3, 3.8, 3.4, 3.0, 2.65, 2.4, 2.2, 2.1, 2.1, 2.0, 2.1, 2.3, 2.3, 2.2, 1.9, 1.8, 1.3, 0.93, 0.34, 0.3, 0.3, 0.3, 0.3, 0.3, 0.3, 0.3, 0.3)

AEL [@Z] D, 2*,2, floating point
added Helium electrons

AHM [MHM] D, 2, floating point
H^- bound-free absorption coefficient
Default: (0.01989, 0.04974, 0.1302, 0.4052, 0.7407, 1.107, 1.485, 1.862, 2.226, 2.571, 2.887, 3.172, 3.419, 3.625, 3.789, 3.906, 3.977, 4.001, 3.977, 3.907, 3.791, 3.632, 3.432, 3.194, 2.923, 2.624, 2.302, 1.965, 1.619, 1.275, 0.9453, 0.7918, 0.6512, 0.5431)

AL [NL] D, 2, floating point
added recombination fraction
Default: $\mathrm{AL}_1 = 1.0$, $\mathrm{AL}_i = 0.0$, $i \leq 2 \leq \mathrm{NL}$

ALBDT [NDT] D, 2, floating point
Type-2 dust albedo
Default: 0.9

ALBDUST [LDU] D, 2, floating point
Type-1 dust albedo

ALBK [NKA] D, 1, floating point
scattering albedo parameter for Background Line Opacities (see Section 9)
Default: (1.0, 0.0)

ALK [@Z] H, 2*,2, floating point
singly-ionized Aluminum number density
Default: computed in LTE

ALN [@Z] H, 3*,3, floating point
Aluminum-I level populations
Default: ALN_{ij} computed in LTE, for all levels j such that $j >$ NAL

AOWXP D, 1, floating point
alpha-old weight exponent for Special He-II (Special N-1 calculation, Diffusion)

APARAD D, 1, floating point
dielectronic recombination parameter

APCDP D, 1, floating point
dielectronic recombination parameter

APCI [NAPKNT] D, 1, floating point
dielectronic recombination parameter

APDDIFC D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: 90.7

APDDTFC D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: 36.6

APDTEXP D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: 1.76

APDXICA D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: 1.75

APDXICB D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: 4.5

APDXICC D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: 0.02

APDXICD D, 1, floating point
ambipolar diffusion velocity calculation parameter
Default: -3.5 $\times 10^5$

APEI [NAPKNT] D, 1, floating point
dielectronic recombination parameter

APETA D, 1, floating point
dielectronic recombination parameter

APWRA D, 1, floating point
dielectronic recombination parameter

APWRB D, 1, floating point
dielectronic recombination parameter

ASMCR ***92** D, 1, floating point
sequential smoothing parameter
Default: 0.001

ATOLAB D, 2, alphanumeric
"name" of ion model data file
Default: "!NONAME!"

AW [@Z] D, 5*,5, floating point
integrated diagonal of WN-matrix

BANDE ***77** [NAB] B, 2, integer
Composite Line Opacities wavelengths bands continuum eclipse calculation switch

BANDL ***77** [NAB] B, 2, floating point
lower limits of Composite Line Opacity wavelengths bands (see Section 9)

BANDU ***77** [NAB] B, 2, floating point
upper limits of Composite Line Opacity wavelengths bands (see Section 9)

BANDY [NAB] D, 2, floating point
method control parameter for Composite Line Opacity (see Section 9)
Default: all = -1.0

BD [@Z] D, 3*,3, floating point
departure coefficient of the levels of the ion of the run
Default: computed, using input number densities

BDAL [@Z] H, 3*,3, floating point
departure coefficients of the levels of Aluminum-I
Default: computed, using input Aluminum-I level populations

BDC [@Z] H, 3*,3, floating point
departure coefficients of the levels of Carbon-I
Default: computed, using input Carbon-I level populations

BDCA [@Z] H, 3*,3, floating point
departure coefficients of the levels of Calcium-I
Default: computed, using input Calcium-I level populations

BDFE [@Z] H, 3*,3, floating point
departure coefficients of the levels of Iron-I
Default: computed, using input Iron-I level populations

BDH [@Z] H, 3*,3, floating point
departure coefficients of the levels of Hydrogen
Default: computed, using input Hydrogen level populations

BDHE [@Z] H, 3*,3, floating point
departure coefficients of the levels of Helium-I
Default: computed, using input Helium-I level populations

BDHE2 [@Z] H, 3*,3, floating point
departure coefficients of the levels of Helium-II
Default: computed, using input Helium-II level populations

BDHM [@Z] D, 2*,2, floating point
departure coefficient of H-minus
Default: $\mathrm{BDHM}_i = 1.0$, all i

BDMG [@Z] H, 3*,3, floating point
departure coefficients of the levels of Magnesium-I
Default: computed, using input Magnesium-I level populations

BDNA [@Z] H, 3*,3, floating point
departure coefficients of the levels of Sodium-I
Default: computed, using input Sodium-I level populations

BDO [@Z] H, 3*,3, floating point
departure coefficients of the levels of Oxygen-I
Default: computed, using input Oxygen-I level populations

BDOPT ***43** D, 1, alphanumeric
b-ratios selection parameter
Default: "BDJ"

BDO2 [@Z] H, 3*,3, floating point
departure coefficients of the levels of Oxygen-II
Default: computed, using input Oxygen-II level populations

BDO3 [@Z] H, 3*,3, floating point
departure coefficients of the levels of Oxygen-III
Default: computed, using input Oxygen-III level populations

BDS [@Z] H, 3*,3 floating point
departure coefficients of the levels of Sulphur-I
Default: computed, using input Sulphur-I level populations

BDSI [@Z] H, 3*,3 floating point
departure coefficients of the levels of Silicon-I
Default: computed, using input Silicon-I level populations

BHORIZ [@Z] D, 2*,2, floating point
magnetic field strength

BLCSW ***14** D, 4, integer
broadening components switch (*a.k.a.* damping components selector)
Default: 31

BLIMG ***34** D, 1, floating point
absorption contributors graph axis limit
Default: -1.301 [= log(0.05)]

BMWAC D, 1, floating point
beam width parameter for continuum eclipse calculation
Default: 0.1

BXI ***66** [KBX] D, 2, floating point
background lines frequency table (half profile)
Default: (0., .03, .06, .1, .15, .22, .3, .4, .6, .9, 1.2, 1.5, 2., 3., 5., 10., 20., 40., 70., 110., 200., 500., 1000., 2000., 5000.)

CAK [@Z] H, 2*,2, floating point

singly ionized Calcium number density

Default: computed in LTE

CAN [@Z] H, 3*,3, floating point

Calcium-I level populations

Default: CAN_{ij} computed in LTE, for all levels j such that $j >$ NCA

CCHX ***95** D, 1, floating point

upper-level charge-exchange cross-section multiplier

Default: 1.0

CDL ***77, *105** [LDL] D, 4, floating point

weights for blended line components

Default: 1.0

CDZ ***82** D, 1, floating point

fluid velocity parameter

Default: 100.

CE ***25, *93** [NTE] D, 5, floating point

collisional excitation coefficient

Default: computed (see Section 19)

CEDMN D, 1, floating point

impact-parameter CE-value calculation parameter (for integration)

Default: 10^{-6}

CEDMX D, 1, floating point

impact-parameter CE-value calculation parameter (for integration)

Default: 10^{3}

CEFEQ D, 1, floating point

impact-parameter CE-value calculation parameter (for integration)

Default: 10^{-2}

CEMETHOD ***93, *139** D

CE-method selectors

Default: for Hydrogen: (`SCHOLZ`, `GIOVAN`, `JOHNSON`); otherwise: (`SEATON`, `VREGE`)

CEQMX D, 1, floating point

H2 number density control parameter

Default: 10^{6}

CGR D, 1, floating point
gravity ratio, with respect to Sun
Default: 1.0

CHEFLOW D, 1, floating point
Helium flow constant for RHEAB calculation

CHI [@Z] D, 5*,5, floating point
RHO-like line transfer quantity

CHLIM ***19** D, 1, floating point
RHOW parameter
Default: 0.5

CHOP ***19** D, 1, floating point
a RHO selection parameter
Default: 1.0

CI ***93** [NTE] D, 3, floating point
collisional ionization coefficient
Default: computed (see Section 19)

CIJADD ***91** [@Z] D, 5*,5, floating point
term to be added to CIJ

CIMETHOD ***93, *139** D
CE-method selectors
Default: for Hydrogen: (`SHAH`, `CLARK`); otherwise: (`AR`, `CLARK`)

CK [@Z] H, 2*,2, floating point
singly-ionized Carbon number density
Default: computed in LTE

CKADD [@Z] D, 3*,3, floating point
term to be added to CK

CLEVELS D, 1, floating point
diffusion calculation parameter
Default: 2.0

CLM D, 1, floating point
scattering albedo parameter for Background Line Opacities (see Section 9)
Default: 1.0

CLOGG D, 1, floating point

log(surface gravity)

Default: as implied by CGR

CLNH D, 1, floating point

HSE calculation parameter

Default: 2.0

CN [@Z] H, 3*,3, floating point

Carbon-I level populations

Default: CN_{ij} computed in LTE, for all levels j such that $j >$ NLC

CN1S D, 1, floating point

rcheck-criterion for Special-N1 (diffusion)

Default: 0.01

COLINES *112 D

CO lines control parameters

Default: see Note *112

COMU D, 1, floating point

mu-value for CO lines opacity calculation

CORMAX *130 D, 1, floating point

limit parameter for ORIGINS and CONTRIBUTORS printouts

Default: -1.0

CORMIN *130 D, 1, floating point

limit parameter for ORIGINS and CONTRIBUTORS printouts

Default: -1.0

CP *56, *93 [NSL] D, 2, floating point

photoionization cross-section

Default: computed (see Section 19)

CPRESS D, 1, floating point

specified constant pressure

CQA *117 [NCQ] D, 2, floating point

'Line Opacity' scattering albedo parameter

Default: $(10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}, 1.0)$

CQM D, 1, floating point

scattering albedo parameter for Background Line Opacities (see Section 9)

CQT ***117** [NCQ] D, 2, floating point
'Line Opacity' scattering albedo parameter
Default: (4000, 5000, 6000, 7000, 8000)

CRD ***77, *93,* 105** [LDL] D, 4, floating point
radiative broadening halfwidth

CRS ***93** D, 4, floating point
resonance broadening halfwidth

CSDW D, 1, floating point
number of Doppler widths from line center at which the Hydrogen Stark components strengths are reduced by the factor 1/e
Default: 1.0

CSFCRIT D, 2, floating point
convergence criterion for CSF iteration
Default: 10^{-5}

CSK ***93, *105** D, 4, floating point
Stark broadening halfwidth

CSTARK ***107** D, 4, floating point
Hydrogen Stark broadening (convolution) switch

CUTFE D, 1, floating point
cut-off criterion for injection function integration (fast electrons)
Default: 10^{-8}

CTCO D, 1, floating point
NCO calculation temperature enhancement factor

CTMX D, 1, floating point
maximum NCO temperature enhancement
Default: 0.2

CVSB ***82** D, 1, floating point
fluid velocity parameter for VSB

CVW ***93, *105** D, 4, floating point
van der Waals broadening halfwidth

CVX ***82** [NVX] F, 2, floating point
fluid velocity parameters for VX

CVXF ***82** F, 1, floating point
fluid velocity parameter for flow broadening velocities
Default: 25.0

CVXM ***82** F, 1, floating point
fluid velocity parameter for flow broadening velocities

CVXS ***82** D, 1, floating point
fluid velocity parameter for VXS

CVZ ***82** D, 1, floating point
fluid velocity parameter
Default: smallest Z_i such that $NH_i > 10^{11}$

CWJ ***19** D, 1, floating point
a RHOJ calculation parameter
Default: 0.5

CWR ***19** D, 1, floating point
a RHO selection parameter
Default: 0.1

DDL ***77, *105** [LDL] D, 4, floating point
displacements from reference wavelength of blended line components, in Angstroms (see also DWN)

DDR ***42** [NDR] D, 2, floating point
DR parameter, PRD transitions
Default: (1.0, 0.9, 0.65, 0.4, 0.1, 0.05, 0.0)

DDT D, 1, floating point
Type-2 dust opacity calculation convergence criterion
Default: 0.01

DELLIM D, 1, floating point
DEL-criterion for using DIRECT instead of FULL solution
Default: 10^{-6}

DELTB D, 1, floating point
departure coefficients editing parameter
Default: 0.01

DELWAVE *76 [NWS] D, 2, floating point
'subtractional' wavelengths for continuum calculations

DFDUST [LDU] D, 2, floating point
Type-1 dust factor

DGM ***138** [@Z] D, 2*,2, floating point
depth-dependent G multiplier (HSE)
Default: all = 1.0

DGMZ ***138** [NGM] D, 2, floating point
standard table of DGM (as a function of ZGM) for the quiet sun
Default: (.64, .645, .66, .68, .71, .74, .77, .81, .86, .89, .92, .95, .97, .985, .99, .995, .995, .995, .99, .98, .97, .965, .96)

DLU D, 1, floating point
dilution factor
Default: 1.0

DO [variable] B, 2, alphanumeric
enable program options (see Section 6 for further details)

DOFDB ***80** [$\leq$ 2×NT] D, 2, integer
alternate form of LSFFDB

DOFLUX ***79** [$\leq$ 2×NT] D, 2, integer
alternate form of LFLUX

DOPROF ***78** [$\leq$ 2×NT] D, 2, integer
alternate form of PROF

DOSFPRNT ***81** [$\leq$ 2×NT] D, 2, integer
alternate form of LSFPRINT

DPMULT D, 4, floating point
damping multiplier
Default: 1.0

DQMAX D, 1, floating point
parameter for injection function integration (fast electrons)
Default: 2.0

DQMIN D, 1, floating point
parameter for injection function integration (fast electrons)
Default: 0.01

DRHO D, 4, floating point
RHO editing parameter
Default: 0.05

DRLIM ***42** D, 1, floating point

DR parameter, PRD transitions

Default: 0.01

DWAVE ***65** [NDV] D, 2, floating point

Continuum Source Function dump wavelengths table

DWN ***77** [LDL] D, 4, floating point

= DDL, but in wavenumbers

DZMSS D, 1, floating point

Z-from-Mass calculation parameter

Default: 0.01

ECLI ***58** D, 4, integer

Eclipse line profiles computation switch

EIDIF D, 1, floating point

NE-iterations convergence criterion

Default: 10^{-4}

ELEMENT D

element data (see Section 10)

ELLED D, 1, floating point

particle energy dissipation calculation parameter 'L' (fast electrons)

Default: 2.4×10^{-11}

ELSYM ***93** D, 1, alphanumeric

chemical symbol of the ion of the run

Default: "ZZ"

EMXED D, 1, floating point

particle energy dissipation calculation parameter 'EMAX' (fast electrons)

Default: 10^{-6}

EPCBR D, 1, floating point

branching ratio for supplementary levels in Lyman EPSILON-1

EPDUST [LDU] D, 2, floating point

Type-1 dust dilution factor

EP1 [@Z] D, 2*,2, floating point

Lyman EPSILON-1

EP2 [@Z] D, 2*,2, floating point
Lyman EPSILON-2

ESCTAU ***48** D, 1, floating point
TAU criterion for automatic use of escape probability solution
Default: 5.0

EXLYM ***67** D, 1, floating point
Lyman change-over TAU parameter
Default: 10.

FABD D, 1, floating point
multiplier for element abundances
Default: 1.0

FBVMX F, 1, floating point
maximum velocity value for flow broadening
Default: 100.

FCE [@Z] D, 5*,5, floating point
CE-enhancement factors

FEK [@Z] H, 2*,2, floating point
singly-ionized Iron number density
Default: computed in LTE

FEN [@Z] H, 3*,3, floating point
Iron-I level populations
Default: FEN_{ij} computed in LTE, for all levels j such that $j >$ NFE

FILE ***44** B,D,F,H alphanumeric
input file designation

FINK [INK] D, 2, floating point
incident radiation input values
Default: (0., 3.0×10^{-12}, 3.0×10^{-12}, 1.5×10^{-12}, 1.5×10^{-12}, 0.)

FKUR [KURNWV] D, 2, floating point
multiplier for Statistical Line Opacity (see Section 9)
Default: all = 1.0 (KURNWV = 53, built in)

FMCDL D, 1, floating point
Hydrogen Stark splitting components elimination criterion
Default: 0.1

FMVLIM ***82** D, 1, floating point

fluid velocity multiplier limit

Default: 10^{-4}

FNH [NFH] F, 2, floating point

standard tabel of flow velocity for flow broadening

Default: (10., 9., 7., 5., 3., 2., 1., 0.)

FNRMLA 65 D, 2, floating point

normalizing factor for simulated background H Ly α profile

Default: all = 1.0

FNRMLB 65 D, 2, floating point

normalizing factor for simulated background H Ly β profile

Default: all = 1.0

FRCDL D, 1, floating point

Hydrogen Stark splitting components elimination criterion

Default: 0.01

FROSCE ***93** D, 1, floating point

fraction-of-classical-oscillator-strength used in the calculation of collision rates for forbidden transitions

Default: 0.01

FRR [MRR] D, 2, floating point

radius fraction

Default: (0.0, 0.5, 0.8, 0.9, 0.95, 1.0)

FSTKM D, 1, floating point

Hydrogen Stark splitting reduction factor

Default: 1.0

FZION D, 1, floating point

ZION-multiplier for diffusion calculation

Default: 1.0

FZLIM D, 1, floating point

Z-from-Mass calculation parameter

Default: 1.5

GK ***123** [KK] D, 2, floating point

Gaunt factors for Level-KOLEV-to-Continuum calculation

Default: RRCP(KOLEV)

GMMA ***42** D, 4, floating point

gamma-parameter, PRD transitions

Default: -1.0

HEABL D, 1, floating point

Helium abundance limit factor for RHEAB calculation

Default: 3.0

HEK [@Z] H, 2*,2, floating point

singly-ionized Helium number density

Default: computed in LTE

HEL D, 1, floating point

weight for HSE calculation

Default: 1.0

HEN [@Z] H, 3*,3, floating point

Helium-I level populations

Default: HEN_{ij} computed in LTE, for all levels j such that $j >$ NLZ

HE2K [@Z] H, 2*,2, floating point

doubly-ionized Helium number density

Default: computed in LTE

HE2N [@Z] H, 3*,3, floating point

Helium-II level populations

Default: $\mathrm{HE2N}_{ij}$ computed in LTE, for all levels j such that $j >$ NZ2

HE304 [@Z] D, 2*,2, floating point

He-II λ304 line mean intensity

HN [@Z] H, 3*,3, floating point

Hydrogen level populations

Default: HN_{ij} computed in LTE, for all levels j such that $j >$ NLH

HNAJL D, 1, floating point

limit for NH-adjustment factor in HSE calculation

Default: 10^{20}

HNDF [NFH] F, 2, floating point

Hydrogen density table for FNH

Default: (1.0×10^{11}, 3.0×10^{11}, 1.0×10^{12}, 3.0×10^{12}, 1.0×10^{13}, 3.0×10^{13}, 1.0×10^{14}, 3.0×10^{14})

HNDV ***90** [NVH] D, 2, floating point

Hydrogen density table for VNH

Default: (1.0×10^{9}, 2.0×10^{9}, 5.0×10^{9}, 1.0×10^{10}, 2.0×10^{10}, 5.0×10^{10}, 8.38×10^{10}, 1.07×10^{11}, 1.61×10^{11}, 3.17×10^{11}, 7.73×10^{11}, 2.71×10^{12}, 9.32×10^{12}, 2.04×10^{13}, 6.69×10^{13}, 9.82×10^{13}, 2.25×10^{14}, 3.55×10^{14}, 6.01×10^{14}, 9.87×10^{14}, 1.64×10^{15}, 2.09×10^{15}, 3.37×10^{15}, 4.22×10^{15}, 6.58×10^{15}, 1.02×10^{16}, 2.33×10^{16}, 4.24×10^{16}, 6.05×10^{16}, 8.33×10^{16}, 1.03×10^{17}, 1.15×10^{17}, 1.22×10^{17}, 1.27×10^{17}, 1.30×10^{17}, 1.32×10^{17}, 1.34×10^{17}, 1.35×10^{17})

HSBDMN D, 1, floating point

Hydrogen Stark broadening parameter, for convolution calculation

Default: 10^{-5}

HSBDMX D, 1, floating point

Hydrogen Stark broadening parameter, for convolution calculation

Default: 10^{3}

HSBFEQ D, 1, floating point

Hydrogen Stark broadening parameter, for convolution calculation

Default: 0.1

HSBM D, 1, floating point

Hydrogen Stark broadening parameter, for convolution calculation

Default: 20.0

HSEC ***15** D, 1, floating point

weight for HSE calculation

Default: 1.0

HSLITER D, 1, floating point

number of HSL iterations

Default: 1

HTAU D, 1, floating point

HSE calculation parameter

Default: 1.0

IBETSW ***126** D, 1, integer

beta-equation selection switch, diffusion

IBNVIEW D, 1, integer

depth index for illustration of BD- and ND-calculations trace

Default: (JEDIT+1)

IBRDP D, 1, integer
diffusion d-coefficients debug dump switch

ICDIT ***101** D, 1, integer
dI/dh continuum wavelengths selector
Default: 1

ICHDP D, 1, integer
hydrogen collision rates calculation dump depth index

ICHSW ***136** D, 1, integer
collision-with-Hydrogen switch

ICR [NCR] D, 2, floating point
values of incident coronal radiation

ICXDP ***95** D, 1, integer
upper-level charge-exchange dump depth index

IDEDP D, 1, integer
ion broadening (Hydrogen) dump switch

IDEX D, 1, integer
extra information switch for standard-output (or log file)
Default: 10

IDFDI ***89** D, 1, integer
d-coefficients dump index
Default: N/4

IDFDM ***89** D, 1, integer
d-coefficients method selection switch
Default: 1

IDFDS D, 1, integer
d-coefficients smoothing
Default: 1

IDFSW D, 1, integer
dI/dh details print switch

IDNRT D, 1, integer
switch for calculation of DNRT, DNRTC in Lyman
Default: 1

IDRCD D, 1, integer
index of disk ray for CSF debug printout
Default: 1

IDRDP D, 1, integer
depth index for option DRDMP
Default: N/2

IDWIN D, 1, integer
DW-dump index increment

IFXDS ***70** D, 1, integer
continuum flux detail output control

IGII ***42** D, 1, integer
RII-approximation selector (PRD)
Default: 1

IGMSW ***42** D, 1, integer
alternate GMMA for H Lyman alpha and beta (PRD)

IHDMP D, 1, integer
dump output control switch for Line Flux Distribution calculation

IHEAB D, 1, integer
reference depth index for RHEAB calculation

IHSDD ***106** D, 1, integer
Hydrogen Stark broadening dump switch

IHSDP ***106** D, 1, integer
Hydrogen Stark broadening dump switch

IHSKM D, 1, integer
Hydrogen Stark broadening calculation table limit
Default: 100

IHSSM D, 1, integer
Hydrogen Stark broadening calculation table limit
Default: 2000

IHSSP D, 1, integer
Hydrogen Stark splitting control switch

IHSSW D, 1, integer
Hydrogen Stark broadening (convolution) switch

ILI ***19** D, 1, integer
a RHO selection parameter

IMUCD D, 1, integer
index of XMU for Continuum Source Function debug printout
Default: 1

INCEI ***93** D, 1, integer
depth index for CI and CE comparison calculations
Default: index of TE-value closest to 8000 K, going in

INCH D, 1, floating point
RHO weight adjustment parameter
Default: 0.1

INDRN D, 1, integer
input number densities renormalization switch
Default: 1

INFSM D, 1, integer
Lyman RK-Kolev smoothing delimiter
Default: 1

INK B, 1, integer
length of XINK
Default: 6

INLSM D, 1, integer
Lyman RK-Kolev smoothing delimiter
Default: N

INPAIR ***2, *77** [2×NT] B, 2, integer
list of transition indices

INRHO D, 4, integer
input-RHO use switch

IOMX D, 1, integer
number of overall iterations
Default: 1

IONSTAGE ***93** D, 1, integer
stage of ionization of the ion of the run
Default: 1

IORIC D, 1, integer
line-center depths-of-formation print switch
Default: 1

IPDEE ***125** D, 1, integer
d-coefficients printout switch, diffusion calculation

IPDIJ ***127** D, 1, integer
DIJ printout switch, diffusion analysis

IPERFA D, 1, integer
performance data archive record switch
Default: 1

IPEX ***113** D, 1, integer
switch for extra debug output

IPIJG D, 1, integer
fudge GNV in the equation for PIJ
Default: 1

IPPOD ***52** D, 1, integer
'population ion' absorption/emission calculation dump switch

IPR01 ***59** D, 1, integer
Line Source Function debug printout limiting index
Default: 1

IPR02 ***59** D, 1, integer
Line Source Function debug printout limiting index
Default: 5

IPR03 ***59** D, 1, integer
Line Source Function debug printout limiting index
Default: 10

IPR04 ***59** D, 1, integer
Line Source Function debug printout limiting index
Default: 15

IPRDD ***30** D, 1, integer
depth interval for PRD printout
Default: 1

IPRDF ***30** D, 1, integer
frequency printout for PRD printout
Default: 1

IPZER ***71** D, 1, integer
dump printout selector for subroutine `DIVIDE`

IRATE ***100** D, 1, integer
depth index for 'minimal' rates printout

IRFNC ***111** D, 1, integer
depth index of reference value of charged particle number density for printed sample values of Hydrogen CE and CI
Default: i such that TE_i "equals" the middle value of TER, where i is the smallest such value

IRKCOMP ***45** [NSL] D, 2, integer
RK-components compute switches
Default: all =1

IRLCOMP ***45** [NSL] D, 2, integer
RL-components compute switches
Default: all =1

IRLSN ***39** D, 1, integer
RL integration methods switch
Default: 1

IRLS1 ***39** D, 1, integer
RL integration methods switch
Default: 1

IRPUN ***84** D, 1, integer
RABD calculation data output switch
Default: 1

IRTIS ***63** D, 1, integer
incident radiation table interpolation selector
Default: 2

IRUNT ***74, *84** D, 1, integer
run type switch

ISCOMP D, 1, integer
line source functions comparison printout details switch

ISCRS ***20, *84** B, 1, integer
scratch I/O mode switch

ISRCD D, 1, integer
index of shell ray for Continuum Source Function debug printout
Default: 1

ISMBD D, 1, integer
intensity integration (`SIMBA`) dump interval

ISMSW ***99** D, 1, integer
iteration summaries format switch

ISMVE D, 1, integer
small-values editing switch
Default: 1

ISNDD ***121** D, 1, integer
S(n) calculation dump switch

ISNUD D, 1, integer
PRD SNU-shift debug dump switch

ISOD D, 1, integer
depth index for Sobolev integration dump

ISSV ***55** [NVX] F, 2, integer
shock velocity depth indices

ISTARK D, 1, integer
default value of NE-index for Stark splitting of Hydrogen lines
Default: largest index where NE $\approx 10^{12}$

ISUB D, 1, integer
number of sub-iterations (= RHO-iterations)
Default: 1

ITKZA D, 1, integer
Z-augmentation (diffusion) iteration limit
Default: 1

ITN1R D, 1, integer
"Special N1" iterations limit (diffusion calculations)
Default: 10

ITPRD ***42** D, 1, integer,
PRD-iterations limit
Default: 4

ITRFI D, 1, integer
TR-iteration debug output control

IVOIT ***50** D, 1, integer
Voigt profile methods selector
Default: 1

IWEIT D, 1, integer
weighting details print switch

IWSMD D, 1, integer
WAVELENGTHS summary Part-2 switch

IXASM D, 1, integer
smoothing dump (IPEX=25) detail control index

IXNCS ***111** D, 1, integer
switch controlling calculation of on-the-fly Hydrogen CE and CI values

IXSTA ***84** D, 1, integer
performance statistics printout control
Default: 1

IZOPT ***38** D, 1, integer
graph Z-scale (axis) option
Default: 1

I4DEQ ***122** D, 1, integer
four-diagonal method ("Special N1"), equation selector

I4DFM ***122** D, 1, integer
four-diagonal method ("Special N1"), version selector
Default: 1

I4DIO ***122** D, 1, integer
four-diagonal method ("Special N1"), flow direction specifier
Default: 1

JATAW D, 1, integer
write values of WRAT and RRCP as part of atomic data defaults output

JBAR [@Z] D, 5*,5, floating point
mean intensity

JBDNC ***84** D, 1, integer
Rho and b-ratio calculation bypass switch

JBFSW D, 1, integer
b calculation method selector for supplementary levels
Default: 1

JDMCE ***115** D, 1, integer
debug dump switch for default calculation of Hydrogen CE values

JDMCI ***115** D, 1, integer
debug dump switch for default calculation of Hydrogen CI values

JEDIT D, 1, integer
depth index for N-editing
Default: N/2

JHBFD D, 1, integer
debug dump switch for H-bf background absorption and emission

JHEAS D, 1, integer
secret HEABD switch

JHLSK ***137** D, 1, integer
Stark broadening in H Lyman lines background opacity
Default: 1

JH1 ***102** D, 1, integer
photoionization rates multiplier index

JH2 ***102** D, 1, integer
photoionization rates multiplier index

JM B, 1, integer
lenght of LMM
Default: 1

JNEDP D, 1, integer
N-editing dump switch

JNUNC ***46** D, 1, integer
JNU input switch

JSFEX D, 1, integer
LSF-solution-explanation print switch
Default: 1

JSSV *** 55** D, 1, integer
shock temperature depth index

JSTCN ***5, *6, *11** D, 1, integer
Continuum-only run type selector

JSTIN ***6, *40, *84** D, 1, integer
input-check only switch

JZATMO ***133** D, 1, integer
zero-print mode switch for ATMOSPHERE

JZATOM ***133** D, 1, integer
zero-print mode switch for ATOM

JZOPT ***38** D, 1, integer
graph Z-scale (axis) option

K B, 1, integer
= KS

KALHD ***73** B, 1, alphanumeric
`Hi/Bye/Abort`-system control parameter
Default: " " (*i.e.,* blank)

KALOR ***73** B, 1, integer
`Hi/Bye/Abort`-system control parameter
Default: 1

KANTNU ***129** D, 1, integer
TNU-analysis switch

KAPDB D, 1, integer
continuum contributors control debug switch

KARB ***75** B, 1, integer
'print character' selector for 'banner' page
Default: 1

KB ***66** B, 1, integer
length of XIBLU
Default: KS

KBNDS ***122** D, 1, integer
boundary condition switch for diffusion ("Special N1")
Default: 1

KBT ***66** D, 4, integer
length of XIBLUT
Default: KST

KBTMAX B, 1, integer
maximum of the various values of KBT occurring in **Part D**

KBX ***66** B, 1, integer
length of BXI
Default: 25

KB1WA ***128** D, 1, integer
B1-weights depth index

KB1WB ***128** D, 1, integer
B1-weights depth index

KB1WS ***128** D, 1, integer
B1-weights type selection switch
Default: 2

KCOAA D, 1, integer
switch of short form of Composite Line Analysis output

KDAMP ***122** D, 1, integer
matrix solution damping switch for "Special N1" (diffusion)

KDIAG ***122** D, 1, integer
diagonal method selector for diffusion ("Special N1")
Default: 3

KDIFD1 ***119** D, 1, integer
method switch for derivatives in diffusion calculations
Default: -1

KDIFGA ***124** D, 1, integer
GNV-fudging depth index
Default: -1

KDIFGB *124 D, 1, integer

GNV-fudging depth index

Default: -1

KDIFGS *124 D, 1, integer

GNV-fudging switch

KDRDP D, 1, integer

frequency index for option DRDMP

Default: K/2

KDUST D, 1, floating point

dust constant

KHFFS *41 D, 1, integer

H free-free contribution to Total Hydrogen cooling

Default: 1

KININT D, 1, integer

plot index selection increment for Line Background opacities (see Section 9)

Default: 5

KINMAX D, 1, integer

plot index for Line Background opacities (see Section 9)

Default: index of depth near the minimum of TE

KK B, 1, integer

length of XK

Default: MR(KOLEV)

KKPR D, 1, integer

frequency index for detailed Lyman printout

Default: KK

KLDIN D, 1, integer

Lyman dump depth interval

KLFIN D, 1, integer

Lyman dump frequency interval

KMMAX *66 D, 1, integer

maximum XIFUL length

KODNT D, 1, integer

Composite Line Opacity raw data dump interval (see Section 9)

KOELS D, 1, integer

every-line switch for ORIGIN printout

Default: 1

KOLEV B, 1, integer

level index (*i.e.* $\mathcal{N}$) for 'Level-$\mathcal{N}$-to-Continuum' transfer calculation

Default: 1

KONFORM *12 D, 1, integer

detail contributions printout format selector

Default: 2

KOOLSUM *41 D, 1, integer

control for components added into Total Cooling Rate for Hydrogen runs

KPC *10 [@Z] D, 5*,5, floating point

continuous opacity

Default: $\mathrm{KPC}^{u,\ell} = \mathrm{KPC}^{MS,NS} \times \mathrm{KPCR}^{u,\ell}$, for $u \neq$ MS, $\ell \neq$ NS

KPCR D, 4, floating point

ratio of the continuous opacity with respect to that of transition (MS,NS)

KR *66 B, 1, integer

length of XIRED

Default: KS

KRATE *118 D, 4, integer

single-vs.-net rate switch for transition terms

Default: 1

KRT *66 D, 4, integer

length of XIREDT

Default: KST

KRTMAX B, 1, integer

maximum of the various values of KRT occurring in **Part D**

KS *66 B, 1, integer

length of XISYM

Default: 24

KST *66 D, 4, integer

length of XISYMT

Default: KS

KSTMAX B, 1, integer
maximum of the various values of KST occurring in **Part D**

KTRANS *33 D, 4, alphanumeric
transition descriptor
Default: "RADIATIVE"

KUDNT D, 1, integer
Statistical Line Opacity raw data dump interval (see Section 9)

KURIN D, 1, integer
step selection index for Statistical Line Opacity data (see Section 9)

KURMA D, 1, integer
long-wavelength cutoff for Statistical Line Opacity data (see Section 9)
Default: 9000.0

KURMI D, 1, integer
short-wavelength cutoff for Statistical Line Opacity data (see Section 9)
Default: 1682.0

KXLYM D, 1, integer
XK-table augmentation switch

L *24 B, 1, integer
length of MU
Default: LF

LCEX D, 1, integer
charge exchange index
Default: 1

LCH *136 [NSL] D, 2, integer
collisions-with-Hydrogen codes

LCOA [NCB] D, 2, floating point
CO-lines opacity wavelength band lower limit

LCOB [NCB] D, 2, floating point
CO-lines opacity wavelength band upper limit

LCOD D, 1, floating point
CO-lines opacity dump printout wavelength

LCR [LCR] D, 2, floating point
wavelengths at which incident coronal radiation is specified

LDFD1 D, 1, integer
smoothing control switch for computed derivatives

LDINT ***54** D, 1, integer
depth increment for detailed printout of transition terms
Default: 5

LDL ***77, *105** D, 3, integer
length of DDL
Default: 1

LDLMAX B, 1, integer
maximum of the various values of LDL occurring in **Part D**
Default: 1

LDT [NDT] D, 2, floating point
wavelengths tables for Type-2 dust opacity calculation
Default: (910.0, 952.0, 1000.0, 1050.0, 1110.0, 1180.0, 1250.0, 1330.0, 1430.0, 1540.0, 1670.0, 1820.0, 2000.0, 2080.0, 2170.0, 2270.0, 2380.0, 2500.0, 3330.0, 5000.0, 1.0×10^4, 3.0×10^4, 1.0×10^5, 3.0×10^5, 1.0×10^6, 3.0×10^6, 1.0×10^7, 3.0×10^7, 1.0×10^8)

LDTYP ***54** D, 1, integer
type control for detailed printout of transition terms
Default: 1

LDU B, 1, integer
length of LMDUST
Default: 1

LEEDS D, 1, integer
He-I background lines opacity calculation debug switch

LEVDES ***53** [NSL] D
level designation (term designation)

LF ***17, *24** B, 1, integer
length of MUF
Default: 2

LFLUX ***72** D, 1, integer
Line Flux Distribution calculation control switch

LG B, 1, integer

length of XMU

Default: 8

LHEDS D, 1, integer

He-II background lines opacity calculation debug switch

LHHSE D, 1, integer

reference depth index for H and M in HSE

LHM [MHM] D, 2, floating point

wavelengths for H-minus continuum calculations

Default: (16300.0, 16200.0, 16000.0, 15500.0, 15000.0, 14500.0, 14000.0, 13500.0, 13000.0, 12500.0, 12000.0, 11500.0, 11000.0, 10500.0, 10000.0, 9500.0, 9000.0, 8500.0, 8000.0, 7500.0, 7000.0, 6500.0, 6000.0, 5500.0, 5000.0, 4500.0, 4000.0, 3500.0, 3000.0, 2500.0, 2000.0, 1750.0, 1500.0, 1250.0)

LLY B, 1, integer

length of LMXX

LMA ***104** D, 1, floating point

Lyman EP-1 edit parameter

Default: 0.3

LMB ***104** D, 1, floating point

Lyman EP-1 edit parameter

Default: 10^4

LMCR ***137** D, 1, floating point

Hydrogen Lyman lines background opacity parameter

Default: 85.0

LMDL2 ***137** D, 1, floating point

DR parameter, Hydrogen Lyman lines background opacity

Default: 0.01

LMDL3 ***137** D, 1, floating point

DR parameter, Hydrogen Lyman lines background opacity

Default: 0.01

LMDR ***137** [LLY] D, 2, floating point

DR parameter, Hydrogen Lyman lines background opacity

LMDUST [LDU] D, 2, floating point
wavelengths table for Type-1 dust opacity data
Default: 5000.0

LME ***104** D, 1, floating point
Lyman EP-1 edit parameter
Default: 10^{-4}

LMF ***104** D, 1, floating point
Lyman EP-1 edit parameter
Default: 10^{-5}

LMH ***137** D, 1, floating point
wavelength cutoff for highest H Lyman lines background opacity
Default: 950.

LMM [JM] D, 2, floating point
wavelengths table for opacity multiplier
Default: 1682.0

LMR ***104** D, 1, floating point
Lyman EP-1 edit parameter
Default: 10^{4}

LMT ***104** D, 1, floating point
Lyman EP-1 edit parameter
Default: 0.3

LMXC ***137** D, 1, floating point
DR parameter, Hydrogen Lyman lines background opacity
Default: 2.0

LMXP ***137** D, 1, floating point
DR parameter, Hydrogen Lyman lines background opacity
Default: 3.0

LMXX ***137** [LLY] D, 2, floating point
DR parameter, Hydrogen Lyman lines background opacity

LMZ D, 1, floating point
Lyman alpha wing background opacity cut-off wavelength
Default: 2500.0

LN ***67** D, 1, integer
depth index limit for saturation approximation in "Lyman" calculation
Default: 8

LODCG ***88** D, 1, integer
depth index for diffusion calculation graphs
Default: -1

LOGAS ***114** D, 1, integer
location analysis graph switch

LOXDS D, 1, integer
O-I background lines opacity calculation debug switch

LPMLR F, 1, integer
mass-loss-rates print switch (used with LPVEL)
Default: 1

LPVEL F, 1, integer
profile-velocities print switch
Default: 1

LR ***77** [NL] B, 2, integer
number of RKC values (one LR for each level)

LSFBOC ***16** D, 4, integer
Line Source Function background opacity control

LSFFDB ***36** D, 4, integer
Line Source Function background type selector

LSFGC ***68** D, 1, integer
Line Source Function graph control code
Default: 1

LSFPRINT ***81** D, 4, integer
Line Source Function printout switch

LSTMP D, 1. integer
STIM-for-GTN details print switch

LSFTYP ***48** D, 4, integer
Line Source Function solution method selector

LWNT D, 1, integer
'Line Opacity' printout wavelengths interval (see Section 9)
Default: 1

LX2DS D, 1, integer
O-II background lines opacity calculation debug switch

LX3DS D, 1, integer
O-III background lines opacity calculation debug switch

LYMITER D, 1, integer
number of Lyman iterations
Default: 1

LYODS D, 1, integer
H Lyman background lines opacity calculation debug switch

LZA B, 1*, integer
length of ZAUX

M B, 1, integer
length of TS
Default: 33

MAMAS D, 1, integer
matrix elements magnitude scan switch
Default: 1

MASS D, 1, floating point
atomic mass

MATRIX *140 D
matrix manipulation control data

MAUX D,F,H, 1, integer
index specifying a ZAUX table

MCE [NSL] D, 2, floating point
CE (default) multiplier
Default: 1.0

MCI [NSL] D, 2, floating point
CI (default) multiplier
Default: 1.0

MCOA D, 1, floating point
mulitplier of van der Waals damping for CO-lines profiles
Default: all = 1.0

MCON D, 1, integer
CO number density output switch

MDFG D, 1, integer
diffusion terms (GVL) output switch
Default: 1

MDFV D, 1, integer
diffusion velocities output switch
Default: 1

MDTR1 D, 1, integer
Type-2 dust opacity calculation iteration limit
Default: 10

MDTR2 D, 1, integer
Type-2 dust opacity calculation iteration limit
Default: 20

METEP *21 D, 1, integer
Lyman EP-1 and EP-2 calculation methods selector
Default: 3

METSE *35 D, 4, integer
Statistical Equilibrium equations calculation methods selector
Default: **METSEDG** or **METSEDW**

METSEDG *35 D, 1, integer
general default value of METSE
Default: 1

METSEDW *35 D, 1, integer
default value of METSE for transitions down to Level 1
Default: 3

MFONT D, 1, integer
Fontenla atmosphere data output switch
Default: 1

MGK [@Z] H, 2*,2, floating point
singly-ionized Magnesium number density
Default: computed in LTE

MGN [@Z] H, 3*,3, floating point
Magnesium-I level populations
Default: MGN_{ij} computed in LTE, for all levels j such that $j >$ NMG

MHM B, 1, integer
length of LHM
Default: 34

MH2N D, 1, integer
H2 number density output switch

MKURU D, 1, integer
Kurucz spectrum data output switch
Default: 1

MLC [JM] D, 2, floating point
opacity multiplier
Default: 1.0

MN1 D, 1, integer
depth limit for N1 recalculation in the ambipolar diffusion calculation
Default: N

MNG1 D, 1, integer
depth limit for GNV-1 replacement in the ambipolar diffusion calculation
Default: -MN1

MODLAB *37 D, 1, alphanumeric
name of atmospheric model
Default: "!NONAME!"

MOPRNT D, 1, integer
switch to print built-in population-ion models
Default: 1

MQT B, 1, integer
length of QTAIL
Default: 3

MR *29, *77 [NSL] B, 2, integer
number of WRAT values (one MR for each level)

MRR B, 1, integer
length of FRR
Default: 6

MS ***2, *59** D, 1, integer
index of upper level of 'reference transition'
Default: from INPAIR; see Note *2

MSKIP ***62** D, 1, integer
ray selection parameter for computing weight matrices in spherical coordinates

MSSPR D, 1, integer
print switch for matrix of simultaneous "Special N1" solution (diffusion)
Default: 1

MTHEI ***83** D, 1, integer
exponential integral method selector
Default: 1

MTREF D, 1, integer
TR-effective output switch

MU ***24** [L] F, 2, floating point
cosine-of-lookangle values for emergent intensity calculation
Default: MUF

MUF ***24** [LF] F, 2, floating point
cosine-of-lookangle values for emergent flux calculation
Default: (1.0, 0.3)

MXPPI D, 1, integer
limit for individual KZAUG values (Z-augmentation, diffusion)
Default: 5

MXTAP D, 1, integer
limit for sum of KZAUG values (Z-augmentation, diffusion)
Default: 100

M304 D, 1, integer
index of reference value of He-II λ304 line mean intensity
Default: 10

N B, 1, integer
length of Z

NAB ***77** B, 1, integer
length of BANDL (see Section 9)

NABS ***7** [37] D, 2, integer
absorber/emitter switches
Default: NABS_i = on, for all i

NAK [@Z] H, 2*,2, floating point
singly-ionized Sodium number density
Default: computed in LTE

NAL B, 1, integer
number of levels for which Aluminum populations are specified

NAME ***3** D, 1, alphanumeric
name of ion of run

NAN [@Z] H, 3*,3, floating point
Sodium-I level populations
Default: NAN_{ij} computed in LTE, for all levels j such that $j >$ NNA

NANAL1 D, 1, integer
profile ANALYSIS depth selection parameter
Default: 1

NANAL2 D, 1, integer
profile ANALYSIS depth selection parameter
Default: 5

NAPKNT D, 1, integer
recombination parameter

NAPWRA D, 1, integer
recombination parameter
Default: 1

NAPWRB D, 1, integer
recombination parameter
Default: 2

NARB ***75** B, 1, integer
number of 'banner' pages

NBS D, 1, integer
b-smoothing control (level) index
Default: 2

NC [@Z] H, 2*,2, floating point
charged particle number density

NCA B, 1, integer
number of levels for which Calcium populations are specified

NCB B, 1, integer
length of LCOA, LCOB

NCL ***29, *109** B, 1, integer
length of XCOL
Default: 5

NCOI [@Z] D, 2*,2, floating point
CO number density, input (to replace computed values)

NCOPT D, 1, integer
CO-lines opacity calculations statistics-keeping switch

NCOSW D, 1, integer
Carbon Monoxide abundance correction computation method selector
Default: 1

NCQ B, 1, integer
length of CQT
Default: 5

NCR B, 1, integer
length of LCR

ND ***32** [@Z] D, 3*,3, floating point
number densities of the levels of the ion of the run
Default: computed in LTE

NDR B, 1, integer
length of XDR
Default: 7

NDSN1 D, 1, integer
skip Special N-1 recalculation in first overall calculation

NDT B, 1, integer
length of LDT
Default: 29

NDV B, 1, integer
length of DWAVE

NDW ***86** D, 1, integer
depth index for reference value of DW (Doppler width)
Default: either index of Z-value closest to ZNDW, or N/2

NDWM D, 1, integer
depth index for reference value of DW (Doppler width), for atmospheric model
Default: NDW

NE [@Z] D, 2*,2, floating point
electron number density

NECLIP D, 1, integer
continuum eclipse printout quantity selector

NED D, 4, integer
RHO editing index
Default: N

NEFDF ***125** D, 4, integer
switch for NE for d-coefficients in diffusion calculation
Default: 1

NERM ***85** D, 1, integer
limit for some error messages from `EDITH`
Default: 10

NEWELE D
element data (see Section 10)

NFB B, 1, integer
number of isotropic flow broadening velocities
Default: 6

NFE B, 1, integer
number of levels for which Iron populations are specified

NFH B, 1, integer
length of HNDF
Default: 8

NGM ***138** B, 1, integer
length of DGMZ
Default: 23

NGNV ***116** D, 1, integer
GNVL-suppression level limit

NGRL ***38** D, 1, integer
graphs Z-scale (axis) limit

NGRR ***38** D, 1, integer
graphs Z-scale (axis) limit

NH [@Z] D, 2*,2, floating point
total Hydrogen number density

NHN
= "HN 1 "

NHTSW ***64** D, 1, integer
H2 abundance correction method selector
Default: 2

NIASM D, 1, integer
sequential smoothing parameter
Default: 20

NIL ***19** D, 1, integer
a RHO selection parameter
Default: 2

NK [@Z] D, 3*,3, floating point
ionized number density of the ion of the run
Default: computed in LTE

NKA B, 1, integer
length of ZALBK (see Section 9)
Default: 2

NL ***29, *77** B, 1, integer
number of levels of the ion of the run
Default: 2

NLC B, 1, integer
number of levels for which Carbon populations are specified

NLH B, 1, integer
number of levels for which Hydrogen populations are specified

NLO B, 1, integer
number of levels for which Oxygen populations are specified

NLPAIR ***94, *95** [2×NL] B, 2, integer
list of quantum numbers

NLS B, 1, integer
number of levels for which Silicon populations are specified

NLU B, 1, integer
number of levels for which Sulphur populations are specified

NLY D, 1, integer
H Ly lines background opacity limit
Default: 15

NLZ B, 1, integer
number of levels for which Helium populations are specified

NMG B, 1, integer
number of levels for which Magnesium populations are specified

NMLR D, 1, integer
mass-loss-rate index
Default: NDW

NMT ***16, *77** B, 1, integer
number of rows in the table ELE (see Section 10)
Default: 38

NNA B, 1, integer
number of levels for which Sodium populations are specified

NNDFE D, 1, integer
dump control for injection function FJIN (fast electrons)
Default: -1

NODCG ***88** D, 1, integer
depth index for diffusion calculation graphs
Default: -1

NOION ***11, *84** B, 1, integer
'no ion' switch

NO2 B, 1, integer
number of levels for which Oxygen-II populations are specified

NO3 B, 1, integer
number of levels for which Oxygen-III populations are specified

NP [@Z] H, 2*,2, floating point
proton number density
Default: computed in LTE

NQLYM ***137** D, 1, integer
weight limit for highest H Lyman lines background opacity

NS ***2, *59** D, 1, integer
index of lower level of 'reference transition'
Default: from INPAIR; see Note *2

NSL ***29, *77** B, 1, integer
total number of levels of the ion of the run (including supplementary levels)
Default: NL

NSPED D, 1, integer
particle energy dissipation calculation parameter "NS" (fast electrons)
Default: 1

NSPRD D, 1, integer
secret PRD switch

NSW ***134** B, 1, integer
length of SCOW

NT ***29, *77** B, 1, integer
number of transitions specified in INPAIR

NTAN ***62** B, 1, integer
ray selection parameter for computing weight matrices in spherical coordinates
Default: 4

NTE B, 1, integer
length of TER
Default: 1

NU ***93** [NSL] D, 2, floating point
frequency intervals between levels of the ion of the run, in frequency units (see also WNU)

NUC ***93** [NSL] D, 2, floating point
auxiliary continuum frequency intervals of the ion of the run, in frequency units (see also WNUC)
Default: NUK

NUK ***93** D, 1, floating point
continuum frequency interval of the ion of the run, in frequency units (see also WNUK)

NVDFE D, 1, integer
dump control for injection function FINJ (fast electrons)
Default: -1

NVF B, 1, integer
number of velocity values (fast electrons)
Default: 30

NVH ***90** B, 1, integer
length of HNDV
Default: 38

NVOIT ***50, *84** D, 1, integer
Voigt profiles subroutine execution statistics printout switch
Default: 1

NVX ***29, *82, *108** B, 1, integer
number of VX tables

NWS B, 1, integer
length of DELWAVE

NWV B, 1, integer
length of WAVES

NXF B, 1, integer
maximum number of integrand values for injection functions (fast electrons)
Default: 1000

NZDFE D, 1, integer
dump control (fast electrons)
Default: -1

NZE B, 1, integer
length of ZECL

NZ2 B, 1, integer
number of levels for which Helium-II populations are specified

N1MET ***122** D, 1, integer
"Special N1" (diffusion calculation), method selector
Default: 2

N1NUP D, 1, integer
populations-of-the-run update switch, "Special N1" calculation
Default: 1

OK [@Z] H, 2*,2, floating point
singly-ionized Oxygen number density
Default: computed in LTE

OLL ***18** D, 4, floating point
line opacity multiplier
Default: 1.0

OMIT [variable] B, 2, alphanumeric
disable program options (see Section 6 for further details)

OML ***16** D, 4, floating point
line-background opacity multiplier
Default: 1.0

ON [@Z] H, 3*,3, floating point
Oxygen-I level populations
Default: ON_{ij} computed in LTE, for all levels j such that $j >$ NLO

OPF D, 1, floating point
incident radiation extinction factor
Default: 1.0

OUTPUT ***23** B, 1, alphanumeric
'general printout' file scope switch
Default: "MERGE"

O2K [@Z] H, 2*,2, floating point
doubly-ionized Oxygen number density
Default: computed in LTE

O2N [@Z] H, 3*,3, floating point
Oxygen-II level populations
Default: $O2N_{ij}$ computed in LTE, for all levels j such that $j >$ NO2

O3K [@Z] H, 2*,2, floating point
triply-ionized Oxygen number density
Default: computed in LTE

O3N [@Z] H, 3*,3, floating point
Oxygen-I level populations
Default: $O3N_{ij}$ computed in LTE, for all levels j such that $j >$ NO3

P ***93** [NSL] D, 2, floating point
statistical weight

PALBET [@Z] D, 2*,2, floating point
Helium diffusion parameter

PART ***61** D, 1, floating point
partition function for the ion of the run

PARTLIM D, 1, floating point
partition functions component limit (for ions in table ELE)
Default: 3.0

PBETAL [@Z] D, 2*,2, floating point
Helium diffusion parameter

PBETGM [@Z] D, 2*,2, floating point
Helium diffusion parameter

PCE D, 5, floating point
FCE adjustment factors

PGMBET [@Z] D, 2*,2, floating point
Helium diffusion parameter

PMSK D, 1, floating point
multiplier of default Stark half-width
Default: 1.0

PNH D, 1, floating point
scattering albedo parameter for Background Line Opacities (see Section 9)

POPION ***28** H
'population update' ion data

POPRCP ***28** H
'population update' ion data

POPUP ***8** D, 1, alphanumeric
populations data update switch

POPXLM ***28** H
'population update' ion data

PRDCV ***42** D, 1, floating point
PRD-iterations convergence criterion
Default: 0.1

PROF ***17** D, 4, integer
emergent line profiles calculations switch

PROGLI ***98** D, 4, floating point
profile graphs control parameter

PW D, 1, floating point
exponent for Stark broadening term
Default: 1.0

PZERO ***103** D, 1, floating point
Z-from-TAUKIN recalculation parameter

QIN [@Z] D, 2*,2, floating point
K-shell ionization calculation data

QNL [NSL] D, 2, integer
number of "$n\ell$" electrons
Default: all = 1

QTAIL [MQT] D, 2, floating point
Lyman EP-1 Q-smoothing tail
Default: (0.5, 0.1, 0.01)

RABD ***120** [@Z] D, 2*,2, floating point
depth variation of abundance ratio
Default: antilog(RABDL$_i$), or RABD$_i$ = 1.0, for all i

RABDL ***120** [@Z] D, 2*,2, floating point
depth variation of log of abundance ratio

RCCFE D, 1, floating point
accuracy criterion for injection function integrations (fast electrons)
Default: 0.1

RCHX ***95, *97** D, 4, floating point
upper-level charge-exchange parameter

RCOMIN D, 1, floating point
CO abundance lower limit
Default: 10^{-10}

REFLM ***103** D, 1, floating point
wavelength to which TAUKIN values correspond
Default: 911.1236

RFAC D, 1, floating point
reduction factor for all collision rates
Default: 1.0

RFHEAB D, 1, floating point
Helium abundance coefficient reduction factor for RHEAB calculation
Default: 1.0

RFMAS ***103** D, 1, floating point
reference mass

RHEAB [@Z] D, 2*,2, floating point
depth dependence of total Helium abundance
Default: $\mathrm{RHEAB}_i = 1.0$, for all i

RHO [@Z] D, 5*,5, floating point
net radiative bracket

RHOPT ***4**, ***19** D, 1, alphanumeric
a RHO selection parameter
Default: "RHOJ"

RHOWT ***13, *131** [@Z] D, 5*,5, floating point
RHO weights

RHWT ***13, *131** [@Z] D, 5*,5, floating point
RHO weights
Default: 1.0

RK ***45** [@Z] D, 3*,3, floating point
photoionization rate (for level KOLEV)

RKC [LR] D, 3, floating point
additional photoionization parameter

RKMULT [NSL] D, 2, floating point
RK enhancement factor

RKW ***13, *131** [@Z] D, 3*,3, floating point
RK-KOLEV weights

RKWT ***13, *131** [@Z] D, 3*,3, floating point
RK-KOLEV weights
Default: 1.0

RL ***39**, ***45** [@Z] D, 3*,3, floating point
photorecombination rate (for level KOLEV)

RQCP ***22, *93** [MR+1] D, 3, floating point
= RRCP

RRCP ***22**, ***56** [MR] D, 3, floating point
ratios of photoionization cross-sections
Default: computed for Level 1 for some non-Hydrogen runs

RUNTOPOP *8 [8] B, 2, integer
ion-of-the-run vs. built-in population-ion-model level correspondences, for 'population update' runs

RZM [@Z] D, 2*,2, floating point
metal electrons multiplier
Default: $\mathrm{RZM}_i = 1.0$, for all i

R1N D, 1, floating point
distance from illuminating source

SCH ***47** D, 4, integer
partial redistribution calculation selector for Line Source Function calculations

SCOW ***134** [NSW] D, 2, floating point
selected Continuum output wavelengths

SCTA ***55** D, 1, floating point
shock temperature amplitude

SCTS ***55** D, 1, floating point
shock temperature scale height

SCVA ***55** F, 1, floating point
shock velocity amplitude

SCVB ***55** F, 1, floating point
shock velocity parameter

SCVS ***55** F, 1, floating point
shock velocity scale height

SGRAF ***98** D, 4, integer
profile graphs control parameter

SHCOC D, 1, floating point
CO chromospheric scale height
Default: 100.

SHCOP D, 1, floating point
CO photospheric scale height
Default: 400.

SIK [@Z] H, 2*,2, floating point
singly-ionized Silicon number density
Default: computed in LTE

SIN [@Z] H, 3*,3, floating point
Silicon-I level populations
Default: SIN_{ij} computed in LTE, for all levels j such that $j >$ NLS

SK [@Z] H, 2*,2, floating point
singly-ionized Sulphur number density
Default: computed in LTE

SMATC D, 1, floating point
matrix samples output selection criterion

SMOOTH ***49** D
RHO smoothing control parameters
Default: see Note *49

SMP D, 1, floating point
RHO weights adjustment parameter
Default: 0.3

SN [@Z] H, 3*,3, floating point
Sulphur-I level populations
Default: SIN_{ij} computed in LTE, for all levels j such that $j >$ NLU

SN1CC D, 1, floating point
convergence criterion for "Special N1" calculation (diffusion)
Default: 10^{-8}

SOBDMN *51 D, 1, floating point
Sobolev escape probability calculation integration control parameter
Default: 0.001

SOBDMX *51 D, 1, floating point
Sobolev escape probability calculation integration control parameter
Default: 0.01

SOBFEQ *51 D, 1, floating point
Sobolev escape probability calculation integration control parameter
Default: 0.001

SOBOLEV *51, *82 [2] D, 5, integer
Sobolev solution limit indices
Default: (1, 1)

SRCO D, 1, floating point
scattering ratio for CO lines
Default: 0.1

STARKI D, 4, floating point
value of NE-index for Stark splitting of Hydrogen lines
Default: ISTARK

TAUCL *42 D, 1, floating point
DR parameter, PRD transitions
Default: 10^4

TAUKIN *103 [N] D, 2*,2, floating point
input TAUK values

TB [@Z] D, 2*,2, floating point
blanketing temperature
Default: TE

TBAR D, 1, floating point
change-over TAU-value for weight matrix calculation
Default: 0.5

TDST [@Z] D, 2*,2, floating point
Type-2 dust opacity calculation temperature values

TDUST D, 1, floating point
Type-1 dust temperature
Default: 200.0

TE [@Z] D, 2*,2, floating point
kinetic temperature

TER ***93** [NTE] D, 2, floating point
temperature table for input values of CE and CI
Default: 4000.0

TEX [@Z] D, 2*,2, floating point
excitation temperature
Default: TE

TGLYM ***67** D, 1, floating point
Lyman change-over TAU parameter
Default: 100.0

TKR [LR] D, 3, floating point
wavelengths for which additional photoionization values are specified

TLARGE D, 1, floating point
TNP-from-TNU selection parameter
Default: 200.0

TLIMG ***34** D, 1, floating point
absorption contributors graph axis limit
Default: 0.0 [= log(1.0)]

TLTR D, 1, floating point
limiting multiplier for TDST recalculation
Default: 1.3

TML D, 1, floating point
large-TAU cut-off for intensity integrals
Default: 30.0

TMS D, 1, floating point

small-TAU change-over for RT weight matrices

Default: 5.0

TOPE ***84** D, 1, integer

Continuum Plots save switch

TR

= "TRN 1 "

TRFLI D, 1, floating point

limit-interval for TR-effective calculation

Default: 1.1

TRN ***9, *102** [@Z] D, 3*,3, floating point

radiation temperature (for a given level of the ion of the run)

Default: $\mathrm{TRN}_{i,1} = \mathrm{TE}_i, \quad \mathrm{TRN}_{i,j} = \mathrm{TRN}_{i,1},$ all $i,$ all $j > 1$

TS [M] D, 2, floating point

standard TAU table

Default: (0.0, 0.0001, 0.0002, 0.0003, 0.0006, 0.001, 0.002, 0.003, 0.006, 0.01, 0.02, 0.03, 0.06, 0.1, 0.2, 0.3, 0.6, 1.0, 2.0, 3.0, 5.0, 7.0, 10.0, 15.0, 20.0, 30.0, 50.0, 75.0, 100.0, 150.0, 200.0, 300.0, 500.0)

TSM D, 1, floating point

change-over TAU for mean intensity and emergent intensity calculations

Default: 10^{-4}

TSMALL D, 1, floating point

TNP-from-TNU selection parameter

Default: 10^{-10}

TX D, 1, floating point

brightness temperature of illuminating source

USE ***44** B,D,F,H, 1, alphanumeric

input file designation

Default: "INPUT"

V ***69, *82, *90** [@Z] D, 2*,2, floating point

broadening velocity

VM ***82** [@Z] D, 2*,2, floating point

mass motion velocity

VMNFE D, 1, floating point
minimum velocity (fast electrons)
Default: 0.003

VNH ***90** [NVH] D, 1, floating point
standard table of V (as a function of HNDV) for the quiet sun
Default: (15.18, 13.68, 11.92, 10.75, 9.68, 8.44, 7.81, 7.52, 6.95, 6.28, 5.52, 4.60, 3.59, 2.98, 2.20, 2.00, 1.54, 1.38, 1.18, 1.00, 0.86, 0.80, 0.68, 0.65, 0.55, 0.52, 0.63, 0.90, 1.10, 1.30, 1.46, 1.56, 1.64, 1.71, 1.76, 1.80, 1.82, 1.83)

VOITC ***50** D, 1, floating point
Voigt function calculation cut-off
Default: 10^{-6}

VR ***69, *82** [@Z] D, 2*,2, floating point
broadening velocity

VSB ***51, *82** [@Z] D, 2*,2, floating point
Sobolev velocity
Default: VXS or VM

VSMLL ***71** D, 1, floating point
replacement value for divisors that equal zero (subroutine `DIVIDE`)
Default: 10^{-100}

VT ***82** [@Z] D, 2*,2, floating point
turbulent pressure velocity

VX ***57, *82** [N] F, 3, floating point
additional expansion velocity for emergent profile calculation

VXS ***60, *82** [@Z] D, 2*,2, floating point
basic expansion velocity for Line Source Function calculations
Default: VM

WAVEMN ***110** D, 1, floating point
automatic additional wavelengths limit

WAVEMX ***110** D, 1, floating point
automatic additional wavelengths limit

WAVES ***27** [NWV] D, 2, floating point
additional wavelengths for continuum calculations

WBD ***26** D, 1, floating point
weight for departure coefficient updating
Default: WPOP

WBDIR D, 1, floating point
weight for results of "direct" departure coefficient calculation
Default: 1.0

WEIGHT D, 6, floating point
weight for Statistical Equilibrium equations calculation

WEP ***104** D, 1, floating point
Lyman EP-1 weighting parameter
Default: 1.0

WFB F, 1, floating point
weight for flow broadening component velocities
Default: 0.6

WMN ***131** D, 1, floating point
RHO weight adjustment parameter
Default: 0.3

WMX ***131** D, 1, floating point
RHO weight adjustment parameter
Default: 0.9

WNJUNK ***87** D, 1, floating point
WN-matrix "cleanup" parameter

WNU [NSL] D, 2, floating point
= NU, but in wavenumbers

WNUC [NSL] D, 2, floating point
= NUC, but in wavenumbers

WNUK D, 1, floating point
= NUK, but in wavenumbers

WORLDLY ***132** B, 1, alphanumeric
storage management dump control switch

WPOP ***26** D, 1, floating point
weight for number densities updating
Default: WBD, or 1.0

WPRESS D, 1, floating point
weight for adjusting NH to achieve constant pressure
Default: 1.0

WR ***13** D, 4, floating point
RHO weighting parameter
Default: 1.0

WRAT ***22**, ***56** [MR] D, 3, floating point
wavelengths for rates integrations

WRATMN ***135** D, 1, floating point
standard rates integrations wavelengths table limit
Default: 100.

WRATMX ***135** D, 1, floating point
standard rates integrations wavelengths table limit
Default: 20000.

WRMN ***131** D, 1, floating point
RHO weight adjustment parameter
Default: 0.1

WRMX ***131** D, 1, floating point
RHO weight adjustment parameter
Default: 0.7

WSM D, 1, floating point
Lyman RK-KOLEV smoothing parameter

WSN1D D, 1, floating point
weight for Special N1 and Special NK, Diffusion
Default: 1.0

WTD D, 1, floating point
weight for TDST recalculation
Default: 1.0

WZ D, 1, floating point
Z-from-TAUKIN weight
Default: 0.5

WZM ***103** D, 1, floating point
Z weighting parameter
Default: 0.8

XC ***42** D, 4, floating point
DR parameter, PRD transitions
Default: 2.0

XCL ***42** D, 1, floating point
DR parameter, PRD transitions
Default: 3.5

XCOL [NCL] D, 2, floating point
table of wavelengths for *each* CO line, in doppler widths, for the CO-lines opacity
Default: (0.0, 0.5, 1.0, 1.5, 2.0)

XCOMX D, 1, floating point
width limit for *each* CO line, in Å, for the CO-lines opacity
Default: 3.0

XDR ***42** [NDR] D, 2, floating point
DR parameter, PRD transitions
Default: (5.5, 6.0, 7.0, 8.0, 10.0, 12.0, 15.0)

XI D, 2, floating point
= XISYM

XIBLU ***66** [KB] D, 2, floating point
Line Transitions frequency table, for blue side
Default: XISYM

XIBLUT ***66** [KBT] D, 5, floating point
Line Transition frequency table, for blue side
Default: XISYMT

XINK [INK] D, 2, floating point
table of frequencies for which incident radiation is specified
Default: (5.948, 5.949, 7.48, 7.51, 13.16, 13.17)

XIRED ***66** [KR] D, 2, floating point
Line Transitions frequency table, for red side
Default: XISYM

XIREDT ***66** [KRT] D, 5, floating point
Line Transition frequency table, for red side
Default: XISYMT

XISYM ***66** [KS] D, 2, floating point

Line Transitions frequency table, for half of a symmetric profile

Default: (0.0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9, 1.1, 1.3, 1.5, 1.8, 2.1, 2.4, 2.8, 3.4, 3.9, 4.5, 6.0, 8.0, 15.0, 50.0)

XISYMT ***66** [KST] D, 5, floating point

Line Transition frequency table, for half of a symmetric profile

Default: XISYM

XJFE D, 1, floating point

electron flux (fast electrons)

Default: 2.0×10^{-10}

XK ***123** [KK] D, 2, floating point

Level-$\mathcal{N}$-to-Continuum calculation (Lyman) frequency table

Default: RRNU(KOLEV), where RRNU is computed from WRAT

XMU [LG] D, 1, floating point

MU table for GR-method weight matrix calculation

Default: (1.0, 0.8, 0.6, 0.5, 0.4, 0.3, 0.2, 0.1)

XP ***42** D, 4, floating point

DR parameter, PRD transitions

Default: 2.0

XR ***42** D, 4, floating point

DR parameter, PRD transitions

Default: -1.0

XQMAX D, 1, floating point

parameter for injection function integrations (fast electrons)

Default: 200.0

XRKH ***95, *96** [@Z] D, 5,5*, floating point

upper-level charge-exchange data for Hydrogen

XRLH ***95, *96** [@Z] D, 5,5*, floating point

upper-level charge-exchange data for Hydrogen

Y D, 1, floating point

damping parameter for frequency integrations weights (see Section 12)

Default: 0.5

YCOL D, 1, floating point
weight matrix method control parameter for the continuum calculations required for the CO-lines opacity (see Section 12)
Default: -1.0

YCONT D, 4, floating point
weight matrix method parameter, for Continuum calculations (see Section 12)
Default: -1.0

YCR [NCR] D, 2, floating point
weight matrix method control parameter, for incident coronal radiation (see Section 12)
Default: -1.0

YFLUX D, 1, floating point
damping parameter for emergent continuum flux
Default: 0.5

YH D, 1, floating point
Helium-to-Hydrogen ratio
Default: Helium abundance (from ELE table)

YHM [MHM] D, 2, floating point
weight matrix method parameter, for H-minus calculation (see Section 12)
Default: -1.0

YK [NSL] D, 2, floating point
Hydrogen recombination parameter

YKR [LR] D, 3, floating point
weight matrix method parameter, for additional photoionization (see Section 12)
Default: -1.0

YL D, 1, floating point
weight matrix parameter, for Level-$\mathcal{N}$-to-Continuum source function calculation (see Section 12)
Default: -1.0

YLDT [NDT] D, 2, floating point
weight matrix method parameter, for Type-2 dust opacity calculation (see Section 12)
Default: -1.0

YLINE D, 4, floating point
weight matrix method parameter, for Line Source Function (see Section 12)
Default: -1.0

YLYM [KK] D, 2, floating point
weight matrix parameter, for Level-$\mathcal{N}$-to-Continuum continuum source function calculations (see Section 12)
Default: -1.0

YPRE D, 1, floating point
damping parameter for standard weight matrix (see Section 12)

YRATE ***22** [MR+1] D, 3, floating point
weight matrix method parameter, for rates calculations (see Section 12)
Default: -1.0

YRATS D, 1, floating point
damping parameter for standard rates integrations wavelengths (see Section 12)
Default: -1.0

YWAVE [NWV] D, 2, floating point
weight matrix method parameter, for additional calculations (see Section 12)
Default: -1.0

Z [N] D, 2, floating point
grid of geometrical depths (main Z-table of the run)

ZALBK [NKA] D, 1, floating point
scattering albedo parameter for Background Line Opacities (see Section 9)
Default: (Z_1, Z_N)

ZAUX [LZA] D,F,H, 3, floating point
auxiliary Z-table

ZECL [NZE] F, 2, floating point
selected Z-values for eclipse continuum calculation

ZGM ***138** [NGM] D, 2, floating point
Z-table for DGMZ
Default: (-2000, -1900, -1800, -1700, -1600, -1500, -1400, -1300, -1200, -1100, -1000, -900, -800, -700, -600, -500, -400, -300, -200, -100, -50, 0, 50)

ZMASS ***103** [N] D, 2, floating point
gas column mass

Notes

ZME [@Z] D, 2*,2, floating point
non-H electron ratio

ZNDW ***86** D, 1, floating point
Z-value for optional NDW-default calculation

ZRCO D, 1, floating point
CO reference height
Default: -500.

ZXMIN D, 1, floating point
diffusion calculation parameter for ZION
Default: 0.1

***1**

The default value of **ABD** can be obtained from the element tables (see Section 10), provided that **ELSYM** is a recognizable chemical element symbol.

***2**

INPAIR is a list of pairs of integers u, ℓ $(u > \ell)$, which specify transitions between levels. These pairs may be listed in any order, as long as the proper pair relationships are preserved. For example, if (2,1), (5,1), (5,2), (5,3) and (5,4) are the transitions to be specified, then the input statement might be:
"`INPAIR ( 5 1 5 2 5 3 2 1 5 4 )` ".
The first pair will be used as the default for (**MS**,**NS**).

***3**

NAME must not have more than 8 characters, and may not contain imbedded blanks.

***4**

RHOPT specifies the RHO option, and may only take on one of the following values: "`RHOS`", "`RHOJ`", or "`RHOW`".

***5**

Notes

When **JSTCN** > 0, then PANDORA will do only background continuum calculations and emergent continuous spectrum calculations (depending on the specific options settings); this is called: a 'continuum-only' run.
The value of **JSTCN** controls which wavelengths will be included in the computations of this run.
JSTCN should be set equal to $KAW + 2 \times KOM + 4 \times KCO$, where
$KAW = 1$ means: use 'additional wavelengths' (*i.e.* **WAVES**), $KAW = 0$ means: do not;
$KOM = 1$ means: use Composite Lines Opacity wavelengths; $KOM = 0$ means: do not;
$KCO = 1$ means: use CO-lines opacity wavelengths; $KCO = 0$ means: do not.

***6**

JSTCN and **JSTIN** may not both be > 0 for the same run.
JSTCN and **NOION** may not both be > 0 for the same run.

***7**

Any of the absorbers/emitters automatically included in the background opacity/emission calculations can be turned off by mentioning them in **NABS** statement(s). For this purpose, the absorbers/emitters are specified using the "index" by which they are identified in the left margin of the 'List of potential contributors to "continuum" or "background" absorption and emission.' which is part of the ATMOSPHERE printout at the beginning of the regular output from a run. For example, the following statement will cause the H Ly alpha Abs and the H_2^+ opacity to be turned off: "`NABS ( 11 9 )` ".

***8**

The **POPUP** switch is used to tell PANDORA whether this is a run in which the number densities computed at the end of every overall iteration must also be copied into the appropriate 'non-LTE populations' tables set aside for certain ions. The **POPUP** switch may only take on the values:
1) `HYDROGEN`, 2) `CARBON`, 3) `SILICON`, 4) `HELIUM`, 5) `HELIUM2`, 6) `ALUMINUM`, 7) `MAGNESIUM`, 8) `IRON`, 9) `SODIUM`, 10) `CALCIUM`, 11) `OXYGEN`, or 12) `SULFUR`; *i.e.*: "`POPUP ( CARBON )` ". A run that is not concerned with one of these should not have **POPUP** among its input statements. Moreover, runs with 'population ions' can be made without 'population updating' simply by not specifying **POPUP**.
In a 'population update' run, the values of the integer array **RUNTOPOP** specify the correspondence between the levels of the ion-of-the-run and the levels of the built-in population-ion-model. (The description of the built-in population-ion-model is printed as part of the first printout of the corresponding 'population ion' number densities and departure coefficients; note that specific options must be turned on for this, *e.g.* CARPRNT.) $\mathbf{RUNTOPUP}_i = j$ means that level j of the ion-of-the-run corresponds to level i of the built-in population ion model.
If k is the lowest level of the built-in population-ion-model to which no level of the ion-of-the-run corresponds, then $\mathbf{RUNTOPOP}_\ell = 0, k < \ell \leq$ LIMDAT, is re-

quired. (Note that the default values are $\mathbf{RUNTOPOP}_i = 0, 1 \leq i \leq$ LIMDAT.)

***9**

Input tables of **TRN** may be specified in abbreviated forms: either

(a) **TR (I** k x_k x_{k+1} x_{k+2} ... x_m **)** ,

i.e. "`TR ( I 12 3600. 3700. 3750. 3800. )` ", or

(b) **TRN** j **(I** k x_k x_{k+1} x_{k+2} ... x_m **)** ,

i.e. "`TRN 2 ( I 12 3600. 3700. 3750. 3800. )` "

In both these forms, several elements of an array, (beginning, here, with the 12. one), are set equal to the floating point numbers given.

Case (a) tells PANDORA to do the following (after **GO** has been read):
to set $\mathrm{TR}_i = x_k,\ 1 \le i \le k$, to leave $\mathrm{TR}_i = x_i,\ k+1 \le i \le m$, as specified in the input statement, and to set $\mathrm{TR}_i = \mathrm{TE}_i,\ m+1 \le i \le$N.

Case (b) is equivalent to (a) when $j = 1$; otherwise, it specifies the j'th TRN table.

The rationale for this procedure derives from the structure of a typical TRN table, as follows: the initial elements of the table are equal to some constant value, then there is a variation extending over several values, until, finally, the values of TRN are equal to the values of TE at the corresponding interior depths. Thus the abbreviated input form specifies the index of the last of the constant values, that constant itself, and then the set of values which differ from TE.

Note: This abbreviated input form may only be used when the TRN table is specified with respect to the main depth table of the run; it may not be used when the TRN table is specified with respect to a **ZAUX** (auxiliary depth) table.

***10**

After **GO** has been read, PANDORA examines the values of $\mathbf{KPC}^{u,\ell}$ for every radiative transition (u, ℓ). If all the values of $\mathbf{KPC}^{u,\ell}$ are $= 0$ (normal default), then it sets $\mathbf{KPC}^{u,\ell} = \mathbf{KPCR}_i^{u,\ell} \times \mathbf{KPC}_i^{MS,NS},\ 1 \le i \le$ N, where (**MS**,**NS**) is the reference transition. After this process is finished, $\mathbf{KPC}_i^{u,\ell} = 0$ can only come about because $\mathbf{KPC}_i^{MS,NS} = 0$ (if there were no explicit input values $\neq 0$), or, for $i, j \neq MS, NS$, because either $\mathbf{KPC}_i^{MS,NS} = 0$, or because $\mathbf{KPCR}^{u,\ell} = 0$.

Those transitions for which nonzero input values of continuous opacity were obtained by this procedure, will retain those values for the first overall iteration.

For those transitions for which no nonzero values of continuous opacity could be obtained, PANDORA will compute them. (Normally, PANDORA computes opac-

ity values for every radiative transition in every overall iteration.)

***11**

When **NOION** = 1 (*i.e.* if the option DOION is off), then no ion-related calculations will be done. **JSTCN** and **NOION** may not both be > 0 for the same run. See also Note 84.

***12**

KONFORM controls the format of the printing of detailed contributions to the background opacity and the absorption source function (*i.e.* the detailed printouts of 'absorbers' and 'emitters').
KONFORM = 1 means: print their absolute values, using Fortran E-format conversion;
KONFORM = 2 means: print them as fractions of the total, using Fortran F-format conversion.

***13**

$X_i^{s+1} = (1 - W_i) \times X_i^{new} + W_i \times X_i^s,\ 1 \le i \le N$, where X stands for RHO; or $X_i^{s+1} = [(X_i^{new})^{(1-W_i)}] \times [(X_i^s)^{W_i}],\ 1 \le i \le N$, where X stands for RK-KOLEV (Lyman).
The values of X_i for iteration $s + 1$ will be obtained, in the manner shown, from the values of X_i used during iteration s and the *new* values of X_i calculated at the end of iteration s. The values of W_i (which may all be equal to some constant) are obtained from WRHO, **WR**, **WRLY**, and $\mathbf{WTW}_j$ as described in the writeup [7/3/72], (WRHO is continually recomputed as the calculation proceeds), or from $\mathbf{RHOWT}_i$ or $\mathbf{RKW}_i$, respectively, as described in the writeup [74 Oct 23].
Important: Note 13 is now obsolete; **see Note 131**.

***14**

$\mathbf{BLCSW}^{u,\ell}$ tells which components of DP to use for the Line Source Function calculation for transitions (u, ℓ). Its input value should be established according to $BLCSW = SRD + 2 \times SVW + 4 \times SSK + 8 \times SRS + 16 \times SIC$.
Here $SRD = 1$ if radiative broadening should be used, $= 0$ if not; SVW, SSK, SRS, and SIC similarly control van der Waals, Stark, resonance, and ion colli-

sion broadening, respectively. (*Note*: ion collision broadening is used for Hydrogen transitions above level 5 only.) In the ATOM printout, the values of SRD, SVW, SSK, SRS, and SIC are shown as a string of digits (*i.e.* as a binary number) in order from right to left.

***15**

$X_i^{s+1} = \mathbf{HSEC} \times X_i^{new} + (1 - \mathbf{HSEC}) \times X_i^s,\ 1 \le i \le N$, where X stands for either NE or NH.
When the option HSE is on, the X_i for overall iteration $s+1$ will be obtained, in the manner shown, from the X_i used during iteration s and the *new* values of X_i calculated at the end of overall iteration s.

***16**

$\mathbf{LSFBOC}^{u,\ell}$ and $\mathbf{OML}^{u,\ell}$ control whether any of the 'Line Background' opacities (see Section 9) are allowed as potential contributors to the total background (or "continuum") opacity at wavelength(s) pertaining to transition (u, ℓ). If $\mathbf{LSFBOC} = 0$ then all these 'Line Background' opacities will be suppressed; if $\mathbf{LSFBOC} = 1$ then the appropriate one, multiplied by **OML**, will be used. By default, all $\mathbf{LSFBOC} = 0$ and all $\mathbf{OML} = 1$.

***17**

If the value of $\mathbf{PROF}^{u,\ell} = 0$, then no emergent intensity nor flux profiles will be computed for transition (u, ℓ). If any value of $\mathbf{PROF}^{u,\ell}$ is > 0, then $\mathbf{LF} > 0$ is required. (A flux profile will not be computed if $\mathbf{LF} = 1$; see also Note 24.)
Line profile intensity and flux values are computed for tables of $\Delta\lambda$ values which are derived for frequency (**XI**) values; see Section 18, Frequency Tables, for additional information.

***18**

$\mathbf{OLL}^{u,\ell}$ multiplies the values of $\mathrm{GTN}^{u,\ell}$. ($\mathrm{GTN}_i^{u,\ell}$ multiplies the line absorption profile $\phi_i^{u,\ell}$ in the equation for the monochromatic total opacity at the various frequency points of transition (u, ℓ).)

***19**

The RHO selection parameters:

RHOPT –

Values of $\mathrm{RHO}_i^{u,\ell}$ are calculated three different ways:

• as part of the Line Source Function calculation (RHOS);

• from S, S*, RHOS and **CWJ** (RHOJ); and

• by combining RHOS and RHOJ (RHOW). (See also the explanation printed with the RHO AND RBD section of the normal output.) The value of **RHOPT** tells which of these is to be chosen as the final $\mathrm{RHO}_i^{u,\ell}$, to be used in subsequent iterations.

NWRHO, **WMN** and **WMX** –

At the end of every iteration s, the current values of CHECK_i^j are compared to the ones from the previous iteration $s-1$, for $1 \le i \le N$ and $3 \le j \le NL$. A counter K is initialized to zero. Whenever: $CC = |\mathrm{CHECK}_i^j - 1| > 0.002$ and $OC = |\mathrm{CHECK}_{i-1}^j - 1| > 0.002$ and $OC/CC \le 0$, then K will be increased by 1. All values of CHECK_i^j will be tested to determine K. If $K >$ **NWRHO** then, if WRHO < **WMX**, WRHO will be increased by 0.1. If $K \le$ **NWRHO**, then, if WRHO > **WMN**, WRHO will be decreased by 0.1. (If WRHO < **WMN** or WRHO ≥ **WMX**, then WRHO will remain unchanged.) This new value of WRHO will then be used in the next iteration, as specified in Note 13.

CHOP, **CWR**, **ILI**, **NIL**, **CHLIM**, and option RHOWOPT –

The significance of these parameters is explained in the text accompanying the RHO AND RBD printout (when option RHBPRNT is on). (If such a printout happens not to be immediately at hand, it won't hurt to set up a one-iteration run using the automatic defaults.)

***20**

If the option ISCRS is on (*i.e.* if **ISCRS** = 0), then 'scratch I/O' will be done 'in memory' to the extent possible (*i.e.* depending on the amount of memory reserved for the `MEMOIR` routines). When memory is full, scratch I/O will overflow to the temporary scratch disk file (logical unit 1, see Section 7). (For some runs, scratch I/O can be accomodated entirely in memory, and no temporary scratch disk file will be required; in other runs, the size of the temporary scratch disk file will be reduced.) This 'in-memory scratch I/O mode' may be particularly benefi-

cial when PANDORA is run on systems with real memory so large that no hard page faults occur.
If the option ISCRS is off (*i.e.* if **ISCRS** = 1), then 'in-memory scratch I/O' is not allowed; *all* scratch I/O will use the temporary scratch disk file.
See also Note 84.

***21**

METEP specifies the method for computing EP1 and EP2 in the Level-$\mathcal{N}$-to-Continuum (Lyman) transfer calculation.
METEP=0 means: NOVA-like method (writeup dated 06/04/68);
METEP=1 means: COMPLEX/UPPER-like method (writeup dated 04/12/90);
METEP=2 means: COMPLEX/LOWER-like method (writeup dated 06/22/76);
METEP=3 means: CHAIN-like method (writeup dated 11/24/76).
(The values of **METEP** are analogous to those of **METSE**; see Note 35.)

***22**

For a particular energy level j, $\mathbf{WRAT}^j$ specifies a set of wavelength values, $\mathbf{RRCP}^j$ a tabular function of these wavelength values, and $\mathbf{YRATE}^j$ a set of method control parameters (see Section 12) for Continuum Source Function calculations at these wavelengths. We have $\mathbf{WRAT}^j_m$, $\mathbf{RRCP}^j_m$, and $\mathbf{YRATE}^j_m$, $1 \leq m \leq \mathbf{MR}^j + 1$. Since the value of $\mathbf{WRAT}^j_1$ is obtained from $(\mathbf{NUC}^j - \mathbf{NU}^j)$, this value need not (actually: *cannot*) be input; and since $\mathbf{RRCP}^j_1$ usually = 1.0, this value normally need not be input. Thus, for every level for which $\mathbf{MR}^j > 0$, the input must contain specifications of the values of $\mathbf{WRAT}^j_m$ and $\mathbf{RRCP}^j_m$, $2 \leq m \leq \mathbf{MR}^j + 1$. On the other hand, all values of $\mathbf{YRATE}^j_m$ can (actually: *must*) be input. Thus, the input statements for **WRAT** and **RRCP** are different from those for **YRATE**. For example, if we have:

m	WRAT^2_m	RRCP^2_m	YRATE^2_m
1	(3612.0)	(1.0)	-1.0
2	3575.0	0.99	1.0
3	3540.0	0.97	0.9

the input statements might be:
“`WRAT 2 ( 3575. 3540. )` ”,
“`RRCP 2 ( 0.99, 0.97 )` ”,
“`YRATE 2 ( -1.0 1.0 0.9 )` ”.
However, there are infrequent occasions when $\mathbf{RRCP}^j_1$ should not = 1.0. In such a case, such a value can be input by referring to that array under another name, namely **RQCP**, for which the first value can (actually: *must*) be input (as with **YRATE**). Thus if, in the above example, $\mathbf{RRCP}^2_1 = 1.2$ is wanted, the input statements might be:

"`WRAT 2 ( 3575. 3540. )` ",
"`RQCP 2 ( 1.2 .99, .97 )` ",
"`YRATE 2 ( -1.0 1.0 0.9 )` ".

***23**

OUTPUT can take on the values: `MERGE`, `SPLIT`. See Section 7, the part headed "**Output files**".

***24**

The **MU** table (for intensity) must be a proper subset of the **MUF** table (for flux); thus it is required that $\mathbf{L} \leq \mathbf{LF}$ and that, for every m, $\mathbf{MU}_m = \mathbf{MUF}_n$, some n. Both **MU** and **MUF** must be in order of decreasing values.

***25**

CE is used in the calculations of the collisional transition rates, which normally depend on NE. However, if some input value of $\mathbf{CE}^j$ is negative, then its absolute value will be used, and the corresponding rate calculation for level j will use NH in place of NE.

***26**

WPOP is used for the iterative calculation of number densities, as follows: $P^{i+1} = 10^{[W \times \log(P^{new}) + (1-W) \times \log(P^i)]}$, where W stands for **WPOP** and P stands for the level populations or the ionized number density computed at the end of an overall iteration. When the POPUP switch is on, the values of P^{i+1} for overall iteration $i+1$ will be obtained, in the manner shown, from the P^i available at the start of iteration i and the P^{new} computed during iteration i.

WBD is used similarly for departure coefficients.

***27**

Any values of $\mathbf{WAVES}_k$ may be < 0.0, and only $|\mathbf{WAVES}_k|$ will be used, both for the 'additional' background continuum calculations and the emergent continuous spectrum calculations. Moreover, when $\mathbf{WAVES}_k < 0.0$, then the Continuum Eclipse Intensities for $|\mathbf{WAVES}_k|$ will also be computed (provided the option ECLIPSE is on).

***28**

These input statements are not intended for general use. They provide emergency means for changing the built-in contents of the population-ion-model data tables. (These data are printed the first time that the values of number density and departure coefficient for the 'population update ion' are printed.) The preferred way to change these data is for me to change the program.
The statements have the following forms:
POPION k j (V),
where k is the 'population update ion' number (as in Note 8); V is a simple array specifying all or some of the elements of data table j; and j designates one of the population-ion-model data tables, as follows: $j = 1$ for XLMTHR, threshhold wavelength (floating point), $j = 2$ for CCPLEV, coefficient CCP (floating point), $j = 3$ for NPTABL, LM-table length (integer), $j = 4$ for SCPLEV, exponent SCP (floating point), $j = 5$ for PILEVL, statistical weight (floating point), $j = 6$ for LLABEL, term designation (alphanumeric, ≤ 16 characters, embedded blanks not permitted).
POPXLM k ℓ (V),
where k and V are as for **POPION** above, and ℓ designates a level of the population-ion-model. This statement provides values for one of the LM tables.
POPRCP k ℓ (V),
which is like **POPXLM**, but provides values for one of the RCP tables.

***29**

The size limits on **NAB**, **NCL**, **NMT**, **NSL**, **NVX** and the total number of Composite Lines Opacity wavelengths (see Section 3, Notes) are for programming convenience; to enlarge them requires changing the source code.

***30**

When detailed PRD results are printed, the amount of output can be controlled as follows: data for frequency value $XI = 0$ are printed, and for every **IPRDF**th one from there; data for the first Z value are printed, and for every **IPRDD**th one thereafter.

***31**

$\mathbf{A}^{u,\ell}$ can be greater than or equal to zero. If zero, then there is no line transition between levels u and ℓ; if greater than zero, then there is. The input parameter $\mathbf{KTRANS}^{u,\ell}$ (see Note 33) further specifies the type of transition. Line Source Functions are computed iteratively for radiative transitions, and only once (from the final iterated results) for passive transitions.

***32**

The default values of $\mathbf{ND}_i^j$, $1 \leq i \leq \mathrm{N}$, $1 \leq j \leq \mathrm{NL}$, are zero, unless this is a run with the POPUP switch on, in which case the input population data, or the LTE population data computed before the first overall iteration, will be used as the defaults for $\mathbf{ND}_i^j$.

***33**

$\mathbf{KTRANS}^{u,\ell}$ is used only when $\mathbf{A}^{u,\ell} > 0$, and describes that transition. It may take on the values: "`RADIATIVE`", "`PASSIVE`", "`THICK`, "`THIN`", or "`2-PHOTON`".

***34**

The ordinates controlled by the options OPAGRAF and EMIGRAF increase logarithmically (base 10) upwards from **BLIMG** to **TLIMG**.

***35**

$\mathbf{METSE}^{u,\ell}$ selects the method of computing the statistical equilibrium equations (*i.e.* the values of $\mathrm{PE}^{u,\ell}$ and $\mathrm{FE}^{u,\ell}$) for transition (u, ℓ).
$\mathbf{METSE}^{u,\ell} = 0$ means: NOVA;
$\mathbf{METSE}^{u,\ell} = 1$ means: COMPLEX/upper;
$\mathbf{METSE}^{u,\ell} = 2$ means: COMPLEX/lower;
$\mathbf{METSE}^{u,\ell} = 3$ means: CHAIN;
$\mathbf{METSE}^{u,\ell} = 4$ means: VAMOS.
(Except for VAMOS, the values of **METSE** are analogous to those of **METEP**; see Note 21.) Suggestions for choosing **METSE** are given in the printout section "LINE (U/L)." The default value of $\mathbf{METSE}^{u,\ell} =$ **METSEDW** if $\ell = 1$, and =

METSEDG otherwise.

***36**

LSFFDB$^{u,\ell}$ = 0 means: use 'constant background' for the Line Source Function calculation (*i.e.* use line-core background opacity and source function for all line integration frequencies). **LSFFDB**$^{u,\ell}$ = 1 means: use 'varying background' for the Line Source Function calculation (*i.e.* compute background opacity and source function explicitly at all line integration frequencies, as in a PRD solution). FDB solutions can only be calculated for radiative transitions (*i.e.* **KTRANS**$^{u,\ell}$ = "`RADIATIVE`") using the 'full' solution (*i.e.* **LSFTYP**$^{u,\ell} = 0$). *Note:* **LSFFDB** is set = 1 automatically when PRD is used (see Note 47).

***37**

MODLAB (up to 8 characters long) is an 'atmospheric model name' used for the MODEL DATA section of the normal output, and for the 'performance data archive record' (in file 28; set Section 7).

***38**

The PANDORA output includes many printed graphs as functions of depth. The abscissae of the graphs are established under control of input parameters **IZOPT**, **NGRL** and **NGRR**, as follows:
IZOPT = 1 means: the abscissa is depth index i, $LG \le i \le MG$;
IZOPT = 2 means: the abscissa is Z_i, $LG \le i \le MG$;
IZOPT = 3 means: the abscissa is $\log(|Z_i|)$, $LG \le i \le MG$, but excluding $Z = 0$, (moreover, if Z_i changes sign in the range of interest, proceed as if **IZOPT** = 1);
IZOPT = 4 means: the abscissa is $\log(TAU_i)$, $LG \le i \le MG$.
Here LG and MG are determined as follows: if **NGRL** ≤ 0, then $LG = 1$; if **NGRL** > 0, then $LG =$ **NGRL**, but the limit $LG \le (N-1)$ is enforced; if **NGRR** ≤ 0, then $MG = N$; if **NGRR** > 0, then $MG =$ **NGRR**, but the limit $MG \le N$ is enforced.
For some graphs, LG and MG are also controlled by the value of the input parameter **JZOPT**, as follows:
JZOPT = 1 means: use the above procedure controlled by **IZOPT**;
JZOPT = 0 means: LG is set to the greatest value of i such that $TAU_i \le 10^{-4}$ ($LG > 1$ if **IZOPT** = 4), and MG is set to the smallest value of i such that

$TAU_i \geq 10^3$.

***39**

The selector **IRLS1** is used to select RLA (**IRLS1** = 1) or RLB (**IRLS1** = 2) for $RL^j, j =$ **KOLEV**; **IRLSN** is used similarly for RL^j, $j \neq$ **KOLEV**.

***40**

When the option JSTIN is on (i.e. if **JSTIN** $>$ 0), then PANDORA will just read all the input, print it, and stop; this is called an 'input-only' run. See also Note 84.

***41**

KHFFS controls whether H free-free is part of the subtotal labelled 'Total Hydrogen' in the cooling rate calculation of a Hydrogen run. **KHFFS** = 1 means that it is, **KHFFS** = 0 means that it is not, part of that subtotal.

KOOLSUM controls which components are added to 'Total Hydrogen' to compute the grand total labelled 'Total Cooling Rate' in a Hydrogen run.
KOOLSUM should be set equal to $K1 + 2 \times K2 + 4 \times K3 + 8 \times K4 + 16 \times K5$, where
$K1 = 1$ means: add H-minus, $K1 = 0$ means: do not add H-minus;
$K2 = 1$ means: add conduction, $K2 = 0$ means: do not add conduction;
$K3 = 1$ means: add composite lines, $K3 = 0$ means: do not add composite lines;
$K4 = 1$ means: add X-ray, $K4 = 0$ means: do not add X-ray;
$K5 = 1$ means: add CO-lines, $K5 = 0$ means: do not add CO-lines.

***42**

See Section 15, Partial Redistribution.

***43**

BDOPT specifies the BD option, and may take on one of the following values: "`BDJ`", "`BDR`", or "`BDQ`" (see explanation in RHO AND RBD section of normal printout).

***44**

PANDORA can read input from several files. The parameter **USE** specifies which one of these files to use; it can take on any one of the following values: "`ATOM`", "`INPUT`", "`MODEL`", "`RESTART`" or "`GENERAL`".
After a **USE** statement has been read, the next input statement(s) will be read from the file designated by the last **USE** statement. Specifications to read from any file may be arbitrarily intermixed among the input statements. The first occurrence of **USE** *must* be in `INPUT` (*i.e.* file 03, see Section 7).
When "`USE ( GENERAL )` " occurs, reading will continue from the file defined by the last preceding **FILE** statement. Thus, at least one **FILE** statement *must precede* the first occurrence of "`USE ( GENERAL )` ".
The **FILE** statement specifies two parameters, k and f, in that order; for example, "`FILE ( 0 FILESPEC )` ". f is alphanumeric ($\leq$ 60 characters, embedded blanks not permitted); it is the "complete" file specification of a file to be read, *i.e.,* whatever the operating system requires under the current circumstances to identify the file uniquely, in other words, f is used as the file-name specification with the FILE keyword in a Fortran '`open`' statement. k (integer) is a switch: when $k = 1$, a message containing the value of f will be printed on in the 'message printout file' (*i.e.,* file 16, see Section 7) whenever "`USE ( GENERAL )` "occurs; when $k = 0$, no message will be printed.

***45**

IRKCOMP is an array of switches specifying for which levels RK should be computed in the Rates calculation of the first iteration. $\mathbf{IRKCOMP}^j = 1$ means: compute RK^j; $\mathbf{IRKCOMP}^j = 0$ means: do not compute RK^j (in this case, presumably, RK^j was supplied in the input of the run). **IRLCOMP**, analogously, concerns RL.

***46**

If a set of JNU values for partial redistribution (PRD) calculations has been provided in a file on unit 09, then PANDORA can be made to read them by setting $\mathbf{JNUNC} = 1$. These JNU values pertain to particular values of Z and XI; if necessary, these data will be interpolated to the values of $Z_i,\ 1 \leq i \leq N$, and of $XI_k,\ 1 \leq k \leq K$, currently in use.

***47**

For general background, see Section 15.
SCH$^{u,\ell} = 0$ means: do not include partial redistribution (PRD) calculations for line (u, ℓ);
SCH$^{u,\ell} = 1$ means: do include PRD calculations for line (u, ℓ).
Note: Only **SCH**$^{u,\ell} = 0$ is allowed when **DIRECT**$^{u,\ell} = 1$.
Note: PRD solutions are only calculated for radiative transitions, *i.e.* those with **KTRANS**$^{u,\ell}$ = "`RADIATIVE`".
Note: When PRD is requested for line (u, ℓ), then **LSFFDB**$^{u,\ell}$ is set = 1 automatically.
Note: In a stationary plane-parallel atmosphere, a single ray (*i.e.* the normal) is traced; in a spherical and/or expanding atmosphere, many rays are traced. The number of frequency values used must be less than 1000. Moreover, the product of the number of frequency values used (see also Note 66) times the number of depth points probably should not be larger than 10000, except for good reason.

***48**

LSFTYP$^{u,\ell}$ is the Line Source Function solution method selection selector, used as follows:
LSFTYP$^{u,\ell} = 0$ means: do a 'full Line Source Function solution', computing the line source function using frequency/angle sums and a final grand matrix, and then RHO and $JBAR$ from that S;
LSFTYP$^{u,\ell} = 1$ means: compute the line source function 'directly' from the number densities of levels u and ℓ, do frequency/angle sums, then compute RHO from those sums and S, and then $JBAR$;
LSFTYP$^{u,\ell} = 2$ means: compute the line source function from the number densities of levels u and ℓ, compute RHO with the 'escape probability approximation', and then $JBAR$ from them. (See also Note 51.)
'Direct' solutions are only calculated for radiative transitions, *i.e.* **KTRANS**$^{u,\ell}$ = "`RADIATIVE`".
Note: If transition (u, ℓ) is a passive transition, or if the Line Flux Distribution calculation has been requested for it, then the value of **LSFTYP**$^{u,\ell}$ will automatically be forced = 1!
Note: If $TAU_2^{u,\ell} >$ **ESCTAU**, then the 'static' escape probability approximation is used for transition (u, ℓ), regardless of the value of **LSFTYP**$^{u,\ell}$.

***49**

The statement **SMOOTH** $u\ \ell$ **(** q **)** (*e.g.* "`SMOOTH 3 1 ( ILS 17 WSM 0.5 )` ") is used for the parameters governing smoothing of the RHO values of transition (u, ℓ). q consists of pairs of input fields of the form "$A\ v$ ", where A is an alphanumeric identification field whose value may be "`WSM`", "`IFS`" or "`ILS`", and v is a numerical field, which must be floating point if it follows `WSM`, and integer otherwise. WSM is the smoothing weight (= 0.0 means: no smoothing; 0.0 is the default). IFS and ILS are limiting indices such that smoothing is done only for $\text{RHO}_i^{u,\ell}$, $1 \le IFS \le i \le ILS \le N$; (defaults are: IFS = 1 and ILS = N).

***50**

The Voigt profile may be computed by one of three subroutines, as specified by the input parameter **IVOIT**.
IVOIT = 1 selects George Rybicki's method; this is the most precise routine but also the slowest, as it takes about 12 times longer than the high-speed routine.
IVOIT = 2 selects S. R. Drayson's method, which takes about 2 times longer than the high-speed routine; its relative difference from Rybicki's routine is generally below the seventh significant figure, but sometimes in the fourth significant figure.
IVOIT = 3 selects Eric Peytremann's method, which is the high-speed routine; it has a relative difference from Rybicki's routine that is generally less than 0.001, but sometimes as large as 0.05.
If the value $V = Voigt(x, a)$ must be computed immediately after the value $V' = Voigt(x', a')$ has been computed, then, if both $x = x'$ and $a = a'$ to relative accuracy **VOITC**, $V = V'$ will be used (to save time).
Note: If **IHSSW** = 1 and any value of $\textbf{CSTARK}^{u,\ell} = 1$ (indicating that a convolved Stark profile should be computed) in a Hydrogen run, then PANDORA will set **IVOIT** = 3 and **NVOIT** = 1.

***51**

The **SOBOLEV** statement specifies a particular transition (u, ℓ), and provides an array of two indices: the first of these is $\text{ISB1}^{u,\ell}$, and the second of these is $\text{ISB2}^{u,\ell}$.

The 'escape probability' solution for transition (u, ℓ) (*i.e.* $\mathbf{LSFTYP}^{u,\ell} = 2$) comes in two flavors: 'static' and 'Sobolev'. The static solution is used by default. If $\text{ISB1}^{u,\ell} > 1$, the Sobolev solution will be used for depths i, $1 \leq i \leq \text{ISB1}^{u,\ell}$; the static solution will be used for the depths i, $\text{ISB2}^{u,\ell} \leq i \leq N$; and a linear transition from one to the other for depths i, $\text{ISB1}^{u,\ell} < i < \text{ISB2}^{u,\ell}$.

A table of velocity values, **VSB**, is needed for the Sobolev calculation (see Section 16, Velocities).

The integral needed for the Sobolev solution is computed by trapezoidal rule using an interval refinement procedure which seeks to achieve a piecewise-linear approximation to the run of the integrand, with a specified tolerance. Three parameters control this interval refinement process: **SOBDMN** is the smallest interval size needed (*i.e.* intervals need not be reduced further than **SOBDMN**); **SOBDMX** is the maximum acceptable interval size (*i.e.* intervals must be reduced to a size smaller than **SOBDMX**); **SOBFEQ** is the tolerance to which interpolated and actual values of the integrand must agree (*i.e.* these two quantities are computed at the midpoint of the current interval, and if they do not agree to this tolerance, then the interval must be reduced further).

***52**

IPPOD controls absorption/emission calculation debug dumps at all wavelengths for all 'population update ions'; **IPPOD** = 0 for nothing, **IPPOD** = 1 for absorption, **IPPOD** = 2 for emission, **IPPOD** = 3 for both. Printout occurs for every Z_i such that `mod`[i,**LDINT**] = 0.

***53**

'Level designations' are alphanumeric labels consisting of up to 8 (non-blank) characters, which will be printed with the levels data as part of the ATOM printout.

The **LEVDES** statement DOES NOT conform to the standard PANDORA input conventions. It has the form:

"`LEVDES ( label1 label2 . . . . )` ".
Exactly **NSL** labels *must* be provided.

***54**

Detailed printout of transition terms (*i.e.* 'A*RHO' and 'Term added to upward C') is controlled by **LDINT** and **LDTYP**. (Of course, option ARHODMP must be on.)
LDTYP specifies the context from which printout is wanted:
LDTYP = 1 means: statistical equilibrium calculation;
LDTYP = 2 means: b-ratio calculation;
LDTYP = 3 means: both.
LDINT specifies the depth points for which printout is wanted:
LDINT $>$ 0 means: print every **LDINTH**'th depth point, beginning with the first point;
LDINT $<$ 0 means: print for depth # |**LDINT**| only;
LDINT = 0 means: no printout.
In the same way, **LDINT** specifies the interval between depth points for the printouts controlled by the options EPDMP and SEBUG, and by **IPPOD** (see Note 52).

***55**

A simple simulation of a shock wave can be obtained by specifying the shock's velocity and temperature perturbation. The shock velocity is further treated in Section 16. The temperature perturbation is computed from input parameters and then added to the input values of **TE** to obtain the TE_i actually used in the run:

$$TE_i^{used} = \mathbf{TE}_i^{input} + DTE_i\,,$$

where $DTE_i = 0$ for $i <$ **JSSV** but

$$DTE_i = \mathbf{SCTA}\exp[(\mathbf{Z_{JSSV}} - \mathbf{Z}_i)/\mathbf{SCTA}]\,.$$

Here **JSSV** is the depth index of the shock's location, **SCTA** is the amplitude of the temperature perturbation, and **SCTS** is the temperature scale height.

***56**

$\mathbf{CP}^{NSL+1} > 0.0$ is the signal that the K-shell photoionization effect is to be computed. If $\mathbf{MR}^{NSL+1}$ is then set $\neq 0$ but, say, equal to IKS, then values of

Notes

RRCP$_m^{NSL+1}$, $1 \leq m \leq IKS$ must be provided (as for the other levels), as well as $IKS+1$ values of **WRAT** (see also Note 22). Note that **WRAT** input for the K-shell differs from that of the other levels in that the wavelength of the head of that continuum must be specified explicitly.

***57**

VX values must be specified as functions of **Z** (the main depth-table of the run). Extra(inter)polation involving **ZAUX** tables has not been provided for **VX**.

***58**

If the value of $\mathbf{ECLI}^{u,\ell}$ is $>$ 0, then Eclipse emergent line intensity and flux profiles will be computed for transition (u, ℓ), but only if this is a transition for which a full-profile integration is done.

***59**

Detailed dump printouts from the Line Source Function calculations performed in subroutine `PERSEUS` can be obtained using the options PERDMP0, PERDMP1, PERDMP2 and PERDMP3.
The 'frequency sums' (subroutine `DIANA`) or the 'frequency/angle sums' (subroutine `ORION`) accumulate the contributions from the 'frequency data blocks' or the 'frequency/angle data blocks'. The contents of these data blocks will be printed when the option PERDMP0 is on.
WN matrices of each data block, and the results of computing the above sums, will be printed when the option PERDMP1 is on.
All terms and intermediates for these sums at selected depths will be printed when the option PERDMP2 is on.
PRD data arrays will be printed when the option PERDMP3 is on.
The data blocks are identified by the value of the index IND, whose values range from 1 to K, or from 1 to $NR \times K$, where NR is the total number of rays, and K is the number of entries in the XI table, as explained in Note 66, below. Only data for $\mathbf{IPR01} \leq IND \leq \mathbf{IPR02}$ will be dumped by PERDMP0, PERDMP1, PERDMP2 and/or PERDMP3. Moreover, only the details for the depths $\mathbf{IPR03} \leq i \leq \mathbf{IPR04}$ will be dumped by PERDMP2.
These dump printouts will be provided only for transition (**MS**,**NS**).

***60**

PANDORA can be instructed to compute an expanding atmosphere by turning the option EXPAND on. When EXPAND is on, then the velocity table **VXS** is

used; see Section 16, Velocities.

***61**

PART is the partition function of the next higher stage of ionization of the ion of the run, and is a constant.
If **PART** $>$ 0.0, then all values of the depth-dependent partition function table will be set equal to it.
If **PART** $\leq$ 0.0, then values of the depth-dependent partition function of the ion of the run can be obtained as follows:
If the option PARTVAR is off, then, if the appropriate value of U2 can be located in the element data tables (see Section 10), that will be used; if not, the run will stopped.
If the option PARTVAR is on, then PANDORA attempts to compute the values of the depth-dependent partition function with the subroutines incorporating the 'Hamburg' data. If this is unsuccessful, then the run will be stopped.
Note: Therefore, to obtain truly depth-varying entries in the partition function table, the option PARTVAR must be on, and the value of **PART** must not be greater than 0.0.

***62**

The set of shell rays, and the associated weight matrices, for a spherical atmosphere, are regulated by **NTAN** and **MSKIP**. The value of **NTAN** must be $>$ 0, that of **MSKIP** must be 0, 1, or 3.
Rays will be sent tangent to every **NTAN**th shell (= depth), beginning with the innermost one (*i.e.* Z_N), and going out as far as possible. (The option TANG also plays a role here.)
The value of **MSKIP** matters only when **NTAN** = 1. In that case,
when **MSKIP** = 0, then the weight matrices for every shell ray will be computed directly;
when **MSKIP** = 1, then only weight matrices for every 2^{nd} shell ray will be computed directly, while the others will be obtained by interpolation;
when **MSKIP** = 3, then only weight matrices for every 4^{th} shell ray will be computed directly, while the others will be obtained by interpolation.

***63**

IRTIS controls extra(inter)polation of the input table of incident radiation.

Notes

IRTIS = 1 means: linear in XINK, linear in FINK;
IRTIS = 2 means: linear in XINK, linear in log(FINK);
IRTIS = 3 means: linear in log(XINK), linear in log(FINK).

***64**

NHTSW controls the calculation of the correction to the abundance of atomic Hydrogen due to the possible presence of H_2 molecules.
NHTSW = 0 means: do not compute the H2 abundance correction;
NHTSW = 1 means: compute the H2 abundance according to Kurucz (1970);
NHTSW = 2 means: compute the H2 abundance according to Tsuji;
NHTSW = 3 means: compute the H2 abundance according to Kurucz (1985).

***65**

Detailed dump printouts from the Continuum Calculations (intended to help with handchecks) can be obtained by means of various options and input switches. Such printouts will only be provided for wavelengths listed in the input table **DWAVE**, of length **NDV**, *except* when $\mathbf{DWAVE}_1 = 0.0$, in which case such printouts will be provided for all wavelengths. When values of **DWAVE** are provided they must match to 8 figures or more the values of the Continuum Calculation wavelengths for which dumps are wanted.

***66**

See Section 18, Frequency Tables, for more information about this input parameter. **See also** the *Note* at the end of Note 47.

***67**

The "Lyman" source function can be calculated in three ways:
1) using the coupled "Lyman" continuum equations, Case A;
2) using the large-depth, saturation, or generalized on-the-spot approximation, Case B (see: Avrett and Loeser 1988, Ap.J., **331**, 221, Appendix B); or
3) using Case A for depths 1 through η (if any), and Case B for depths $\eta + 1$ to N (if any); this is Case C, the 'normal' procedure.
(*Note* that η = N means: Case A throughout; $\eta = 0$ means: Case B throughout.)
PANDORA computes the value of η as follows: it finds smallest index k for which both $TAUK_k >$ **TGLYM** and $(EP1_k)^2 \times TAUK_k \geq$ **EXLYM**. (If it finds no such index, then k = N.) It then sets $\eta = k$ unless: (a) if **LN** ≤ 1, it sets $\eta = 0$; (b) if $k \leq$ **LN**, it sets $\eta = 0$; or (c) if $\mathrm{TAUK}_2 \geq 10$, it sets $\eta = 0$.

Notes

TGLYM, **EXLYM** and **LN** are input parameters.

Special cases:

1) When the option SPHERE is on, η is set = N;

2) when the option SPHERE is off but the option FINITE is on, η is set = N.

***68**

LSFGC controls the format of all the Line Source Function graphs.
When **LSFGC**= 1, then the x-axis is **Z**-index;
when **LSFGC**= 2, then the x-axis is $\mathbf{Z}_i$;
when **LSFGC**= 3, then two graphs will be provided, one of each format.

***69**

Use of broadening velocity (= microturbulent velocity) depends on the option VSWITCH. When the option VSWITCH is off, then the broadening velocity is isotropic and is specified by the input table **V**. When the option VSWITCH is on, then the broadening is anisotropic: the input values of **V** are the tangential component, and the input values of **VR** are the radial component. See Section 16, Velocities.

***70**

The input value of **IFXDS** should $= 8 \times ICF + 4 \times ICM + 2 \times IFD + IFX$.
To print flux tables, use $IFX = 1$, to omit them, use $IFX = 0$.
To print flux derivative tables use $IFD = 1$, to omit them, use $IFD = 0$.
To print cumulative derivative tables, use $ICM = 1$, to omit them, use $ICM = 0$.
To print quadratic coefficients, use $ICF = 1$, to omit them, use $ICF = 0$.
The default is **IFXDS** $= 0$ (*i.e.* no details at all are printed.)

***71**

Many quotient calculations are done in subroutine `DIVIDE`, which checks for denominator = 0.0. **VSMLL** is used in place of such vanished divisors.
`DIVIDE` will print various error messages, depending on the value of the control switch **IPZER**. When **IPZER** = 0, no messages are printed; when **IPZER** = 1, a message will be printed every time '$A/0$' occurs; when **IPZER** = 2, a message will be printed every time '0/0' occurs; **IPZER** = 3 enables both messages.

***72**

When $\mathbf{LFLUX}^{u,\ell} = 1$, then the Line Flux Distribution and the Radiative Force

for transition (u, ℓ) will be computed. The option LFDPRNT affects the amount of printout. Dump output (for transition [**MS**,**NS**]) is controlled by **IHDMP**.

***73**

The 'HI/BYE' system, and the control parameters for it, are intended as debugging aids for me as program developer. 'HI/BYE' is not intended for use in regular production runs.

***74**

When the option IRUNT is on (*i.e.* when **IRUNT** = 1), then more extensive execution performance data and program version description data will be printed than when the option IRUNT is off (*i.e.* when **IRUNT** = 0 (the default)). It should not be necessary to use **IRUNT** = 1 in regular production runs.

***75**

The 'banner' pages at the start of the printout file (see Section 3) display 'giant' characters that are themselves composed (in 'dot-matrix' fashion) of individual print characters. The value of **NARB** tells how many such pages to print, the value of **KARB** selects the print character(s) used for this purpose.
KARB = 1 means: use "$" to represent the giant character.
KARB = -1 means: use "O" over "X" over "+" (this of course works only with processing systems which fully implement traditional 'Fortran carriage control').
NARB may assume the values 0, 1, or 2.

***76**

In many runs, the sets of 'Composite Lines Opacity' wavelengths and 'CO-lines Opacity' wavelengths are added automatically to the list of wavelengths for which continuum calculations are done. If any value of $\mathbf{DELWAVE}_i, 1 \leq i \leq \mathbf{NWS}$, equals (to one part in 10^{10}) a wavelength in one of these two sets, then that wavelength value will be deleted from the list of wavelengths for which continuum calculations are done. (These counterparts to the 'additional' wavelengths are therefore called 'subtractional' wavelengths.)

***77**

See also the note regarding maximum counter values, and order of occurrence

among the input, at the end of Section 3. See also Note 29.

***78**

DOPROF is an alternate form of the **PROF** statement; it contains pairs of transition indices, like the **INPAIR** statement (see Note 2). The occurrence of the index pair u, ℓ in **DOPROF** causes the program to set $\mathbf{PROF}^{u,\ell} = 1$.

***79**

DOFLUX is an alternate form of the **LFLUX** statement; it contains pairs of transition indices, like the **INPAIR** statement (see Note 2). The occurrence of the index pair u, ℓ in **DOFLUX** causes the program to set $\mathbf{LFLUX}^{u,\ell} = 1$.

***80**

DOFDB is an alternate form of the **LSFFDB** statement; it contains pairs of transition indices, like the **INPAIR** statement (see Note 2). The occurrence of the index pair u, ℓ in **DOFDB** causes the program to set $\mathbf{LSFFDB}^{u,\ell} = 1$.

***81**

DOSFPRNT is an alternate form of the **LSFPRINT** statement; it contains pairs of transition indices, like the **INPAIR** statement (see Note 2). The occurrence of the index pair u, ℓ in **DOSFPRNT** causes the program to set $\mathbf{LSFPRINT}^{u,\ell} = 1$.
Note: $\mathbf{LSFPRINT}^{u,\ell}$ and option LSFPRNT are different beasties, but they work together.

***82**

See Section 16, Velocities, for more information about this input parameter.

***83**

When **MTHEI** = 0, then exponential integrals are computed using Cooley's routine, which gives about 8 figures for the first exponential integral; higher orders are computed with the recursion relation which rapidly loses precision for increasing orders. See Avrett & Loeser, SAO Special Report No. **303**, 1969.

When **MTHEI** = 1, then exponential integrals are computed using a routine published by Press and Teukolsky. This routine has been set up to deliver about 14 figures for all orders; it is slower than Cooley's routine. See Press & Teukolsky, Computers in Physics, Sep/Oct 1988.

***84**

The switches **ISCRS**, **NOION**, **NVOIT**, **IXSTA**, **JBDNC**, **JSTIN**, **IRPUN**, **IRUNT** and **TOPE** are alternate forms of the options ISCRS, DOION, NVOIT, IXSTA, JBDNC, JSTIN, RABDAT, IRUNT and TOPE, respectively. The program will set their *default* values to agree with the status of the corresponding options.

***85**

Subroutine `EDITH` is used in various context to edit values ≤ 0 out of various computed tables; it is set up to print error messages to report what it did. For each editing context k, a separate count of error messages, $KERM_k$, is kept. The value of the input parameter **NERM** controls the printing of error messages:
when **NERM** $= 0$, then no error messages are printed;
when **NERM** > 0, then error messages from context k are printed as long as $KERM_k \leq$ **NERM**;
when **NERM** < 0, then all error messages are printed, but greatly abbreviated.

***86**

If **ZNDW**$\neq 0$, then **NDW** will be set equal to i, where $\min(|Z_i - ZNDW|)$, $1 \leq i \leq N$. If **ZNDW** $= 0$, then, if **NDW** < 1 or **NDW** $> N$, **NDW** will be set equal to $N/2$.

***87**

As the final step in constructing WN-matrices (which are used in source function calculations), the computed matrix is scanned and every element whose absolute value is less than **WNJUNK** is set $= 0$.

***88**

LODCG and **NODCG** are parameters controlling the depth range for diffusion graphs (no graphs appear when **NODCG** $= 0$). Various parameters are plotted as functions of **Z**, for the range $\mathbf{Z}_I$ to $\mathbf{Z}_J$.
When **LODCG**< 0, then $I = 1$; when **LODCG**> 0, then $I =$ **LODCG**.

Notes

When **NODCG**< 0, then $J = K$; when **NODCG**> 0, then $J =$ **NODCG** or K, whichever is less. K is the smallest depth index such that $\mathbf{TE}_K < 9000$.

***89**

d-coefficients are computed for the diffusion calculations.
When **IDFDM** = 0, the "original" method is used;
when **IDFDM** = 1, an "improved," more complete method is used.
When options AMDDMP and/or GNVDMP are on, then the d-coefficients will be printed for depth i; when **IDFDI** > 0, then $i =$ **IDFDI**, but when no value of **IDFDI** is input, then $i = \mathbf{N}/4$.

***90**

If the input values of $\mathbf{V}_i = 0, 1 \leq i \leq \mathbf{N}$, then, if **NVH** > 0, "default" values of $\mathbf{V}_i$ will be computed from $\mathbf{VNH}_j, 1 \leq j \leq \mathbf{NVH}$. Here **VNH** is a velocity table appropriate for the quiet Sun, and is specified as a function of Hydrogen density, **HNDV**. Values of $\mathbf{V}_i$ corresponding to the input values of $\mathbf{NH}_i$ are obtained by interpolation from the tables $\mathbf{HNDV}_j$ and $\mathbf{VNH}_j$; the logarithms of $\mathbf{NH}_i$ and $\mathbf{HNDV}_j$ are used for this purpose.

IMPORTANT: if $\mathbf{V}_i = 0$ is intended, then **NVH** must be set = 0 explicitly in the input, since the default value of **NVH** > 0.

***91**

CIJADD uses special cases of Statement Forms 5* and 5, in that $u > \ell$ is not required – rather, all combinations $u \neq \ell$ are accepted.

***92**

ASMCR and **NIASM** are parameters used in sequential smoothing; see write-ups [89 Dec 22] and [92 Jan 29]. The smoothing used here is based on the following principle. Consider the sequence of graphical points representing the values of a function. If the function varies smoothly, a given point usually lies within the triangle defined by the two lines through the pair of points on either side and the line through the point on either side, provided the two lines intersect within the given interval. If the given point falls outside, it is moved to the boundary of this triangle; if the given point lies within this triangle, it is left unchanged.
Smoothing consists of a repeated search for the most deviant point, and then

changing it if necessary. Then this edited sequence is searched for the most deviant point; and so on. The search is repeated at most **NIASM** $\times$ n times, where n is the number of points in the sequence. However, the process stops after the first time that the relative change applied to the most deviant point is less than **ASMCR**.

***93**

See Section 19, Atomic Models, for more information about this input parameter.

***94**

NLPAIR is a list of integers $(n_j, \ell_j),\ 1 \leq j \leq \mathbf{NL}$, such that n_j is the principal quantum number of level j and ℓ_j is the rotational quantum number of level j of the model of the ion-of-the-run. For example, $(n_{22}, \ell_{22}) = (5, 3)$ means the for level 22 the principal quantum number $n = 5$ and the rotational quantum number $\ell = 3$.
The value $\ell_j = -1$ is meaningful; this means that level j is a synthetic level obtained by combining all of the sublevels characterized by the same value of n but different values of ℓ.
When $\ell_j = -1$, then n_j must be > 0. For Hydrogen, default values of (n_j, ℓ_j) are provided: $n_j = j$ and $\ell_j = -1$.
In the **NLPAIR** statement, the (n, ℓ) pairs should be specified in level sequence, beginning with level 1.

***95**

The "upper-level charge-exchange" calculation is enabled when option CHEXUP is on and this is a run with Hydrogen, or with a "charge-exchange" ion. The list of eligible "charge-exchange" ions is built into PANDORA; it consists of: He-I, C-I, N-I, O-I, Na-I, Mg-I, Al-I, Si-I, S-I, and
Ca-I, in that order. A particular "charge-exchange" ion is internally known to PANDORA by the value of $MCX,\ 1 \leq MCX \leq 10$, *i.e.* by the index of that ion in the above list.
In a run other than Hydrogen in which "upper-level charge-exchange" is enabled, only a subset of levels, namely "levels affected by charge-exchange" a.k.a. "CX-levels," is affected. Any level j of the model of the ion-of-the-run whose rotational quantum number $\ell_j \neq 0, 1, 2$ is a CX-level, but only if that level's principal quantum number $n_j > \ell_j$. Such runs produce the output tables **XRKH** and **XRLH** for use in Hydrogen upper-level charge-exchange runs.
In a Hydrogen run with "upper-level charge-exchange," all levels $j,\ j \geq 4$, are CX-levels. Such runs make use of various input sets of **XRKH** and **XRLH** produced by upper-level charge-exchange calculations with other elements.

***96**

The arrays $\mathbf{XRKH}_i^{k,n}$ and $\mathbf{XRLH}_i^{k,n}$ are input for the upper-level charge exchange calculation (option CHEXUP on) in Hydrogen runs.
The superscript $k,\ 1 \leq k \leq 10$, designates a particular charge-exchange element (see also Note 95); the superscript $n,\ 1 \leq n \leq \mathbf{NL}$, designates the affected level of the Hydrogen ion model. (In the case of Hydrogen, the level number is numerically equal to the principal quantum number of that level.) The indices k and n appear in that order in an **XRKH** or **XRLH** input statements; for example:
"`XRKH 4 6 ( . . . . . )` "
which are data from a Mg-I run for level 4 of the Hydrogen ion model; or:
"`XRLH 14 2 ( . . . . . )` "
which are data from a C-I run for level 14 of the Hydrogen ion model.
Note: values of n must not be greater than **NL**.

***97**

$\mathbf{RCHX}^{n,\ell}$ is a parameter used for the upper-level charge-exchange calculation (option CHEXUP on). The value of $\mathbf{RCHX}^{n,\ell}$ is used for all those levels of the model of the ion-of-the-run for which the principal quantum number is n and the rotational quantum number is ℓ. The indices n and ℓ appear in that order in the **RCHX** input statement; for example:
"`RCHX 4 3 ( 1.23 )` "
which sets $\mathbf{RCHX}^{4,3} = 1.23$.

***98**

The emergent line profile graphs for transition (u, ℓ) (option INTGRAF) can be controlled with $\mathbf{PROGLI}^{u,\ell}$, which controls the limits of the wavelength axis, and with $\mathbf{SGRAF}^{u,\ell}$, which applies to 'blended' lines.
When $\mathbf{PROGLI}^{u,\ell} = 0$ (the default), then the x-axis spans the entire $\Delta\lambda$ range.
When $\mathbf{PROGLI}^{u,\ell} > 0$, then the x-axis extends from the core out to **PROGLI**.
When $\mathbf{PROGLI}^{u,\ell} < 0$, then the x-axis extends from the core out to that point where successive intensity values differ relatively by less than |**PROGLI**|.
(If there are several such points, the point with the largest $\Delta\lambda$ value is used.)
If transition (u, ℓ) is a blended line then,
when $\mathbf{SGRAF}^{u,\ell} = 1$, separate graphs are provided for each component;

when $\mathbf{SGRAF}^{u,\ell} = 0$, only a single, composite graph is provided.

***99**

ISMSW provides additional control over the format of Iterative Summaries.
When **ISMSW** $= 0$, then the format is controlled by option SUMGRAF.
When **ISMSW** > 0, then the summaries will be provided in both formats.

***100**

Regardless of the setting of option RATEPRNT, a 'minimal' RATES calculation printout is provided when the input value of **IRATE** is a valid depth index. In that case, values of QU, QS, GM, RK, RL and CK for all levels, and of CIJ and PIJ for all transitions, will be printed, for that depth only.

***101**

ICDIT specifies the classes of continuum wavelengths for which dI/dh analyses will be printed when option DIDHC is on.
ICDIT= 1 means: for all 'additional' wavelengths;
ICDIT= 2 means: for the line center wavelengths of those transitions for which a Line Source Function calculation printout was provided;
ICDIT= 3 means: 1 and 2.

***102**

The photorecombination rates **RL** and photoionization rates **RK** can be computed either by detailed integration of the continuum radiation field, or from specified runs of radiation temperatures (input tables of $\mathbf{TRN}_i$). These alternatives are controlled by option USETRIN.
When USETRIN is on, then the computed values of $\mathbf{RK}_i^\ell, 1 \leq i \leq \mathbf{N}, 1 \leq \ell \leq \mathbf{NSL}$, can be manipulated by means of the factor HJ_i, the photoionization rates multiplier. Values of $HJ_i = 1$ by default; however, if appropriate input values of **JH1** and **JH2** are provided, then various specific runs of HJ_i are constructed such that $HJ = 0.5$ near the surface and $HL = 1.0$ at depth, with an intermediate transition region defined by depth indices **JH1** and **JH2**. This is also explained in a note following the ATMOSPHERE printout.
When full continuum integrations are done (option USETRIN off), PANDORA also computes "effective radiation temperatures"—*i.e.,* those values of radiation

temperature which yield the same values of $\mathbf{RK}_i^\ell$ as the full integrations did. These computed $\mathbf{TRN}_i^\ell$ values are included in output file `FOR020` (see Section 8), and can be used as input for a subsequent restart run with option USETRIN on.

***103**

PANDORA can be requested to adjust the values of **Z** so that certain constraints are satisfied: 1) that each value of the computed mass table be equal to the corresponding value of an input mass table (for this case option HSE must be on), or 2) that each value of a computed TAUK table (continuum optical depth at a specific wavelength) be equal to the corresponding value of an input TAUK table. What happens in such runs is that a particular relationship between **TE** and mass, or between **TE** and TAUK, is intended, and PANDORA tries to make sure —by adjusting the **Z** values—that its computed mass or continuum optical depth values come as close as possible to the specified ones. Like so much else in PANDORA, these 'Z-recalculation' procedures require several iterations to give good results.

(In principle, atmospheric parameters can be specified not only on a grid of Z-values, but also on grids of other quantities, such as mass or optical depth. We did not think to allow for such flexibility during the early years of PANDORA development, and internally PANDORA is solidly based on a grid of geometric depth values. Thus—to allow the user the convenience of working with fixed sets of mass or optical depth values—the program must establish the corresponding geometrical depth values in order to function at all.)

When such 'Z-recalculation' is requested, this will be done whenever appropriate as the calculations proceed.

The final recomputed **Z** table is included in output file `fort.20` (see Section 8), and can then be used to replace the previous **Z** table of that atmospheric model.

1) To specify an input mass table, use the input parameters **ZMASS** and **RFMAS**; these define the 'input' mass table: $MASS_i$ = **ZMASS**$_i$ + **RFMAS**. This Z-recalculation procedure will be done whenever the input values of **ZMASS**$_i$ do not all = 0. It is possible that overcorrections computed during early iterations of this process can cause things to go awry, and a weighting step has been included to keep things under control. Thus, in the current iteration, the final new **Z** values = **WZM** × (newly-computed Z) + (1 - **WZM**) × (final Z from previous iteration).

2) The other Z-recalculation procedure will be done whenever the input values of **TAUKIN**$_i$ do not all = 0; a value of **PZERO** (surface pressure) may need to be specified; the value of **REFLM** (the specific wavelength) can also be specified.

***104**

The meanings of **LMA**, **LMB**, **LME**, **LMF**, **LMR**, **LMT**, **WEP**, and of options ENL and ENL2, are explained in detail in the text included in the LEVEL 1 TO K (*i.e.,* "Lyman") printout.

***105**

When transition (u, ℓ) is designated as a blend of component lines, then $\mathbf{LDL}^{u,\ell}$ input values of the displacements $\mathbf{DDL}^{u,\ell}$ and of the relative line strengths $\mathbf{CDL}^{u,\ell}$ must be provided for that line. The units of **DDL** are Angstroms; however, if it is more convenient to specify displacements in units of wavenumbers (/cm), then the alternate input parameter $\mathbf{DWN}^{u,\ell}$ may be used. The sum of the values of $\mathbf{CDL}^{u,\ell}$ should be 1. Furthermore, $\mathbf{LDL}^{u,\ell}$ input values of $\mathbf{CRD}^{u,\ell}$, of $\mathbf{CVW}^{u,\ell}$, and of $\mathbf{CSK}^{u,\ell}$ must also be provided (zeroes will be used otherwise).
For blended line transition (u, ℓ), the line profile function is calculated as

$$PHI_i = \sum_{L=1}^{LDL} \mathbf{CDL}^L PHI_i^L$$

where each set PHI^L is displaced (in wavelength or in wavenumber) as specified.

***106**

Details of a Hydrogen Stark broadening convolved profile calculation for the (**MS**,**NS**) transition are printed for the **IHSDP**'th depth point and for the **IHSDD**'th frequency value, when option ANALYSIS is on.

***107**

Input parameter **IHSSW** overrides all $\mathbf{CSTARK}^{u,\ell}$.

***108**

When option AMDIFF is on and option VELS is off, then PANDORA will automatically set $\mathbf{NVX} = 1$. See Section 16, Velocities.

***109**

When **NCB** > 0 (*i.e.* when CO-lines wavelength bands are specified):
1) if **NCL** $= 0$, then no CO-related wavelengths will be added to the list of wavelengths for which continuum calculations are done;
2) if **NCL** $= 1$, then $\mathbf{XCOL}_1 = 0$ is assumed, and only CO-line core wavelengths and the specified band limits will be added to the list of wavelengths for which continuum calculations are done.

***110**

If **WAVEMN** $>$ 0 and **WAVEMX** $>$ **WAVEMN**, then PANDORA attempts to use built-in procedures to add more additional wavelengths to the table $\mathbf{WAVES}_i, 1 \leq i \leq \mathbf{NWV}$, as follows.
If **NWV** $>$ 0 and there is an index I, I $<$ **NWV**, such that $\mathbf{WAVES}_i = 0$ for all $\mathrm{I} < i \leq \mathbf{NWV}$, then:
1) all standard rates integration wavelengths λ^c falling in the range **WAVEMN** $\leq \lambda^c \leq$ **WAVEMX**, will replace such zeroes (working systematically upwards from $i = \mathrm{I} + 1$).
If thereafter it is still the case that there is an index I, I $<$ **NWV**, such that $\mathbf{WAVES}_i = 0$ for all $\mathrm{I} < i \leq \mathbf{NWV}$, then:
2) those remaining zeroes will be replaced by values λ^a such that **WAVEMN** $\leq \lambda^a \leq$ **WAVEMX**; these λ^a will be equi-spaced in the log.

***111**

The input switch **IXNCS** (default =1) allows reversion to the "old" method of calculating default values of **CE** and **CI** in Hydrogen runs (see Section 19).
"Old" method (**IXNCS** $= 0$): if no input values of **CE** or **CI** (as tabulated functions of **TER**) are given, then default tables are computed (using the method specified) and listed in the ATOM printout. These calculations do not take the "lowering of the ionization potential" into account. Whenever particular values of $\mathbf{CE}_i^{u,\ell}$ or $\mathbf{CI}_i^j$ as functions of temperature are needed during the calculations, then they will be obtained from these tables by interpolation.
"New" method (**IXNCS** $= 1$): if no input values of **CE** or **CI** (as tabulated functions of **TER**) are given, then particular values of $\mathbf{CE}_i^{u,\ell}$ or $\mathbf{CI}_i^j$ as functions of temperature and charged particle density will be computed as needed during the

calculations; values pertaining to **TER** and a reference value of charged particle density (note input parameter **IRFNC**) appear in the ATOM printout as sample values only. (This only makes sense if the method of Johnson, or of Vriens and Smeets, is specified; or if no set of **TER** values yields acceptable interpolated results.)

***112**

The statement **COLINES (q)** (*e.g.* "`COLINES ( KROT 15 RC1213 17. )` ") is used for parameters controlling the CO-lines calculations. q consists of pairs of input fields of the form "A v", where A is an alphanumeric input field whose value may be "`JFUND`", "`KFUND`", "`JOVER`", "`KOVER`","`JSECN`", "`KSECN`", "`JROT`", "`KROT`", "`ISOSLCT`", "`METHCOF`", "`METHCOW`", or "`RC1213`", and v is a numeric field, which must be floating point if it follows `RC1213`, and integer otherwise. Here:
JFUND ... KROT specify maximum values of the quantum numbers j and ν, as follows:

JFUND is the maximum value of j for fundamental lines (default = 111);
KFUND is the maximum value of ν for fundamental lines (default = 20);
JOVER is the maximum value of j for first overtone lines (default = 111);
KOVER is the maximum value of ν for first overtone lines (default = 13);
JSECN is the maximum value of j for second overtone lines (default = 111);
KSECN is the maximum value of ν for second overtone lines (default = 12);
JROT is the maximum value of j for rotational lines (default = 53);
KROT is the maximum value of ν for rotational lines (default = 21);

ISOSLCT selects the isotope; = 1 means: use ^{12}CO, = 2 means: use ^{13}CO, = 3 means: use both (default = 3);
METHCOF selects the method for computing f-values;
= 1 means: use Chackerian and Tipping, = 2 means: use new Chackerian data, = 3 means: use Goorvitch, 1994 (default = 3);
METHCOW selects the method for computing energies (wavelengths);
= 1 means: use Farrenq *et al.* , = 2 means: use Coxon and Hajigeorgiou, = 3 means: use Goorvitch, 1994 (default = 3);
RC1213 is the isotopic abundance ratio ^{12}CO/^{13}CO (default = 90).
Notes:
The input values of the maximum quantum numbers JFUND ... KROT cannot be set larger than their respective default values.
JFUND = 0 and/or KFUND = 0 means: do not include any fundamental lines.
JOVER = 0 and/or KOVER = 0 means: do not include any first overtone lines.
JSECN = 0 and/or KSECN = 0 means: do not include any second overtone lines.
JROT = 0 and/or KROT = 0 means: do not include any rotational lines.

***113**

IPEX controls debug printout intended to be useful for program development only. **IPEX** $= -1$ will generate a flood of printout; **IPEX** $= k$, where k is one of several integers > 0, will generate selected printouts only.

***114**

LOGAS > 0 turns on the "location analysis graph" of the emergent line profile calculation, and selects the type of abscissa: $= 1$ for $\Delta\lambda$-index or wavenumber-index, $=2$ for $\Delta\lambda$-value or wavenumber-value. (Option WAVENUMB controls whether wavelength or wavenumber is used.)

***115**

Debug output from the calculation of CI (in Hydrogen runs using `AR`, `VORONOV`, `VS`, or `JOHNSON`) can be obtained by setting **JDMCI** $= [(1000 \times i) + j]$, $1 \leq i \leq$ **N**, $1 \leq j \leq$ **NL**, where i is a depth index and j is a level index. When $i = 0$, then output is provided for level j at all depths; when $j = 0$, then output is provided at depth i for all levels.
Debug output from the calculation of CE (in Hydrogen runs using `VS` or `JOHNSON`) can be obtained by setting **JDMCE** $= [1000 \times (100 \times u + \ell) + i]$, $1 \leq i \leq$ **N**, where i is a depth index and (u, ℓ) are transition indices, $u > \ell$. When $i = 0$, then output is provided for transition (u, ℓ) at all depths; when the transition indices are $(0, 0)$, then output is provided at depth i for all transitions.

***116**

When **NGNV** > 0, then GNV^{ℓ}, **NGNV** $\leq \ell \leq$ **NL** will be suppressed (i.e. set $= 0$) in the diffusion calculations.

***117**

CQM_i occurs in the equation of the scattering albedo of the 'Line Background' opacities (see Section 9).
If input parameter $\mathbf{CQM} > 0$, then PANDORA uses $\mathrm{CQM}_i = \mathbf{CQM}$, $1 \le i \le \mathbf{N}$.
If input parameter $\mathbf{CQM} \le 0$, then PANDORA expects to find the tables $\mathbf{CQT}_k$, $\mathbf{CQA}_k$, $1 \le k \le \mathbf{NCQ}$, which specify CQM as a tabulated function of temperature. PANDORA interpolates in $\log[\mathbf{CQA}(\mathbf{CQT})]$ to obtain $\mathrm{CQM}_i = \mathbf{CQA}(\mathbf{TE}_i), 1 \le i \le \mathbf{N}$.

***118**

$\mathbf{KRATE}^{u,\ell}$ controls the formulation of certain terms in the statistical equilibrium equations:
$\mathbf{KRATE}^{u,\ell} = 1$ means: use net-rate (computed from ρ);
$\mathbf{KRATE}^{u,\ell} = 2$ means: use single-rate (computed from $\bar{J}$).

***119**

First derivatives of various quantities need to be computed for the diffusion calculations (option AMDIFF). The input parameter **KDIFD1** selects one of several methods:
KDIFD1 = 1 means: compute the slope at the given point as the slope of the straight line through the two bracketing points.
KDIFD1 = 2 means: first apply "sequential smoothing" to the table of values; then compute the slope at the given point as the average of two slopes: the slope of the straight line through the given point and the adjacent point on the left, and the slope of the straight line through the given point and the adjacent point on the right.
KDIFD1 = 3 means: first apply "improved sequential smoothing with irregular point spacing" to the table of values; then compute the slope at the given point from the cubic spline fitted to all the points.
KDIFD1 = 4 means: compute the slope at the given point as the average of two slopes: the slope of the straight line through the given point and the adjacent point on the left, and the slope of the straight line through the given point and the adjacent point on the right (i.e., like **KDIFD1** = 2 but without smoothing).
The default value is **KDIFD1** = 1.

***120**

If any nonzero values of $\mathbf{RABDL}_i$ were input, then $\mathbf{RABD}_i$ will be set equal to antilog ($\mathbf{RABDL}_i$), all i. Otherwise, if any nonzero values of $\mathbf{RABD}_i$ were input, then those input values will be used. Otherwise, $\mathbf{RABD}_i$ will be set equal to 1.0, all i.

***121**

The detailed dump printout for the calculation of S-from-Number-Densities is controlled by **ISNDD**. When **ISNDD** $= 0$, then no dump ever appears; when **ISNDD** $= 1$, then a dump appears for every such calculation; when **ISNDD** $= 2$, then a dump appears only if an error occurred during the calculation.

***122**

The 'Special N1' calculation (part of the "Diffusion Calculation" when option AMDN1 is on) can be done in various ways; the choice of method is controlled by input parameters **N1MET**, **KDIAG**, **I4DFM**, **I4DEQ**, **I4DIO**, **KBNDS** and **KDAMP**. (A more detailed explanation of these parameters appears in sections INPUT and DIFFUSION of the main output file.)
When **N1MET** $= 1$, use the exponential method (if possible, otherwise, a diagonal method); when **N1MET** $= 1$, use the diagonal method specified by **KDIAG**; when **N1MET** $= 3$, use the simultaneous method (for He-I or He-II only).
KDIAG $= 3$, 4, or 5 selects the 3-diagonal, 4-diagonal, or 5-diagonal method, respectively. Additional controls are needed for the 4-diagonal method: **I4DIO** $= 1$ specifies the inward version, and **I4DIO** $= 2$ the outward version (in the staionary case); **I4DEQ** $= 0$, 1, or 2 specifies the "original," "method-1," or "method-2" equations, respectively; when **I4DEQ** $= 1$, use the results from the Z-formulation, when **I4DEQ** $= 2$, use the results from the ζ-formulation.
KDAMP $= 0$ means: use the raw matrix solution, whereas **KDAMP** $= 1$ means: use the damped matrix solution (obtained by a weighted moving 3-point average), for the three-diagonal, five-diagonal, or simultaneous method.
KBNDS $= 1$ means: use equations incorporating relevant boundary conditions, $= 0$ means: do not.

***123**

If not input values of the "Lyman" calculation tables $\mathbf{XK}_i$, $\mathbf{GK}_i, 1 \leq i \leq \mathbf{KK}$ are specified, then defaults are provided from the rates integration data tables $RRNU_i^{\mathbf{KOLEV}}$, $\mathbf{RRCP}_i^{\mathbf{KOLEV}}, 1 \leq i \leq \mathbf{MR}^{\mathbf{KOLEV}}$. If $\mathbf{MR}^{\mathbf{KOLEV}} > \mathbf{KK}$, then only the first **KK** values of *RRNU* and **RRCP** are copied into **XK** and **GK**, respectively; if $\mathbf{KK} > \mathbf{MR}^{\mathbf{KOLEV}}$, then *RRNU* and **RRCP** are copied into the first **KK** elements of **XK** and **GK**, respectively, while the rest of those tables will be left undisturbed.

***124**

The "Diffusion Calculations" (options AMDIFF and VELGRAD) compute tables of $GNVL_i^\ell$, $1 \leq i \leq \mathbf{N}$, $1 \leq \ell \leq \mathbf{NL}$. At times the raw computed values of these tables should not all be used; instead, they should be set $= 0$ at some depths.
A table of GRF_i values ('*GNVL* reduction factor') has been introduced for this purpose; GRF_i multiplies the raw values to produce the final values of $GNVL_i^\ell$.
The values, and the use, of GRF_i, are controlled by input parameters **KDIFGS**, **KDIFGA**, and **KDIFGB**.
The GRF_i table is established as follows: $GRF_i = 1$, $1 \leq i \leq \mathbf{KDIFGA}$;
$GRF_i = (\mathbf{KDIFGB} - i)/(\mathbf{KDIFGB} - \mathbf{KDIFGA})$, $\mathbf{KDIFGA} < i < \mathbf{KDIFGB}$;
$GRF_i = 0$, $\mathbf{KDIFGB} \leq i \leq \mathbf{N}$.
When $\mathbf{KDIFGS} = 0$, then GRF_i is not used (and the raw values become the final values); when $\mathbf{KDIFGS} = 2$, then all values of $GNVL_i^\ell$, $1 \leq \ell \leq \mathbf{NL}$ are multiplied by GRF_i; when $\mathbf{KDIFGS} = 1$, then only values of $GNVL_i^1$ are multiplied by GRF_i.

***125**

IPDEE and **NEFDF** are related to the calculation of the d-coefficients that are used in the diffusion calculation (the relavant routines are minor adaptations of code written and provided by Juan Fontenla). The d-coefficient-calculation needs values of the electron density; when $\mathbf{NEFDF} = 1$, then internally-computed values of electron density are used, when $\mathbf{NEFDF} = 2$, then the program-wide **NE**-table is used.
A schematic graph of the computed d-coefficients is always printed; the complete set of values will be printed, in addition, when $\mathbf{IPDEE} = 1$.

***126**

The table $beta_i$ (the He II number density) used in the diffusion calculations can be computed in different ways, controlled by **IBETSW**. When **IBETSW** $= 0$, then $beta_i = \frac{1}{2}(HEK_i + HE21_i)$; when **IBETSW** $= 1$, then $beta_i = HEK_i$; when **IBETSW** $= 2$, then $beta_i = HE21_i$.

***127**

The array DIJ is one of the aids that are calculated, printed, and plotted for analyzing the effects of diffusion. When **IPDIJ** $= 0$, then the entire array will be printed; when **IPDIJ** $= 1$, then only an abbreviated analysis of DIJ will be printed.

***128**

KB1WA and **KB1WB** are depth indices that control the generation of B1-weights in the same way that **KDIFGA** and **KDIFGB** control the generation of values of GRF_i (see Note 121).

***129**

The input switch **KANTNU** controls the summary printout of all TNU tables of a radiative transition. (The default is **KANTNU** $= 0$.)
KANTNU $= 0$ means: none;
KANTNU $= 1$ means: for all transitions with **LSFPRINT** $= 1$;
KANTNU $= 2$ means: for all transitions when option LSFPRNT is on;
KANTNU $= 3$ means: for all transitions when option LSFGRAF is on;
KANTNU $= 4$ means: for all transitions.

***130**

The ORIGINS printout, and/or the CONTRIBUTORS printout, part of the spectrum analysis aids, can be restricted to a specified range of wavelengths (or of wavenumbers when option WAVENUMB is on). **CORMIN**, when > 0, is the minimum value, and **CORMAX**, when > 0, is the maximum value of wavelength (or of wavenumber, as the case may be).

***131**

$X_i^{s+1} = W_i \times X_i^{new} + (1 - W_i) \times X_i^s,\ 1 \le i \le N$, where X stands for RHO$^{u,\ell}$ and W syands for RHWT$^{u,\ell}$; or
$X_i^{s+1} = [(X_i^{new})^{W_i}] \times [(X_i^s)^{(1-W_i)}],\ 1 \le i \le N$, where X stands for RK^{KOLEV} and W stands for RKWT, as used in the Lyman calculation.

The values of X_i for iteration $s + 1$ will be obtained, in the manner shown, from the values of X_i used during iteration s and the *new* values of X_i calculated at the end of iteration s.

The first equation above illustrates *linear* weighting, while the second illustrates *logarithmic* weighting. Logarithmic weighting is always used for RK^{KOLEV}; logarithmic weighting can also be used for RHO$^{u,\ell}$, depending on option WATESTR.

The values of **RHWT**$_i$ and **RKWT**$_i$ may vary with depth index i, or may be constants. They are updated in every iteration as described in the writeup [74 Oct 23]. The procedure for updating these weights uses input parameters **INCH**, **WRMN**, and **WRMX**.

Note: RHO and RK weighting used to be done differently, using different input parameters and input tables (see Note 13). The former input quantities NTW, TAW, WTW, NWRHO, WRLY, and WRHO are no longer recognized by the program and must be removed from old files. The former input quantities WMN, WMX, RHOWT, and RKW are no longer used, however, the program continues to recognize them and uses their values to compute related values of **WRMX**, **WRMN**, **RHWT**, and **RKWT**, according to:

WRMX $= 1 - WMN$, **WRMN** $= 1 - WMX$,
RHWT $= 1 - RHOWT$, and **RKWT** $= 1 - RKW$.

Messages are written to the output file whenever these conversions are done. It is best to remove **WMN** and **WMX** from the input (using the above conversions). **RHOWT** and **RKW** tend to occur in the restart files written by old versions of the program; the program now writes **RHWT** and **RKWT** to these files. Thus, the old quantities will normally be encountered only when an old run is restarted with the current program, so that the automatic conversion described here needs to be done only once.

***132**

Notes

The switch **WORLDLY** can take on the values `SCREEN` or `DISK`; it controls the storage-management-system dump (which uses file `fort.97` when **WORLDLY** = `DISK`). I use this to check the source code; it is not intended for general use.

***133**

In the ATMOSPHERE and ATOM printout sections, parameter values = 0 are nomally printed as blanks. If the user prefers to see printed 0's, then the input parameters **JZATMO** and/or **JZATOM** may be set = 1.

***134**

As explained in Section 11, output from the Continuum Calculations at various wavelengths is controlled by various OPTIONS pertaining to the various wavelength types (for example, output will be produced for all Additional Continuum Wavelengths, **WAVES**, when option ADDCOPR is on). However, even if no wavelength-type OPTIONS are on, output will be produced for every wavelength specified in the table **SCOW**, of length **NSW**. For this purpose, a value of **SCOW** must match the value of an actual Continuum Calculation wavelength to at least 8 figures (note that a list of all Continuum Calculation wavelengths appears in the WAVELENGTHS section near the end of the PANDORA printout).

***135**

When option USEWTAB is on, the "standard rates integrations wavelengths" table is added to the list of wavelengths for which continuum calculations are done. (This "standard" table contains values bracketing all the absorption edges contained in the built-in ion models and tries to capture, for integration purposes, all the lines included among the background opacity contributors.) Only that portion of the "standard" table falling between the limits **WRATMN** and **WRATMX** will be used.

***136**

Ionization and excitation rates always include the effects of collisions with electrons; the rates due to collisions with neutral Hydrogen are always computed (and printed if the options RATEPRNT and COLHPRNT are both on), but are used only if the input switch **ICHSW** $= 1$. Rates due to collisions with Hydrogen, however, are computed only for those levels of the ion-of-the-run whose corresponding value of the input array $\mathbf{LCH}^j > 0,\ 1 \leq j \leq \mathbf{NSL}$. $\mathbf{LCH}^1 = 0$ by definition; but a negative value of $\mathbf{LCH}^1$ can be specified and will be used as a special code, as described below.

Ionization rates due to collisions with Hydrogen are computed using the formulation of B. Kaulakys, 1985, J.Phys.B, **18**, L167.

Kaulakys' formulation is also used to compute the effects of collisions with Hydrogen on the collisonial excitation rates for all those transitions (u, ℓ) for which both $\mathbf{LCH}^u$ and $\mathbf{LCH}^\ell > 0$. A second set of collisional ionization rates is then computed from H. W. Drawin, 1969, Z.Physik, **225**, 483 for all transitions to and from those lower levels whose index $\leq |\mathbf{LCH}^1|$. (For an $A = 0$ transition the Drawin rate is zero, and the Drawin rates for transitions whose lower level index $= 1$ are zero if $\mathbf{LCH}^1 = 0$. Such Drawin rates then replace the corresponding Kaulakys transitional rates that had already been computed.

***137**

The Hydrogen Lyman lines background opacity parameters are explained in Section 21, and in section INPUT of PANDORA's regular output file.

***138**

If no input values of **DGM** are specified, and if **NGM** $= 0$ has been specified explicitly, then $\mathbf{DGM}_i = 1,\ 1 \leq i \leq \mathbf{N}$ is set up internally (this is the "general" default, as specified above). However, if no input vales of **DGM** are specified, *and* if **NGM** $= 0$ has *not* been specified (so that **NGM** retains its built-in default value which is > 0), then "solar default" values of $\mathbf{DGM}_i$ will be computed from $\mathbf{DGMZ}_j,\ 1 \leq j \leq \mathbf{NGM}$. Here **DGMZ** is a table appropriate for the quiet Sun, and is specified as a function of Z, **ZGM**. Values of $\mathbf{DGM}_i$ corresponding to the input values of $\mathbf{Z}_i$ are obtained by interpolation from the tables $\mathbf{ZGM}_j$ and $\mathbf{DGMZ}_j$.

Notes

Note: $\mathbf{DGM}_i = 0$ is not acceptable.

***139**

The **CIMETHOD** and **CEMETHOD** statements each may contain an arbitrary number of nonnumeric codewords for specifying the set of methods for calculating automatic values of CI^j and/or $CE^{u,\ell}$. The **CIMETHOD** statement recognizes: `CLARK, AR, VORONOV, JOHNSON, VS, SHAH, ONTHEFLY`; while the **CEMETHOD** statement recognizes: `SEATON, VREGE, SCHOLZ, PB, VS, JOHNSON, AGGRWL, ONTHEFLY`. To enable a method, list its name in the pertinent statement; to turn off a method already enabled (say, because it is enabled by default) preface it with a minus sign (without intervening blank).
With these statements the user can specify method sets different from the default sets. It is necessary to turn off explicitly any unwanted methods that are already enabled! For example, to use only `VS` for all Hydrogen CI^j-values, use: "`CIMETHOD ( VS -SHAH -CLARK )` ".
`ONTHEFLY` is a calculation mode, not a method.
See Section 19 for more details.

***140**

The **MATRIX** statement accepts control parameters for matrix manipulation. Their names are **DRPSW** (integer, default = 0), **EDJSW** (integer, default = 0), and **CRITJ** (floating point, default = 10^{-50}). When one or more of these names appear in a **MATRIX** statement, each name should be followed immediately by its desired input value. For example:

```
MATRIX ( edjsw 1 critj 1.e-30 )
```

When **DRPSW** = 1: two lines of descriptive data will be written to the printout file for every matrix to be inverted.

When **EDJSW** = 1 "junk" is edited out of every matrix prior to inversion or determinant calculation: find Y, the matrix element having the largest absolute value; compute $Z =$ **CRITJ** $\times |Y|$; and then set = 0 every matrix element whose absolute value is less than Z.

This is a listing of input parameters, in alphabetical order by description. Once a parameter's name has been identified by means of this list, its full specification can then be found in the main table at the start of this section.

KCOAA	abbreviated form switch, Composite Line Analysis printout
KALHD	`Abort/Hi/Bye`-system control parameter
KALOR	`Abort/Hi/Bye`-system control parameter
LOGAS	abscissa selector for location analysis graph
NABS	absorber switch
AHM	absorption coefficient for H-minus bound-free
BLIMG	absorption/emission contributions graph limit
TLIMG	absorption/emission contributions graph limit
JZOPT	absorption/emission contributions graph Z-scale option
IPPOD	absorption/emission dump, population ions
KONFORM	absorption source function contributions detail print format switch
ABD	abundance (see also Section 10)
RABD	abundance ratio
IRPUN	abundance ratio calculation output data switch
RABDL	abundance ratio, log
AEL	added electrons
AL	added recombination fraction
ACE	added term for CE (default)
ACI	added term for CI (default)
CIJADD	added term for CIJ
CKADD	added term for CK
VX	additional expansion velocity
NVX	additional expansion velocity tables count
RKC	additional photoionization parameter
TKR	additional photoionization parameter
YKR	additional photoionization parameter
WAVES	additional wavelengths for opacity
WAVEMN	additional wavelengths limit, automatic
WAVEMX	additional wavelengths limit, automatic
PCE	adjustment factor, FCE
INCH	adjustment parameter (RHO weights)
SMP	adjustment parameter (RHO weights)
WMN	adjustment parameter (RHO weights)
WMX	adjustment parameter (RHO weights)
WRMN	adjustment parameter (RHO weights)
WRMX	adjustment parameter (RHO weights)

CQM	albedo multiplier
CQA	albedo parameter
CQT	albedo parameter
CLM	albedo parameter
PNH	albedo parameter
NAL	ALN tables number
AOWXP	alpha(old) weight exponent, Special-N1 (Diffusion)
IGMSW	alternate GMMA for Hydrogen Lyman lines, PRD
BDAL	Aluminum (neutral) departure coefficient
ALN	Aluminum (neutral) level populations
ALK	Aluminum-II (singly ionized) ground level population
LODCG	ambipolar diffusion calculation graphs control code
NODCG	ambipolar diffusion calculation graphs control code
CLEVELS	ambipolar diffusion calculation parameter
IBETSW	ambipolar diffusion calculation parameter
IPDEE	ambipolar diffusion calculation parameter
FZION	ambipolar diffusion calculation parameter
IDFDI	ambipolar diffusion calculation parameter
IDFDM	ambipolar diffusion calculation parameter
IPDIJ	ambipolar diffusion calculation parameter
ITN1R	ambipolar diffusion calculation parameter
KDIFD1	ambipoler diffusion calculation parameter
MN1	ambipolar diffusion calculation parameter
MNG1	ambipolar diffusion calculation parameter
NDSN1	ambipolar diffusion calculation parameter
NEFDF	ambipolar diffusion calculation parameter
ZXMIN	ambipolar diffusion calculation parameter
PALBET	ambipolar diffusion calculation term, Helium
PBETAL	ambipolar diffusion calculation term, Helium
PBETGM	ambipolar diffusion calculation term, Helium
PGMBET	ambipolar diffusion calculation term, Helium
AOWXP	ambipolar diffusion, Special-N1, alpha(old) weight exponent
NDSN1	ambipolar diffusion, Special-N1, calculation control switch
SN1CC	ambipolar diffusion, Special-N1, convergence criterion
N1NUP	ambipolar diffusion, Special-N1, populations-of-the-run update switch
MSSPR	ambipolar diffusion, Special-N1, simultaneous matrix print switch

WSN1D	ambipolar diffusion, Special-N1, weight for N1 and NK
APDDIFC	ambipolar diffusion velocity parameter
APDDTFC	ambipolar diffusion velocity parameter
APDTEXP	ambipolar diffusion velocity parameter
APDXICA	ambipolar diffusion velocity parameter
APDXICB	ambipolar diffusion velocity parameter
APDXICC	ambipolar diffusion velocity parameter
APDXICD	ambipolar diffusion velocity parameter
SCTA	amplitude, shock temperature
SCVA	amplitude, shock velocity
NANAL1	ANALYSIS depth selection parameter
NANAL2	ANALYSIS depth selection parameter
KANTNU	analysis of TNU in radiative transitions
ADMAS	angular diameter
IPERFA	archive record, perfromance data, switch
ADS	angular diameter ratio, Star/Sun
MFONT	atmosphere data (Fontenla's format) output switch
JZATMO	ATMOSPHERE zero-print mode switch
MODLAB	atmospheric 'model name'
NL	atomic levels number
NSL	atomic levels number, including supplementary levels
MASS	atomic mass
NOION	'atom' switch
JZATOM	ATOM zero-print mode switch
KXLYM	augmentation switch for Lyman XK-table
WAVEMN	automatic additional wavelengths limit
WAVEMX	automatic additional wavelengths limit
ESCTAU	automatic use of escape probability
ZAUX	auxiliary depths table
DDR	auxiliary table for PRD
XDR	auxiliary table for PRD
IBNVIEW	b calculation trace illustration, depth index for
NBS	b smoothing level control index
LSFFDB	background for Line Source Function
DOFDB	background for Line Source Function
LEEDS	background lines opacity debug printout switch (Helium-I)

LHEDS	background lines opacity debug printout switch (Helium-II)
LYODS	background lines opacity debug printout switch (Hydrogen)
LOXDS	background lines opacity debug printout switch (Oxygen)
FNRMLA	background lines, Hydrogen Lyman α, normalizing factor
FNRMLB	background lines, Hydrogen Lyman β, normalizing factor
BXI	background lines standard frequencies
LSFBOC	background opacity control
NLY	background opacity, H Lyman lines limit
OML	background opacity multiplier
NAB	BANDL length
KARB	'banner' page character selector
VXS	basic expansion velocity
IBNVIEW	BD-calculation trace illustration, depth index for
BMWAC	beam width parameter for eclipse continuum calculation
IBETSW	beta-equation selection switch, diffusion
IBETSW	β-equation selection switch, diffusion
TB	blanketing temperature
DDL	blended line components offsets
DWN	blended line components offsets
CDL	blended line components weights
SGRAF	blended line emergent intensity graph switch
KBNDS	boundary conditions switch for Special-N1 (diffusion)
AHM	bound-free absorption coefficient for H-minus
EPCBR	branching ratio
TX	brightness temperature of illuminating source
BLCSW	broadening components selector
IBRDP	broadening, ion, dump switch
V	broadening velocity
VR	broadening velocity
VNH	broadening velocity, quiet Sun
MOPRNT	built-in population-ion-model printout switch
DGM	buoyancy factor (G-multiplier), HSE
DGMZ	buoyancy factor (G-multiplier), HSE, standard table
KBX	BXI length
KB1WA	B1-weights depth index
KB1WB	B1-weights depth index

KB1WS	B1-weights type selection switch
BDCA	Calcium (neutral) departure coefficient
CAN	Calcium (neutral) level populations
CAK	Calcium-II (singly ionized) ground level population
NCA	CAN tables number
NCOSW	Carbon Monoxide abundance computation switch
	Carbon Monoxide lines = CO
NCOI	Carbon Monoxide number density, input
MCON	Carbon Monoxide number density output switch
BDC	Carbon (neutral) departure coefficient
CN	Carbon (neutral) level populations
CK	Carbon-I (singly ionized) ground level population
FCE	CE enhancement factors
CEMETHOD	CE method selection
INCEI	CE-values comparion calculations depth index
ACE	CE-values, default, addend
CEDMN	CE-values default calculation parameter
CEDMX	CE-values default calculation parameter
CEFEQ	CE-values default calculation parameter
IXNCS	CE-values default method switch (Hydrogen)
MCE	CE-values, default, multiplier
JDMCE	CE-values dump switch (Hydrogen)
IRFNC	CE-values (Hydrogen) reference index
EXLYM	change-over TAU for Lyman
TGLYM	change-over TAU for Lyman
TSM	change-over TAU for mean intensity and emergent intensity calculations
TMS	change-over TAU for RT weight matrix method
TBAR	change-over TAU for weight matrix
KARB	character selector for ‘banner’ page
NC	charged particle density
IRFNC	charged particle density reference value for CE and CI (Hydrogen)
LCEX	charge exchange index
CCHX	charge exchange, upper-level, parameter
ICXDP	charge exchange, upper-level, parameter
RCHX	charge exchange, upper-level, parameter
XRKH	charge exchange, upper-level, term

XRLH	charge exchange, upper-level, term
CIJADD	CIJ added term
IRATE	CIJ printout
CIMETHOD	CI method selection
INCEI	CI-values comparion calculations depth index
ACI	CI-values, default, addend
IXNCS	CI-values default method switch (Hydrogen)
MCI	CI-values, default, multiplier
JDMCI	CI-values dump switch (Hydrogen)
IRFNC	CI-values (Hydrogen) reference index
CKADD	CK added term
WNJUNK	'cleanup' parameter for WN-matrix
NLC	CN tables number
	CO = Carbon Monoxide
CTCO	CO abundance calculation temperature enhancement factor
CTMX	CO abundance calculation temperature enhancement limit
RCOMIN	CO abundance, lower limit
COLINES	CO isotope abundance ratio
ZRCO	CO reference height
SHCOC	CO scale height, chromospheric
SHCOP	CO scale height, photospheric
CTCO	CO temperature enhancement factor
CTMX	CO temperature enhancement limit
LCOD	CO-lines absorption dump wavelength
LCOA	CO-lines absorption limit
LCOB	CO-lines absorption limit
COLINES	CO-lines control parameters
YCOL	CO-lines method control parameter
COMU	CO-lines mu value
SRCO	CO-lines scattering ratio
NCOPT	CO-lines statistics-keeping switch
MCOA	CO-lines van der Waals damping multiplier
XCOL	CO-lines wavelengths table
XCOMX	CO-lines width limit
NCOI	CO number density, input
CE	collisional excitation coefficient

CI	collisional ionization coefficient
CKADD	collisional ionization rate (CK), added term
CIJADD	collisional transition rate (CIJ), added term
RFAC	collision rates (all), reduction factor
FROSCE	collision rates, forbidden transitions
ICHDP	collisions, Hydrogen, dump switch
LCH	collisions, Hydrogen, codes
ICHSW	collisions, Hydrogen, switch
ZMASS	column mass of gas
WFB	component profiles weight, flow broadening
FMCDL	components elimination criterion for Hydrogen Stark splitting
FRCDL	components elimination criterion for Hydrogen Stark splitting
BLCSW	components selector for line damping
KCOAA	Composite Line opacity (Kurucz) abbreviated analysis printout
KODNT	Composite Line opacity (Kurucz) data dump control
BANDE	Composite Line opacity (Kurucz) eclipse switch
ALBK	Composite Line opacity (Kurucz) parameter
ZALBK	Composite Line opacity (Kurucz) parameter
BANDL	Composite Line opacity (Kurucz) wavelength band
BANDU	Composite Line opacity (Kurucz) wavelength band
LSFFDB	constant background for Line Source Function
DOFDB	constant background for Line Source Function
NDW	constant Doppler width value index
NDWM	constant Doppler width value index, for atmospheric model
CPRESS	constant pressure
WPRESS	constant pressure adjustment weight
KPC	continuous opacity
MLC	continuous opacity multiplier
SCOW	Continuum Calculations output, selected wavelengths for
KAPDB	continuum contributors control debug switch
BANDE	continuum eclipse calculation switch
NECLIP	continuum eclipse printout quantity selector
IFXDS	continuum flux detail output control
YFLUX	continuum flux weight matrix damping parameter
NUC	continuum frequency interval, auxiliary
NUK	continuum frequency interval

WNUC	continuum frequency interval, auxiliary
WNUK	continuum frequency interval
JSTCN	'continuum-only' run type switch
CSFCRIT	Continuum Source Function convergence criterion
IDRCD	Continuum Source Function debug printout disk ray index
IMUCD	Continuum Source Function debug printout MU index
ISRCD	Continuum Source Function debug printout shell ray index
TOPE	'Continuum Summary Graph' file
XK	continuum transition standard frequencies
ICDIT	continuum wavelengths selector for dI/dh
CORMAX	CONTRIBUTORS printouts wavelength limit
CORMIN	CONTRIBUTORS printouts wavelength limit
LSFBOC	control parameter for line background opacity
MATRIX	control parameter for matrix generation and inversion
PROGLI	control parameter for profile graphs
BANDY	control parameter for source function method
YCONT	control parameter for source function method
YHM	control parameter for source function method
YKR	control parameter for source function method
YL	control parameter for source function method
YLINE	control parameter for source function method
YRATE	control parameter for source function method
YWAVE	control parameter for source function method
NCOI	CO number density, input
CSFCRIT	convergence criterion for Continuum Source Function
EIDIF	convergence criterion for NE-iterations
PRDCV	convergence criterion for PRD-iterations
SN1CC	convergence criterion, Special-N1 (diffusion)
IHSDD	convolved Hydrogen Stark profile dump switch
IHSDP	convolved Hydrogen Stark profile dump switch
HSBDMN	convolved Hydrogen Stark profile parameter
HSBDMX	convolved Hydrogen Stark profile parameter
HSBFEQ	convolved Hydrogen Stark profile parameter
HSBM	convolved Hydrogen Stark profile parameter
CSTARK	convolved Hydrogen Stark profile switch
IHSSW	convolved Hydrogen stark profile switch

KHFFS	cooling rate components control
KOOLSUM	cooling rate components control
BLIMG	coordinate limit for graph of absorption contributors
NGRL	coordinate limit for graph of absorption contributors
NGRR	coordinate limit for graph of absorption contributors
TLIMG	coordinate limit for graph of absorption contributors
ICR	coronal incident radiation
COMU	cosine of look-angle for CO
MUF	cosine of look-angle for flux
MU	cosine of look-angle for intensity
NCQ	CQT length
ESCTAU	criterion for automatic use of escape probability solution
DELLIM	criterion for DEL in Line Source Function calculation
CN1S	criterion for rcheck (diffusion calculation, Special-N1)
RHOCR	criterion for RHO calculation
SMATC	criterion for selection for matrix samples output
CCHX	cross-section multiplier, upper-level charge-exchange
LMZ	cut-off for Lyman-α wing opacity
VOITC	cut-off for Voigt profile function recomputation
TML	cut-off TAU for intensity integrals
BLCSW	damping components selector
DPMULT	damping multiplier
Y	damping parameter
YPRE	damping parameter
YFLUX	damping parameter for continuum flux
KDAMP	damping switch for Special-N1 (diffusion)
IDEDP	d-coefficients (diffusion calculation) debug printout switch
IDFDI	d-coefficients (diffusion calculation) dump index
IDFDM	d-coefficients (diffusion calculation) method selection switch
NEFDF	d-coefficients (diffusion calculation) NE selection switch
IPDEE	d-coefficients (diffusion calculation) print switch
IDFDS	d-coefficients (diffusion calculation) smoothing
LDL	DDL length
IPR01	debug printout limit index (Line Source Function)
IPR02	debug printout limit index (Line Source Function)
IPR03	debug printout limit index (Line Source Function)

IPR04	debug printout limit index (Line Source Function)
KAPDB	debug printout switch for continuum contributors control
IDEDP	debug printout switch for diffusion d-coefficients
LEEDS	debug printout switch for Helium-I lines background opacity
LHEDS	debug printout switch for Helium-II lines background opacity
JDMCE	debug printout switch for Hydrogen CE-values
JDMCI	debug printout switch for Hydrogen CI-values
ICHDP	debug printout switch for Hydrogen collisions
LYODS	debug printout switch for Hydrogen Lyman lines background opacity
ISMBD	debug printout switch for intensity integration (`SIMBA`)
IBRDP	debug printout switch for ion broadening (Hydrogen)
LOXDS	debug printout switch for Oxygen lines background opacity
ISNUD	debug printout switch for PRD SNU-shift
IXASM	debug printout switch for smoothing-dump (IPEX=15) details
ISNDD	debug printout switch for S(n) calculation
ITRFI	debug printout switch for TR-iteration
CEDMN	default CE-values calculation parameter
CEDMX	default CE-values calculation parameter
CEFEQ	default CE-values calculation parameter
IXNCS	default CE-values method selector (Hydrogen)
IXNCS	default CI-values method selector (Hydrogen)
PMSK	default Stark halfwidth multiplier
DELLIM	DEL-criterion for DIRECT vs. FULL source function solution
DELWAVE	deletion wavelengths
INFSM	delimiter for Lyman RK-1 smoothing
INLSM	delimiter for Lyman RK-1 smoothing
PROGLI	delta-lambda limit for profile graphs
NWS	DELWAVE length
DLSF	denominator of line source function, limit for
VSMLL	denominator = 0, replacement for
BD	departure coefficient
BDAL	departure coefficient, Aluminum
BDCA	departure coefficient, Calcium
BDC	departure coefficient, Carbon
WBDIR	departure coefficient (direct) weight
DELTB	departure coefficient editing parameter

BDFE	departure coefficient, Iron
BDHE	departure coefficient, Helium
BDHE2	departure coefficient, Helium-II
BDH	departure coefficient, Hydrogen
BDHM	departure coefficient, H-minus
BDMG	departure coefficient, Magnesium
BDO	departure coefficient, Oxygen
BDO2	departure coefficient, Oxygen-II
BDO3	departure coefficient, Oxygen-III
BDSI	departure coefficient, Silicon
BDS	departure coefficient, Sulphur
BDNA	departure coefficient, Sodium
JBFSW	departure coefficients method switch for supplementary levels
JBDNC	departure coefficients ratio and Rho calculations bypass switch
NBS	departure coefficients smoothing level index
WBD	departure coefficients updating weight
Z	depth
ZAUX	depth, auxiliary
IDRDP	depth index for DRDMP
INCEI	depth index for CI,CE comparison calculations
LHHSE	depth index for H and M ins HSE
ICHDP	depth index for Hydrogen collisions dump
JEDIT	depth index for N-editing
IHEAB	depth index for RHEAB calculation
JSSV	depth index for shock temperature
ISSV	depth index for shock velocity
ISOD	depth index for Sobolev integration dump
IBNVIEW	depth index for illustration of trace of BD- and ND-calculations
KLDIN	depth interval for Lyman dump
IPRDD	depth interval for partial redistribution printout
MN1	depth limit for N1 recalculation, ambipolar diffusion
IORIC	depth-of-formation (line center) print switch
NANAL1	depth selection parameter for profile ANALYSIS
NANAL2	depth selection parameter for profile ANALYSIS
RHEAB	depth variation of total Helium abundance
KDIFD1	derivatives calculation method selection switch

LDFD1	derivatives smoothing control switch
LEVDES	designation of atomic level
USE	designation of input file
IXFDS	detail print control parameter for continuum flux
IHDMP	detail print control parameter for 'H' calculation
JNEDP	detail print control parameter for N-editing
LDINT	detail print control parameter for transition terms
LDTYP	detail print control parameter for transition terms
KONFORM	detail print format switch for opacity and BHS
IDFSW	detail print switch, dI/dh (line profiles)
IPPOD	detail print switch, population ions absorption/emission
IXASM	detail print switch, smoothing dump (IPEX=15)
LSTMP	detail print switch, STIM for GTN calculation
IWEIT	detail print switch, weighting
IRUNT	development run switch
NGM	DGMZ length
AW	diagonal, integrated, of WN-matrix
ADS	diameter, angular
ADMAS	diameter, angular
ICDIT	dI/dh continuum wavelengths selector
IDFSW	dI/dh details print switch (line profiles)
IPDEE	diffusion (ambipolar) d-coefficients print switch
LODCG	diffusion (ambipolar) graphs control code
NODCG	diffusion (ambipolar) graphs control code
CLEVELS	diffusion (ambipolar) parameter
FZION	diffusion (ambipolar) parameter
IBETSW	diffusion (ambipolar) parameter
IDFDI	diffusion (ambipolar) parameter
IDFDM	diffusion (ambipolar) parameter
IPDEE	diffusion (ambipolar) parameter
IPDIJ	diffusion (ambipolar) parameter
KDIFD1	diffusion (ambipolar) parameter
MN1	diffusion (ambipolar) parameter
MNG1	diffusion (ambipolar) parameter
NEFDF	diffusion (ambipolar) parameter
ZXMIN	diffusion (ambipolar) parameter

IPDIJ	diffusion analysis (DIJ) printout switch
MXTAP	diffusion calculation, KZAUG sum limit
MXPPI	diffusion calculation, KZAUG value limit
ITKZA	diffusion calculation, Z-augmentation iteration limit
IDEDP	diffusion d-coefficients debug printout switch
AOWXP	diffusion (Special-N1) parameter
CN1S	diffusion (Special-N1) parameter
I4DEQ	diffusion (Special-N1) parameter
I4DFM	diffusion (Special-N1) parameter
I4DIO	diffusion (Special-N1) parameter
KBNDS	diffusion (Special-N1) parameter
KDAMP	diffusion (Special-N1) parameter
KDIAG	diffusion (Special-N1) parameter
NDSN1	diffusion (Special-N1) parameter
N1MET	diffusion (Special-N1) parameter
N1NUP	diffusion (Special-N1) parameter
PALBET	diffusion term, Helium
PBETAL	diffusion term, Helium
PBETGM	diffusion term, Helium
PGMBET	diffusion term, Helium
MDFG	diffusion terms output switch
APDDIFC	diffusion velocity (ambipolar) parameter
APDDTFC	diffusion velocity (ambipolar) parameter
APDTEXP	diffusion velocity (ambipolar) parameter
APDXICA	diffusion velocity (ambipolar) parameter
APDXICB	diffusion velocity (ambipolar) parameter
APDXICC	diffusion velocity (ambipolar) parameter
APDXICD	diffusion velocity (ambipolar) parameter
MDFV	diffusion velocity output switch
IPDIJ	DIJ printout switch, diffusion
DLU	dilution factor
WBDIR	'direct' calculation of departure coefficient, weight
DELLIM	DIRECT calculation of Line Source Function
LSFTYP	DIRECT calculation of Line Source Function
OMIT	disable program options
ISCRS	disk file (temporary) control switch

R1N	distance from illuminating source
VSMLL	divisor = 0, replacement for
IDNRT	DNRT, DNRTC (Lyman) calculation switch
IDWIN	Doppler width recomputation dump index increment
NDW	Doppler width reference index
NDWM	Doppler width reference index, for atmospheric model
ZNDW	Doppler width reference index criterion
LMDL2	DR parameter, Hydrogen Lyman lines background opacity
LMDL3	DR parameter, Hydrogen Lyman lines background opacity
LMDR	DR parameter, Hydrogen Lyman lines background opacity
LMXC	DR parameter, Hydrogen Lyman lines background opacity
LMXP	DR parameter, Hydrogen Lyman lines background opacity
LMXX	DR parameter, Hydrogen Lyman lines background opacity
DDR	DR parameter, PRD transitions
DRLIM	DR parameter, PRD transitions
TAUCL	DR parameter, PRD transitions
XC	DR parameter, PRD transitions
XCL	DR parameter, PRD transitions
XDR	DR parameter, PRD transitions
XP	DR parameter, PRD transitions
XR	DR parameter, PRD transitions
IDRDP	DRDMP depth index
KDRDP	DRDMP frequency index
	dump = debug printout
KLDIN	dump, Lyman, depth interval
KLFIN	dump, Lyman, frequency interval
JHBFD	dump switch, H-bf background absorbers and emitters
IPPOD	dump switch, population ions absorption/emission
WORLDLY	dump switch, storage management system
LCOD	dump wavelength for CO-lines absorption calculation
ALBDUST	Dust albedo (Type-1)
ALBDT	Dust albedo (Type-2)
KDUST	Dust constant
EPDUST	Dust dilution factor
DFDUST	Dust factor
ADT	Dust opacity function

TDUST	Dust temperature
TDST	Dust temperature (Type-2)
DDT	Dust temperature (Type-2) iteration criterion
MDTR1	Dust temperature (Type-2) iteration criterion
MDTR2	Dust temperature (Type-2) iteration criterion
LMDUST	Dust wavelengths table
IDWIN	DW recomputation dump index increment
BANDE	eclipse calculation switch for Composite Line Opacity bands
BMWAC	eclipse continuum calculation beam width parameter
ZECL	eclipse continuum calculation Z values
ECLI	eclipse line profiles switch
NERM	`EDITH` error messages limit
NED	edit index for RHO
DELTB	edit parameter for departure coefficients
LME	edit parameter for Lyman Epsilon-1
LMF	edit parameter for Lyman Epsilon-1
LMT	edit parameter for Lyman Epsilon-1
DRHO	edit parameter for RHO
ISMVE	edit switch, small values
A	Einstein A
RZM	electron-contributing metals multiplier
NMT	electron-contributing metals number
NE	electron density
EIDIF	electron density iterations convergence criterion
NEFDF	electron density values for d-coefficients (diffusion)
ZME	electron ratio, non-H
AEL	electrons, added
QNL	electrons, "$n\ell$"
ELEMENT	element data
NMT	element data tables length
ELSYM	element symbol of the ion of the run
FMCDL	elimination criterion for Hydrogen Stark splitting components
FRCDL	elimination criterion for Hydrogen Stark splitting components
IPPOD	emission/absorption dump switch, population ions
DO	enable program options
ELLED	energy (particle) dissipation parameter

EMXED	energy (particle) dissipation parameter
NSPED	energy (particle) dissipation parameter
FCE	enhancement factors, CE
RKMULT	enhancement factors, RK
METEP	Epsilon (Lyman) method parameter
QTAIL	Epsilon (Lyman) Q-smoothing tail
EP1	Epsilon-1 (Lyman)
EPCBR	Epsilon-1 (Lyman) branching ratio
LMA	Epsilon-1 (Lyman) edit parameter
LMB	Epsilon-1 (Lyman) edit parameter
LME	Epsilon-1 (Lyman) edit parameter
LMF	Epsilon-1 (Lyman) edit parameter
LMR	Epsilon-1 (Lyman) edit parameter
LMT	Epsilon-1 (Lyman) edit parameter
WEP	Epsilon-1 (Lyman) weighting parameter
EP2	Epsilon-2 (Lyman)
NERM	error messages limit for `EDITH`
LSFTYP	escape probability approximation for RHO
ESCTAU	escape probability criterion, for automatic use
SOBOLEV	escape probability (Sobolev) parameter
SOBDMN	escape probability (Sobolev) parameter
SOBDMX	escape probability (Sobolev) parameter
SOBFEQ	escape probability (Sobolev) parameter
VSB	escape probability (Sobolev) velocity
KOELS	every-line switch for ORIGIN printout
CE	excitation coefficient, collsisional
TEX	excitation temperature
IXSTA	execution statistics printout control
VX	expansion velocity, additional
VXS	expansion velocity, basic
CVX	expansion velocity parameter
CVXS	expansion velocity parameter
JSFEX	explanation printing switch (line source function solution)
PW	exponent in Stark broadening term
MTHEI	exponential integral method selector
OPF	extinction factor for incident radiation

IDEX	extra standard-output (log file) information switch
IPEX	extra printout switch (for debugging)
RFAC	factor for all collision rates
DRIN	factor for diffusion reduction (initial value)
CUTFE	fast electrons calculation parameter
DQMAX	fast electrons calculation parameter
DQMIN	fast electrons calculation parameter
NNDFE	fast electrons calculation parameter
NVDFE	fast electrons calculation parameter
NVF	fast electrons calculation parameter
NXF	fast electrons calculation parameter
NZDFE	fast electrons calculation parameter
RCCFE	fast electrons calculation parameter
VMNFE	fast electrons calculation parameter
XJFE	fast electrons calculation parameter
XQMAX	fast electrons calculation parameter
PCE	FCE adjustment factor
NFE	FEN tables number
BHORIZ	field strength, magnetic
USE	file designation for input
CVXF	flow broadening parameter
CVXM	flow broadening parameter
FBVMX	flow broadening parameter
FNH	flow broadening parameter
HNDF	flow broadening parameter
NFB	flow broadening parameter
NFH	flow broadening parameter
WFB	flow broadening parameter
CHEFLOW	flow constant, Helium, for RHEAB calculation
FNH	flow velocity table, standard
VX	fluid velocity
VXS	fluid velocity
CDZ	fluid velocity parameter
CVSB	fluid velocity parameter
CVX	fluid velocity parameter
CVXS	fluid velocity parameter

CVZ	fluid velocity parameter
FMVLIM	fluid velocity parameter
LFLUX	flux distribution (line) calculation control switch
DOFLUX	flux distribution (line) calculation control switch
NFH	FNH length
MFONT	Fontenla atmosphere data output switch
FROSCE	forbidden transition, oscillator strength
ISMSW	format switch for iterative summaries
I4DEQ	four-diagonal method control parameter, Special-N1 (diffusion)
I4DFM	four-diagonal method control parameter, Special-N1 (diffusion)
I4DIO	four-diagonal method control parameter, Special-N1 (diffusion)
LHM	frequencies for H-minus
BXI	frequencies, standard, for background lines
XK	frequencies, standard, for continuum transitions
XI	frequencies, standard, for line transitions
XIBLU	frequencies, standard, for line transitions
XIBLUT	frequencies, standard, for line transitions
XIRED	frequencies, standard, for line transitions
XIREDT	frequencies, standard, for line transitions
XISYM	frequencies, standard, for line transitions
XISYMT	frequencies, standard, for line transitions
LSFFDB	frequency-dependent background for Line Source Function
DOFDB	frequency-dependent background for Line Source Function
KDRDP	frequency index for DRDMP
KLFIN	frequency interval for Lyman dump
IPRDF	frequency interval for partial redistribution printout
NU	frequency intervals
WNU	frequency intervals
MRR	FRR length
IPIJG	fudging of GNV in PIJ-calculation
DELLIM	FULL calculation of Line Source Function
DGAMMA	gamma ($\gamma^{u\ell}$) parameter, PRD transitions
GAMMA	gamma ($\gamma^{u\ell}$) parameter, PRD transitions
ZMASS	gas column mass
GK	Gaunt factors for Level-$\mathcal{N}$-to-Continuum transfer calculation
Z	geometrical depth

DGM	G-multiplier, HSE
DGMZ	G-multiplier, HSE, standard table
KDIFGA	GNV-fudging depth index
KDIFGB	GNV-fudging depth index
IPIJG	GNV-fudging, PIJ-calculation
KDIFGS	GNV-fudging switch
NGNV	GNV suppression level limit
MNG1	GNV-1 replacement limit index (ambipolar diffusion)
XMU	GR-weight-matrix MU table
LODCG	graph, diffusion calculations, control code
NODCG	graph, diffusion calculations, control code
LSFGC	graph, Line Source Function, control code
PROGLI	graph, profiles, delta-lambda limit
NGRL	graph Z-scale limit
NGRR	graph Z-scale limit
IZOPT	graph Z-scale option
JZOPT	graph Z-scale option for absorption/emission contributions
CLOGG	gravity, surface, log of
CGR	gravity ratio, with respect to Sun
LSTMP	GTN calculation print switch for STIM details
LHHSE	H (HSE) reference depth index
JHEAS	HEABD (secret switch)
KARB	'header' page character selector
CHEFLOW	Helium abundance calculation parameter
HEABL	Helium abundance calculation parameter
IHEAB	Helium abundance calculation parameter
RFHEAB	Helium abundance calculation parameter
RFHEAB	Helium abundance coefficient reduction factor
RHEAB	Helium abundance depth variation
HEABL	Helium abundance limit factor
PALBET	Helium diffusion term
PBETAL	Helium diffusion term
PBETGM	Helium diffusion term
PGMBET	Helium diffusion term
LEEDS	Helium lines background opacity debug printout switch
BDHE	Helium (neutral) departure coefficient

HEN	Helium (neutral) level populations
YH	Helium-to-Hydrogen ratio
LHEDS	Helium-II lines background opacity debug printout switch
BDHE2	Helium-II (singly ionized) departure coefficient
HEK	Helium-II (singly ionized) ground level population
HE2N	Helium-II (singly ionized) level populations
HE304	Helium-II λ304 line mean intensity
HE2K	Helium-III (doubly ionized) ground level population
NLZ	HEN tables number
NZ2	HE2N tables number
M304	HE304 reference index
KALHD	`Hi/Bye/Abort`-system control parameter
KALOR	`Hi/Bye/Abort`-system control parameter
AL	higher levels recombination fraction
NLH	HN tables number
HNAJL	HND adjustment factor limit for HSE
NFH	HNDF length
NVH	HNDV length
CLNH	HSE parameter
HNAJL	HSE parameter
HTAU	HSE parameter
LHHSE	HSE parameter
PZERO	HSE parameter
DGM	HSE parameter (buoyancy factor, or G-multiplier)
DGMZ	HSE parameter, standard table
HEL	HSE weight
HSEC	HSE weight
JHBFD	Hydrogen bound-free absorption and emission details printout
IXNCS	Hydrogen CE-values method switch
IXNCS	Hydrogen CI-values method switch
ICHDP	Hydrogen collisions dump depth index
LCH	Hydrogen collisions codes
ICHSW	Hydrogen collisions switch
NH	Hydrogen density
HNDF	Hydrogen density table for FNH
HNDV	Hydrogen density table for VNH

CPRESS	Hydrogen density recalculation parameter
WPRESS	Hydrogen density recalculation parameter
BDH	Hydrogen departure coefficient
KHFFS	Hydrogen free-free cooling rate control
IBRDP	Hydrogen ion broadening dump switch
HN	Hydrogen level populations
FNRMLA	Hydrogen Lyman α simulated background profile normalizing factor
FNRMLB	Hydrogen Lyman β simulated background profile normalizing factor
IGMSW	Hydrogen Lyman lines alternate GMMA, PRD
LMDL2	Hydrogen Lyman lines background opacity, DR parameter
LMDL3	Hydrogen Lyman lines background opacity, DR parameter
LMDR	Hydrogen Lyman lines background opacity, DR parameter
LMXC	Hydrogen Lyman lines background opacity, DR parameter
LMXP	Hydrogen Lyman lines background opacity, DR parameter
LMXX	Hydrogen Lyman lines background opacity, DR parameter
JHLSK	Hydrogen Lyman lines background opacity parameter
LLY	Hydrogen Lyman lines background opacity parameter
LMCR	Hydrogen Lyman lines background opacity parameter
LMDL2	Hydrogen Lyman lines background opacity parameter
LMDL3	Hydrogen Lyman lines background opacity parameter
LMDR	Hydrogen Lyman lines background opacity parameter
LMH	Hydrogen Lyman lines background opacity parameter
LMXC	Hydrogen Lyman lines background opacity parameter
LMXP	Hydrogen Lyman lines background opacity parameter
LMXX	Hydrogen Lyman lines background opacity parameter
NQLYM	Hydrogen Lyman lines background opacity parameter
IGMSW	Hydrogen Lyman lines GMMA, PRD
NLY	Hydrogen Lyman lines limit, background opacity
YK	Hydrogen recombination parameter
KHFFS	Hydrogen-run total cooling rate components control
KOOLSUM	Hydrogen-run total cooling rate components control
HSBDMN	Hydrogen Stark broadening calculation parameter
HSBDMX	Hydrogen Stark broadening calculation parameter
HSBFEQ	Hydrogen Stark broadening calculation parameter
HSBM	Hydrogen Stark broadening calculation parameter
IHSKM	Hydrogen Stark broadening calculation table limits

IHSSM	Hydrogen Stark broadening calculation table limits
IHSDD	Hydrogen Stark broadening dump switch
IHSDP	Hydrogen Stark broadening dump switch
CSTARK	Hydrogen Stark broadening switch
IHSSW	Hydrogen Stark broadening switch
CSDW	Hydrogen Stark splitting parameter
FMCDL	Hydrogen Stark splitting parameter
FRCDL	Hydrogen Stark splitting parameter
FSTKM	Hydrogen Stark splitting parameter
ISTARK	Hydrogen Stark splitting parameter
STARKI	Hydrogen Stark splitting parameter
IHSSP	Hydrogen Stark splitting switch
AHM	H-minus bound-free absorption coefficient
YHM	H-minus Continuum Source Function method control parameter
BDHM	H-minus departure coefficient
LHM	H-minus wavelengths table
NHTWS	H2 abundance computation switch
CEQMX	H2 abundance control parameter
MH2N	H2 number density output switch
TX	illuminating source brightness temperature
IBNVIEW	illustration of trace of BD- and ND-calculations, depth index for
R1N	illuminating source distance
CEDMN	impact-parameter CE-values calculation parameter
CEDMX	impact-parameter CE-values calculation parameter
CEFEQ	impact-parameter CE-values calculation parameter
TX	incident radiation, brightness temperature of illuminating source
ICR	incident radiation, coronal
DLU	incident radiation dilution factor
OPF	incident radiation extinction parameter
IRTIS	incident radiation input interpolation switch
FINK	incident radiation input parameter
XINK	incident radiation input parameter
NBS	index for b-smoothing
KB1WA	index for B1-weights
KB1WB	index for B1-weights
INCEI	index for CE-values comparison calculations

ICXDP	index for charge-exchange (upper-level) dump printout
INCEI	index for CI-values comparison calculations
IDFDI	index for d-coefficients detailed printout
PROGLI	index for delta-lambda axis in profile graphs
KKPR	index for detailed Lyman printout
IDRCD	index for disk rays, Continuum Source Function debug printout
IDRDP	index for DRDMP
KDRDP	index for DRDMP
KDIFGA	index for GNV-fudging
KDIFGB	index for GNV-fudging
LHHSE	index for HSE H and M
KOLEV	index for Level-$\mathcal{N}$-to-Continuum transfer calculation
NMLR	index for mass-loss-rate
JEDIT	index for N-editing
JH1	index for photoionization rates multiplier
JH2	index for photoionization rates multiplier
NDW	index for reference Doppler width
NDWM	index for reference Doppler width, for atmospheric model
M304	index for reference value of He-II λ304 line mean intensity
IHEAB	index for RHEAB calculation
JSSV	index for shock temperature
ISSV	index for shock velocity
ISRCD	index for shell rays, Continuum Source Function debug printout
ISOD	index for Sobolev integration dump
IBNVIEW	index for illustration of trace of BD- and ND-calculations
IMUCD	index for XMU, Continuum Source Function debug printout
IDWIN	index-increment for DW dump
ISCRS	'in memory' scratch I/O mode switch
NT	INPAIR length
USE	input file designation
INDRN	input number densities, renormalization switch
REFLM	input TAUK reference wavelength
INRHO	input-RHO-only switch
AW	integrated diagonal of WN-matrix
ISOD	integration (Sobolev) dump depth index
YRATE	integrations wavelengths damping parameter for rates calculations

WRATMN	integrations wavelengths limit for rates calculations
WRATMX	integrations wavelengths limit for rates calculations
TML	intensity integral TAU cut-off
TSM	intensity integral TAU cut-off
ISMBD	intensity integration (`SIMBA`) dump interval
IRTIS	interpolation switch for incident radiation data
KLDIN	interval, depth, for Lyman dump
IPRDD	interval, depth, for partial redistribution printout
ISMBD	interval for intensity integration (`SIMBA`) dump
KLFIN	interval, frequency, for Lyman dump
IPRDF	interval, frequency, for partial redistribution printout
TRFLI	interval limit for TR-effective calculation
MATRIX	inversion control parameters
IBRDP	ion broadening (Hydrogen) dump switch
ISCRS	I/O (scratch) mode switch
CI	ionization coefficient, collisional
CP	ionization data, K-shell
QIN	ionization data, K-shell
IXNCS	ionization potential lowering (Hydrogen)
IONSTAGE	ionization stage of ion of run
MASS	ion mass
NAME	ion name
RUNTOPOP	ion-of-the-run level correspondences
NOION	ion switch
BDFE	Iron (neutral) departure coefficient
FEN	Iron (neutral) level populations
FEK	Iron-II (singly ionized) ground level population
NFB	isotropic flow broadening velocities, number of
ITRFI	iteration (effective TR) debug output control
HSLITER	iteration limit
IOMX	iteration limit
ISUB	iteration limit
LYMITER	iteration limit
ITN1R	iteration limit (diffusion calculation)
ITPRD	iteration limit, PRD
ISMSW	iterative summaries format switch

WORLDLY	IWORLD dump control switch
JNUNC	JNU input switch for PRD
WNJUNK	'junk' criterion for WN-matrix
TE	kinetic temperature
KMMAX	KM limit
CP	K-shell photoionization data
QIN	K-shell photoionization data
BANDY	Kurucz Composite Line Opacity control parameter
KODNT	Kurucz Composite Line Opacity data dump control
BANDL	Kurucz Composite Line Opacity wavelength band
BANDU	Kurucz Composite Line Opacity wavelength band
ALBK	Kurucz opacity parameter
CQA	Kurucz opacity parameter
CQM	Kurucz opacity parameter
CQT	Kurucz opacity parameter
ZALBK	Kurucz opacity parameter
MKURU	Kurucz spectrum calculations data output switch
KUDNT	Kurucz Statistical Line Opacity data dump control
FKUR	Kurucz Statistical Line Opacity multiplier
KURIN	Kurucz Statistical Line Opacity parameter
KURMA	Kurucz Statistical Line Opacity parameter
KURMI	Kurucz Statistical Line Opacity parameter
MXTAP	KZAUG sum limit (diffusion calculation)
MXPPI	KZAUG value limit (diffusion calculation)
LDLMAX	LDL maximum
NDT	LDT length
LEVDES	level designation
NBS	level index for b-smoothing
NL	levels number
NSL	levels number, including supplementaries
MHM	LHM length
HEABL	limit factor for RHEAB calculation
FMVLIM	limit for fluid velocity multiplier
NLY	limit for Hydrogen Lyman lines, background opacity
HNAJL	limit for NH adjustment in HSE calculation
PARTLIM	limit for partition function component

LN	limit for saturation approximation in Lyman calculation
XCOMX	limit for width of CO-lines
MNG1	limit index for GNV-1 replacement (ambipolar diffusion)
MN1	limit index for N1 recalculation (ambipolar diffusion)
IPR01	limit index for 'PERDMPn' debug printouts
IPR02	limit index for 'PERDMPn' debug printouts
IPR03	limit index for 'PERDMPn' debug printouts
IPR04	limit index for 'PERDMPn' debug printouts
BLIMG	limiting index for graph of absorption/emission contributors
TLIMG	limiting index for graph of absorption/emission contributors
DLSF	limiting value for denominator of line source function
KMMAX	limiting value for XIFUL length
TLTR	limiting multiplier for TDST recalculation
TRFLI	limit interval for TR-effective calculation
NERM	limit on some error messages from `EDITH`
CORMAX	limit wavelength for ORIGINS and CONTRIBUTORS printouts
CORMIN	limit wavelength for ORIGINS and CONTRIBUTORS printouts
DDL	line, blended, component offset
DWN	line, blended, component offset
CDL	line, blended, component weight
BLCSW	line broadening components switch
IORIC	line-center depths-of-formation print switch
LFLUX	Line Flux Distribution (H) calculation control switch
DOFLUX	Line Flux Distribution (H) calculation control switch
LSFBOC	line opacity background control
OML	line opacity background multiplier
OLL	line opacity multiplier
LWNT	'Line Opacity' printout wavelengths interval
PROGLI	line profiles graphs control parameter
PROGLI	line profiles graphs delta-lambda axis limit
LOGAS	line profiles graphs switch
SGRAF	line profiles graphs switch
DOPROF	line profiles switch
PROF	line profiles switch
LSFFDB	Line Source Function background
DOFDB	Line Source Function background

ISCOMP	Line Source Function comparisons printout details switch
IPR01	Line Source Function debug printout limit index
IPR02	Line Source Function debug printout limit index
IPR03	Line Source Function debug printout limit index
IPR04	Line Source Function debug printout limit index
DLSF	Line Source Function denominator, limiting value for
JSFEX	Line Source Function explanation printing switch
LSFGC	Line Source Function graph control code
ESCTAU	Line Source Function method selection criterion
DOSFPRNT	Line Source Function printout
LSFPRINT	Line Source Function printout
LSFTYP	Line Source Function type selector
XI	line transitions standard frequencies
XIBLU	line transitions standard frequencies
XIBLUT	line transitions standard frequencies
XIRED	line transitions standard frequencies
XIREDT	line transitions standard frequencies
XISYM	line transitions standard frequencies
XISYMT	line transitions standard frequencies
INPAIR	list of indices defining line transitions
LDU	LMDUST length
JM	LMM length
LLY	LMXX length
LOGAS	location analysis graph switch
CLOGG	log(surface gravity)
MUF	look-angle cosines for flux
MU	look-angle cosines for intensity
IXNCS	lowering of ionization potential (Hydrogen)
NS	lower level of reference transition
RCOMIN	lower limit for CO abundance
LMZ	Lyman-α wing background opacity cut-off
LN	Lyman calculation parameter
EXLYM	Lyman change-over TAU parameter
TGLYM	Lyman change-over TAU parameter
XK	Lyman continuum transitions standard frequencies
KKPR	Lyman detail print frequency index

IDNRT	Lyman DNRT, DNRTC calculation switch
KLDIN	Lyman dump depth interval
KLFIN	Lyman dump frequency interval
METEP	Lyman Epsilon method parameter
EP1	Lyman Epsilon-1
LMA	Lyman Epsilon-1 edit parameter
LMB	Lyman Epsilon-1 edit parameter
LME	Lyman Epsilon-1 edit parameter
LMF	Lyman Epsilon-1 edit parameter
LMR	Lyman Epsilon-1 edit parameter
LMT	Lyman Epsilon-1 edit parameter
WEP	Lyman Epsilon-1 weighting parameter
EP2	Lyman Epsilon-2
GK	Lyman Gaunt factor
LYMITER	Lyman iteration limit
KOLEV	Lyman level index
LYODS	Lyman lines background opacity debug switch
JHLSK	Lyman lines background opacity parameter
LLY	Lyman lines background opacity parameter
LMCR	Lyman lines background opacity parameter
LMDL2	Lyman lines background opacity parameter
LMDL3	Lyman lines background opacity parameter
LMDR	Lyman lines background opacity parameter
LMH	Lyman lines background opacity parameter
LMXC	Lyman lines background opacity parameter
LMXP	Lyman lines background opacity parameter
LMXX	Lyman lines background opacity parameter
NQLYM	Lyman lines background opacity parameter
INFSM	Lyman RK-1 smoothing delimiter
INLSM	Lyman RK-1 smoothing delimiter
WSM	Lyman RK-1 smoothing parameter
LN	Lyman saturation approximation limit
XKLYM	Lyman XK-table augmentation switch
LHHSE	M (HSE) reference depth index
BDMG	Magnesium (neutral) departure coefficient
MGN	Magnesium (neutral) level populations

MGK	Magnesium-II (singly ionized) ground level population
BHORIZ	magnetic field strength
NMLR	mass loss rate index
LPMLR	mass loss rates printout switch
VM	mass motion velocity
MASS	mass of atom
ZMASS	mass of gas column
RFMAS	mass, reference
MAMAS	matrix elements magnitude scan switch
MATRIX	matrix inversion and generation control parameter
SMATC	matrix sample output selection criterion
FBVMX	maximum value of flow broadening velocity
LDLMAX	maximum value of LDL
KMMAX	maximum value of XIFUL length
JBAR	mean intensity
HE304	mean intensity of He-II λ304 line
M304	mean intensity of He-II λ304 line reference index
TSM	mean intensity change-over TAU
NERM	messages limit for `EDITH`
RZM	metal-electrons multiplier
ZME	metal-electrons ratio
ELEMENT	metals data
YCOL	method control parameter
YCONT	method control parameter
YCR	method control parameter
YHM	method control parameter
YKR	method control parameter
YL	method control parameter
YLDT	method control parameter
YLINE	method control parameter
YLYM	method control parameter
YRATE	method control parameter
YWAVE	method control parameter
IDFDM	method control parameter for d-coefficients (diffusion calculation)
IXNCS	method control parameter for Hydrogen CI-values
METEP	method control parameter for (Lyman) Epsilons

I4DEQ	method control parameter for Special-N1 (diffusion)
I4DFM	method control parameter for Special-N1 (diffusion)
I4DIO	method control parameter for Special-N1 (diffusion)
KBNDS	method control parameter for Special-N1 (diffusion)
KDAMP	method control parameter for Special-N1 (diffusion)
KDIAG	method control parameter for Special-N1 (diffusion)
N1MET	method control parameter for Special-N1 (diffusion)
METSE	method control parameter for statistical equilibrium equations
METSEDG	method control parameter for statistical equilibrium equations
METSEDW	method control parameter for statistical equilibrium equations
CEMETHOD	method selection, CE calculation
CIMETHOD	method selection, CI calculation
NMG	MGN tables number
V	microturbulence velocity
VR	microturbulence velocity
VNH	microturbulence velocity, quiet Sun
IRATE	'minimal' RATES calculation printout
MODLAB	'model name,' atmospheric
ISCRS	mode switch for scratch I/O
	molecular Hydrogen = H2
NHTSW	molecular Hydrogen abundance computation switch
LF	MUF length
COMU	MU for CO
MUF	MU for flux
XMU	MU for GR-weight matrix
MU	MU for intensity
L	MU length
MLC	multiplier for background opacity
MCE	multiplier for CE (default)
MCI	multiplier for CI (default)
MCOA	multiplier for CO-lines van der Waals damping
DGM	multiplier for G (HSE); or buoyancy factor
DGMZ	multiplier for G (HSE), standard table
DPMULT	multiplier for total damping
OML	multiplier for line background opacity
OLL	multiplier for line opacity

CQM	multiplier for scattering albedo
PMSK	multiplier for Stark halfwidth
JH1	multiplier index for photoionization rate
JH2	multiplier index for photoionization rate
FMVLIM	multiplier limit for fluid velocity
MN1	N1 recalculation limit depth (ambipolar diffusion)
NAME	name of ion
NNA	NAN tables length
CTCO	NCO calculation temperature enhancement factor
CTMX	NCO calculation temperature enhancement limit
ZRCO	NCO calculation temperature enhancement reference height
SHCOP	NCO calculation temperature enhancement scale height
SHCOC	NCO calculation temperature enhancement scale height
IBNVIEW	ND-calculation trace illustration, depth index for
ZNDW	NDW-default criterion
JEDIT	N-editing depth index
JNEDP	N-editing details printout switch
JNEDP	N-editing dump switch
ISTARK	NE-index for Stark splitting of Hydrogen lines
STARKI	NE-index for Stark splitting of Hydrogen lines
EIDIF	NE-iterations convergence criterion
	net radiative bracket = RHO
KRATE	net-vs.-single rate switch for statistical equilibrium equations
NEFDF	NE-values for d-coefficients (diffusion calculation)
HNAJL	NH adjustment factor limit for HSE calculation
WSN1D	NK weight, Special-N1 calculation (diffusion)
QNL	"$n\ell$" electrons
NOION	'no ion' switch
ZME	non-H electrons ratio
FNRMLA	normalizing factor for simulated background Hydrogen Lyman α profile
FNRMLB	normalizing factor for simulated background Hydrogen Lyman β profile
ND	number densities
ALN	number densities, Aluminum
CAN	number densities, Calcium
CN	number densities, Carbon
HEN	number densities, Helium

HE2N	number densities, Helium-II
HN	number densities, Hydrogen
INDRN	number densities, input, renormalization switch
FEN	number densities, Iron
MGN	number densities, Magnesium
ON	number densities, Oxygen
O2N	number densities, Oxygen-II
O3N	number densities, Oxygen-III
SIN	number densities, Silicon
NAN	number densities, Sodium
SN	number densities, Sulphur
NK	number density, protons
ALK	number density, Aluminum-II (singly ionized) ground state
CAK	number density, Calcium-II (singly ionized) ground state
CK	number density, Carbon-II (singly ionized) ground state
NC	number density, charged particles
MCON	number density, CO, output switch
HEK	number density, Helium-II (singly ionized) ground state
HE2K	number density, Helium-III (singly ionized) ground state
MH2N	number density, H2, output switch
FEK	number density, Iron-II (singly ionized) ground state
MGK	number density, Magnesium-II (singly ionized) ground state
OK	number density, Oxygen-II (singly ionized) ground state
O2K	number density, Oxygen-III (singly ionized) ground state
O3K	number density, Oxygen-IV (singly ionized) ground state
SIK	number density, Silicon-II (singly ionized) ground state
NAK	number density, Sodium-II (singly ionized) ground state
SK	number density, Sulphur-II (singly ionized) ground state
NL	number of atomic levels
NFB	number of isotropic flow broadening velocities
NSL	number of supplementary atomic levels
TLARGE	numerical control parameter for WN-matrix calculation
TSMALL	numerical control parameter for WN-matrix calculation
WSN1D	N1 weight, Special-N1 calculation (diffusion)
NLO	ON tables number
NO2	O2N tables number

NO3	O3N tables number
KONFORM	opacity contributions details printout format switch
NABS	opacity contributions switch
LSFBOC	opacity control
ADT	opacity function, dust
MLC	opacity multiplier
OML	opacity multiplier
OLL	opacity multiplier
LMM	opacity multiplier wavelengths
WAVES	opacity, wavelengths for additional calculations
TS	optical depth, standard
KTRANS	optically-thin transitions descriptor
DO	options
OMIT	options
KOELS	ORIGINS printouts every-line switch limit
CORMAX	ORIGINS printouts wavelength limit
CORMIN	ORIGINS printouts wavelength limit
FROSCE	oscillator strength for forbidden transitions
SCOW	output, Continuum Calculations, selected wavelengths
IFXDS	output control for continuum flux details
IRPUN	output switch for abundance ratio calculation
MCON	output switch for CO number density
MDFG	output switch for diffusion terms (GVL)
MDFV	output switch for diffusion velocity
MFONT	output switch for Fontenla atmosphere data
MH2N	output switch for H2 number density
MKURU	output switch for Kurucz spectrum calculations data
MTREF	output switch for TR-effective
IOMX	overall iterations limit
LOXDS	Oxygen lines background opacity debug printout switch
BDO	Oxygen (neutral) departure coefficient
ON	Oxygen (neutral) level populations
LX2DS	Oxygen-II lines background opacity debug printout switch
BDO2	Oxygen-II (singly ionized) departure coefficient
OK	Oxygen-II (singly ionized) ground level population
O2N	Oxygen-II (singly ionized) level populations

BDO3	Oxygen-III (doubly-ionized) departure coefficient
O2K	Oxygen-III (doubly ionized) ground level population
O3N	Oxygen-III (doubly ionized) level populations
LX3DS	Oxygen-III lines background opacity debug printout switch
O3K	Oxygen-IV (triply ionized) ground level population
ELLED	particle energy dissipation parameter
EMXED	particle energy dissipation parameter
NSPED	particle energy dissipation parameter
PART	Partition function
PARTLIM	Partition function component limit
IWSMD	Part-2 of WAVELENGTHS summary, switch
KTRANS	passive transition descriptor
IPERFA	performance data archive record switch
IXSTA	performance statistics printout control
NCOPT	performance statistics switch for CO-lines opacity calculation
IPR01	`PERSEUS` 'PERDMPn' debug printout limit index
IPR02	`PERSEUS` 'PERDMPn' debug printout limit index
IPR03	`PERSEUS` 'PERDMPn' debug printout limit index
IPR04	`PERSEUS` 'PERDMPn' debug printout limit index
TSM	Phase-2 intensities change-over TAU
RKC	photoionization (additional) parameter
TKR	photoionization (additional) parameter
YKR	photoionization (additional) parameter
CP	photoionization cross-section
RQCP	photoionization cross-section ratios
RRCP	photoionization cross-section ratios
JATAW	photoionization cross-section ratios, output switch
CP	photoionization data, K-shell
QIN	photoionization data, K-shell
RK	photoionization rate
JH1	photoionization rate multiplier index
JH2	photoionization rate multiplier index
RL	photorecombination rate
Z	photosphere depth
IPIJG	PIJ-calculation, GNV fudging
IRATE	PIJ printout

IPPOD	population ion absorption/emission dump switch
RUNTOPOP	population ion level correspondences
MOPRNT	population-ion-model, built-in, printout switch
N1NUP	populations-of-the-run update switch, Special-N1 (diffusion)
WPOP	populations updating weight
POPUP	population tables update switch
	PRD = partial redistribution
DDR	PRD DR parameter, transitions
DRLIM	PRD DR parameter, transitions
TAUCL	PRD DR parameter, transitions
XC	PRD DR parameter, transitions
XCL	PRD DR parameter, transitions
XDR	PRD DR parameter, transitions
XP	PRD DR parameter, transitions
XR	PRD DR parameter, transitions
IGMSW	PRD GMMA for H Lyman alph and beta
PRDCV	PRD iterations convergence criterion
ITPRD	PRD iterations limit
JNUNC	PRD JNU input switch
SCH	PRD on/off switch
IPRDD	PRD printout depth interval
IPRDF	PRD printout frequency interval
IGII	PRD RII-function approximation selector
ISNUD	PRD SNU-shift debug dump switch
NSPRD	PRD switch (secret)
NLPAIR	principal quantum number
KONFORM	print format switch
JZATMO	print mode switch (zeroes) for ATMOSPHERE
JZATOM	print mode switch (zeroes) for ATOM
KCOAA	print switch, abbreviated form of Composite Line Analysis
IPDEE	print switch, diffusion d-coefficients
JSFEX	print switch, Line Source Function explanation
MSSPR	print switch, Special-N1 simultaneous solution matrix
IWEIT	print switch, weighting details
IPEX	printout, extra, switch (for debugging)
MOPRNT	printout switch for built-in population-ion-model

NECLIP	printout switch for continuum eclipse calculation
IPDIJ	printout switch for DIJ (diffusion)
ISCOMP	printout switch for Line Source Function comparisons details
LPMLR	printout switch for mass loss rates
JNEDP	printout switch for N-editing details
LPVEL	printout switch for profile velocities
IRUNT	production run switch
NANAL1	profile ANALYSIS depth selection parameter
NANAL2	profile ANALYSIS depth selection parameter
VX	profiles expansion velocity (additional)
PROGLI	profiles graphs delta-lambda axis limit
SGRAF	profiles graphs switch
FNRMLA	profile simulation normalizing factor, background Hydrogen Lyman α
FNRMLB	profile simulation normalizing factor, background Hydrogen Lyman β
DOPROF	profiles switch
PROF	profiles switch
LPVEL	profile velocities printout switch
NP	proton density
NLPAIR	quantum number, principal
NLPAIR	quantum number, rotational
VNH	quiet Sun broadening velocity
MQT	QTAIL length
TRN	radiation temperature
FINK	radiation (incident) input parameter
XINK	radiation (incident) input parameter
ICR	radiation, incident coronal
CRD	radiative damping halfwidth
KTRANS	radiative transition descriptor
INPAIR	radiative transitions indices
FRR	radius fraction
IRATE	RATES calculation printout switch
WRAT	rates integrations wavelengths
WRATMN	rates integrations wavelengths limit, (standard table)
WRATMX	rates integrations wavelengths limit, (standard table)
JATAW	rates integrations wavelengths output switch
YRATS	rates integrations wavelengths, standard, damping parameter

ADS	ratio of angular diameters, Sun/Star
KPCR	ratio of input opacities
RRCP	ratio of photoionization cross-sections
JATAW	ratio of photoionization cross-sections, output switch
NTAN	ray-selection parameter for WN-matrix, spherical coordinates
MSKIP	ray-selection parameter for WN-matrix, spherical coordinates
CN1S	rcheck criterion (diffusion calculation, Special-N1)
AL	recombination fraction, added
APARAD	recombination parameter (Aldovrandi and Pequignot)
APCDP	recombination parameter
APCI	recombination parameter (Romanik)
APEI	recombination parameter (Romanik)
APETA	recombination parameter (Aldovrandi and Pequignot)
APWRA	recombination parameter (Aldovrandi and Pequignot)
APWRB	recombination parameter (Aldovrandi and Pequignot)
NAPKNT	recombination parameter (Romanik)
NAPWRA	recombination parameter (Aldovrandi and Pequignot)
NAPWRB	recombination parameter (Aldovrandi and Pequignot)
YK	recombination parameter (Hydrogen)
RFAC	reduction factor, all collision rates
FSTKM	reduction factor, for Hydrogen Stark splitting
RFHEAB	reduction factor, for RHEAB calculation
LHHSE	reference depth index for H and M, HSE
ZRCO	reference height, NCO calculation temperature enhencement
ZNDW	reference index criterion for Doppler width
NDW	reference index for Doppler width
NDWM	reference index for Doppler width (for atmospheric model)
M304	reference index for He-II λ304 line mean intensity
IRFNC	reference index for Hydrogen CE and CI calculation
IHEAB	reference index for RHEAB calculation
RFMAS	reference mass
NS	reference transition lower level index
MS	reference transition upper level index
REFLM	reference wavelength for input TAUK
INDRN	renormalization of input number densities
CRS	resonance broadening halfwidth

	RHEAB = depth dependence of total Helium abundance
CHEFLOW	RHEAB calculation parameter
HEABL	RHEAB calculation parameter
IHEAB	RHEAB calculation parameter
RFHEAB	RHEAB calculation parameter
JHEAS	RHEAB (secret switch)
JBDNC	RHO and departure coefficients ratio calculations bypass switch
RHOCR	RHO criterion
NED	RHO editing index
DRHO	RHO editing parameter
INRHO	RHO, input-only, selector
CWJ	RHOJ calculation parameter
CHI	RHO-like line transfer quantity
CHLIM	RHO selection parameter
CHOP	RHO selection parameter
CWR	RHO selection parameter
ILI	RHO selection parameter
NIL	RHO selection parameter
RHOPT	RHO selection parameter
SMOOTH	RHO smoothing parameters
WR	RHO-weighting factor
RHOWT	RHO weights
RHWT	RHO weights
INCH	RHO weights adjustment parameter
SMP	RHO weights adjustment parameter
WMN	RHO weights adjustment parameter
WMX	RHO weights adjustment parameter
WRMN	RHO weights adjustment parameter
WRMX	RHO weights adjustment parameter
IGII	RII-function approximation selector, PRD
IRKCOMP	RK-components initial calculation switch
RKMULT	RK enhancement factors
RKW	RK-weights
RKWT	RK-weights
IRLCOMP	RL-components initial calculation switch
NLPAIR	rotational quantum number

MR	RRNU length
IRUNT	run type switch
LN	saturation approximation limit in Lyman calculation
SHCOC	scale height, chromospheric, NCO temperature enhancement
SHCOP	scale height, photospheric, NCO temperature enhancement
SCTS	scale height, shock temperature
SCVS	scale height, shock velocity
CQM	scattering albedo multiplier
CQA	scattering albedo parameter
CQT	scattering albedo parameter
CLM	scattering albedo parameter
PNH	scattering albedo parameter
SRCO	scattering ratio for CO lines
NSW	SCOW length
ISCRS	scratch I/O mode switch
NSPRD	secret PRD switch
SCOW	selected wavelengths for Continuum Calculation output
SMATC	selection criterion for matrix sample output
IBETSW	selection parameter for beta-equation, diffusion
KB1WS	selection parameter for b-1 weights
IDFDM	selection parameter for d-coefficients (diffusion calculation)
NEFDF	selection parameter for d-coefficients NE-values (diffusion calculation)
MSKIP	selection parameter for WN-matrix rays, spherical coordinates
NTAN	selection parameter for WN-matrix rays, spherical coordinates
BLCSW	selectors for line broadening
BLCSW	selectors for line damping
ASMCR	sequential smoothing parameter
NIASM	sequential smoothing parameter
JSSV	shock temperature parameter
SCTA	shock temperature parameter
SCTS	shock temperature parameter
ISSV	shock velocity parameter
SCVA	shock velocity parameter
SCVB	shock velocity parameter
SCVS	shock velocity parameter
BDSI	Silicon (neutral) departure coefficient

SIN	Silicon (neutral) level populations
SIK	Silicon-II (singly ionized) ground level population
ISMBD	`SIMBA` (intensity integration) dump interval
FNRMLA	simulated background profile normalizing factor, Hydrogen Lyman α
FNRMLB	simulated background profile normalizing factor, Hydrogen Lyman β
MSSPR	simultaneous solution matrix print switch, Special-N1
KRATE	single-vs.-net rate switch for statistical equilibrium equations
NDSN1	skip Special-N1 (ambipolar diffusion)
TMS	small TAU change-over for RT
VSMLL	small value to replace denominators = 0
ISMVE	small values editing switch
IXASM	smoothing debug printout (IPEX=15) details control index
IDFDS	smoothing of d-coefficients (diffusion calculation)
NBS	smoothing of departure coefficients, level control index
LDFD1	smoothing of derivatives (numerical)
SMOOTH	smoothing of RHO
WSM	smoothing parameter for Lyman RK-1
SMOOTH	smoothing parameters for RHO
ASMCR	smoothing ('sequential') parameter
NIASM	smoothing ('sequential') parameter
QTAIL	smoothing tail for Lyman EP1 Q values
ISNDD	S(n) calculation dump switch
VXS	source function expansion velocity
SOBOLEV	Sobolev calculation parameter
SOBDMN	Sobolev calculation parameter
SOBDMX	Sobolev calculation parameter
SOBFEQ	Sobolev calculation parameter
ISOD	Sobolev integration dump depth index
VSB	Sobolev velocity
CVSB	Sobolev velocity parameter
BDNA	Sodium (neutral) departure coefficient
NAN	Sodium (neutral) level populations
NAK	Sodium-II (singly ionized) ground level population
LSFFDB	source function (line) background type
DOFDB	source function (line) background type
ISNDD	source function (line) dump switch

BANDY	source function method control parameter
YCONT	source function method control parameter
YHM	source function method control parameter
YL	source function method control parameter
YLINE	source function method control parameter
YRATE	source function method control parameter
YWAVE	source function method control parameter
DOSFPRNT	source function printout
LSFPRINT	source function printout
LSFTYP	source function solution type selector
TX	source temperature
AOWXP	Special-N1 (diffusion), alpha(old) weight exponent
SN1CC	Special-N1 (diffusion), convergence criterion
ITN1R	Special-N1 (diffusion), iterations limit
MSSPR	Special-N1 (diffusion), matrix print switch
I4DEQ	Special-N1 (diffusion), method control parameter
I4DFM	Special-N1 (diffusion), method control parameter
I4DIO	Special-N1 (diffusion), method control parameter
KBNDS	Special-N1 (diffusion), method control parameter
KDAMP	Special-N1 (diffusion), method control parameter
KDIAG	Special-N1 (diffusion), method control parameter
N1MET	Special-N1 (diffusion), method control parameter
N1NUP	Special-N1 (diffusion), populations-of-the-run update switch
WSN1D	Special-N1 (diffusion), weight for N1 and NK
MSKIP	spherical coordinates WN-matrix ray selection parameter
NTAN	spherical coordinates WN-matrix ray selection parameter
IONSTAGE	stage of ionization of ion of run
BXI	standard frequencies for background lines
XK	standard frequencies for continuum transitions
XI	standard frequencies for line transitions
XIBLU	standard frequencies for line transitions
XIBLUT	standard frequencies for line transitions
XIRED	standard frequencies for line transitions
XIREDT	standard frequencies for line transitions
XISYM	standard frequencies for line transitions
XISYMT	standard frequencies for line transitions

IDEX	standard-output (log file) extra data switch
FNH	standard table of flow velocity
TS	standard TAU table
YRATS	standard wavelengths for rates integrations, damping parameter
WRATMN	standard wavelengths for rates integrations, limit
WRATMX	standard wavelengths for rates integrations, limit
IHSDD	Stark broadening, convolution, dump switch (Hydrogen)
IHSDP	Stark broadening, convolution, dump switch (Hydrogen)
HSBDMN	Stark broadening, convolution, parameter (Hydrogen)
HSBDMX	Stark broadening, convolution, parameter (Hydrogen)
HSBFEQ	Stark broadening, convolution, parameter (Hydrogen)
HSBM	Stark broadening, convolution, parameter (Hydrogen)
CSTARK	Stark broadening, convolution, switch (Hydrogen)
IHSSW	Stark broadening, convolution, switch (Hydrogen)
IHSKM	Stark broadening, convolution, table limit (Hydrogen)
IHSSM	Stark broadening, convolution, table limit (Hydrogen)
CSK	Stark broadening halfwidth
PW	Stark broadening halfwidth exponent
JHLSK	Stark broadening switch, H Lyman lines background opacity
PMSK	Stark broadening halfwidth multiplier
CSDW	Stark splitting parameter (Hydrogen)
FMCDL	Stark splitting parameter (Hydrogen)
FRCDL	Stark splitting parameter (Hydrogen)
FSTKM	Stark splitting parameter (Hydrogen)
ISTARK	Stark splitting parameter (Hydrogen)
STARKI	Stark splitting parameter (Hydrogen)
IHSSP	Stark splitting switch (Hydrogen)
ADS	Star/Sun angular diameter ratio
WEIGHT	statistical equilibrium equation parameter
METSE	statistical equilibrium equation method control parameter
METSEDG	statistical equilibrium equation method control parameter
METSEDW	statistical equilibrium equation method control parameter
KRATE	statistical equilibrium equation net-vs.-single rate switch
KUDNT	Statistical Line Opacity (Kurucz) data dump control
FKUR	Statistical Line Opacity (Kurucz) multiplier
ALBK	Statistical Line Opacity (Kurucz) parameter

KURIN	Statistical Line Opacity (Kurucz) parameter
KURMA	Statistical Line Opacity (Kurucz) parameter
KURMI	Statistical Line Opacity (Kurucz) parameter
ZALBK	Statistical Line Opacity (Kurucz) parameter
P	statistical weight
LSTMP	STIM for GTN calculation details print switch
WORLDLY	storage management system dump control switch
ISUB	sub-iterations limit
DELWAVE	'subtractional' wavelengths
BDS	Sulphur (neutral) departure coefficient
SN	Sulphur (neutral) level populations
SK	Sulphur-II (singly ionized) ground level population
ISMSW	summaries, iterative, format switch
NSL	supplementary atomic levels
JBFSW	supplementary levels b calculation methods switch
NGNV	suppression level limit for GNV (diffusion calculation)
CLOGG	surface gravity (log)
IBETSW	switch for beta-equation, diffusion
KB1WS	switch for b-1 weights
NABS	switch for controlling absorbers
POPUP	switch for controlling updating of population tables
MCON	switch for CO number density output
IDFDM	switch for d-coefficients method (diffusion calculation)
IDEDP	switch for diffusion d-coefficients debug printout
MDFG	switch for diffusion terms (GVL) output
MDFV	switch for diffusion velocity output
KDIFGS	switch for GNV fudging
MH2N	switch for H2 number density output
IRTIS	switch for incident radiation input data interpolation
JNUNC	switch for input JNU data
INDRN	switch for input number densities renormalization
INRHO	switch for input-RHO-only
IBRDP	switch for ion broadening (Hydrogen) debug printout
MKURU	switch for Kurucz spectrum calculations data output
IDNRT	switch for Lyman DNRT, DNRTC calculation
MAMAS	switch for matrix elements magnitude scan

JNEDP	switch for N-editing details printout
JNEDP	switch for N-editing dump printout
KOELS	switch for ORIGIN printout (every-line)
ISNUD	switch for PRD SNU-shift debug printout
ISCRS	switch for scratch I/O mode
ISNDD	switch for S(n) calculation dump
KRATE	switch for statistical equilibrium equation (net-vs.-single rate)
WORLDLY	switch for storage management system dump
ELSYM	symbol, element, of ion of run
QTAIL	tail for smoothing Lyman EP1 Q values
EXLYM	TAU change-over parameter, Lyman
TGLYM	TAU change-over parameter, Lyman
ESCTAU	TAU criterion for automatic use of escape probability solution
TML	TAU cut-off for intensity integrals
TAUKIN	TAUK input values
REFLM	TAUK input values reference wavelength
TS	TAU, standard
TLTR	TDST recalculation limiting multiplier
WTD	TDST recalculation weight
TB	temperature, blanketing
TX	temperature, brightness, of illuminating source
TDST	temperature, Dust (Type-2)
TE	temperature, electron
CTCO	tempearture enhancement factor, NCO calculation
CTMX	tempearture enhancement limit, NCO calculation
TEX	temperature, excitation
TE	temperature, kinetic
TRN	temperature, radiation
SCTA	temperature, shock, amplitude
JSSV	temperature, shock, depth index
SCTS	temperature, shock, scale height
TER	temperature table for CE and CI
ISCRS	temporary scratch disk file switch
NTE	TER length
ACE	term to be added to CE (default)
ACI	term to be added to CI (default)

CIJADD	term to be added to CIJ
CKADD	term to be added to CK
MCE	term to multiply CE (default)
MCI	term to multiply CI (default)
KTRANS	thick transition descriptor
KTRANS	thin transition descriptor
LR	TKR length
KANTNU	TNU analysis
KOOLSUM	total cooling rates components control
CHEFLOW	total Helium abundance calculation parameter
HEABL	total Helium abundance calculation parameter
IHEAB	total Helium abundance calculation parameter
RFHEAB	total Helium abundance calculation parameter
RHEAB	total Helium abundance, depth variation
KHFFS	total Hydrogen cooling control
NH	total Hydrogen density
KALHD	traceback (`Hi/Bye/Abort`-system) control parameter
IBNVIEW	trace of BD- and ND-calculations, depth index for
KALOR	traceback (`Hi/Bye/Abort`-system) control parameter
KTRANS	transition descriptor
INPAIR	transition indices
NT	transitions number
LDINT	transition terms detail print control parameter
LDTYP	transition terms detail print control parameter
KTRANS	transparent transition descriptor
ITRFI	TR-effective calculation debug output control
TRFLI	TR-effective calculation limit interval
MTREF	TR-effective output switch (file `.msc`)
M	TS length
VT	turbulent pressure velocity
KTRANS	two-photon transition descriptor
CCHX	upper-level charge-exchange parameter
ICXDP	upper-level charge-exchange parameter
RCHX	upper-level charge-exchange parameter
XRKH	upper-level charge-exchange term
XRLH	upper-level charge-exchange term

MS	upper level of reference transition
INRHO	use input-RHO only
CVW	van der Waals broadening halfwidth
MCOA	van der Waals damping multiplier for CO-lines
MDFV	velocity, ambipolar diffusion, output switch
APDDIFC	velocity, ambipolar diffusion, parameter
APDDTFC	velocity, ambipolar diffusion, parameter
APDTEXP	velocity, ambipolar diffusion, parameter
APDXICA	velocity, ambipolar diffusion, parameter
APDXICB	velocity, ambipolar diffusion, parameter
APDXICC	velocity, ambipolar diffusion, parameter
APDXICD	velocity, ambipolar diffusion, parameter
V	velocity, broadening
VR	velocity, broadening
VNH	velocity, broadening, quiet Sun
VX	velocity, expansion, for profiles
VXS	velocity, expansion, for source functions
CVX	velocity, expansion, parameter
CVXS	velocity, expansion, parameter
CVXF	velocity, flow broadening, parameter
CVXM	velocity, flow broadening, parameter
FBVMX	velocity, flow broadening, parameter
NFB	velocity, flow broadening, parameter
WFB	velocity, flow broadening, parameter
VM	velocity, mass motion
V	velocity, microturbulence
VR	velocity, microturbulence
VNH	velocity, microturbulence, quiet Sun
FMVLIM	velocity multiplier limit
CDZ	velocity parameter
CVZ	velocity parameter
SCVA	velocity, shock, amplitude
ISSV	velocity, shock, depth index
SCVB	velocity, shock, parameter
SCVS	velocity, shock, scale height
VSB	velocity, Sobolev

CVSB	velocity, Sobolev, parameter
VT	velocity, turbulent pressure
VOITC	Voigt profile subroutine recomputation cut-off criterion
NVOIT	Voigt profile subroutine execution statistics printout switch
IVOIT	Voigt profile subroutine selection switch
NVX	VX tables number
BANDL	wavelength band limit for Composite Line opacity
BANDU	wavelength band limit for Composite Line opacity
LWNT	wavelength interval for 'Line Opacities' printouts
WAVEMN	wavelength limit for automatic additional wavelengths
WAVEMX	wavelength limit for automatic additional wavelengths
LMH	wavelength limit for H Lyman lines background opacity
CORMAX	wavelength limit for ORIGINS and CONTRIBUTORS printouts
CORMIN	wavelength limit for ORIGINS and CONTRIBUTORS printouts
REFLM	wavelength of input TAUK values
TKR	wavelengths for additional photoionization
LDT	wavelengths for Dust opacity calculation (Type-2)
XCOL	wavelengths for each CO-line
LCR	wavelengths for incident coronal radiation
LMM	wavelengths for opacity multiplier
WRAT	wavelengths for rates integrations
JATAW	wavelengths for rates integrations, output switch
LWNT	wavelengths interval for 'Line Opacity' printouts
SCOW	wavelengths, selected, for Continuum Calculations output
ICDIT	wavelengths selector, continuum, for dI/dh
IWSMD	WAVELENGTHS summary Part-2 switch
DELWAVE	wavelengths to be deleted
NWV	WAVES length
AOWXP	weight exponent for alpha(old), Special-N1 (diffusion)
WPRESS	weight for adjusting NH to constant pressure
WBD	weight for departure coefficient updating
WBDIR	weight for 'direct' departure coefficient
WFB	weight for flow-broadened component profiles
NQLYM	weight for H Lyman lines background opacity
HEL	weight for HSE calculation
HSEC	weight for HSE calculation

WEP	weight for Lyman EP1, EP2
WPOP	weight for populations updating
WSN1D	weight for Special-N1 and -NK (diffusion)
WTD	weight for TDST recalculation
WZM	weight for Z-from-mass calculation
WZ	weight for Z-from-TAUKIN calculation
TBAR	weight matrix change-over TAU
XMU	weight matrix MU table
MSKIP	weight matrix (spherical) ray selection parameter
NTAN	weight matrix (spherical) ray selection parameter
IWEIT	weighting details print switch
RHOWT	weights for RHO calculation
RHWT	weights for RHO calculation
RKW	weights for RK-1 calculation
RKWT	weights for RK-1 calculation
WEIGHT	weights for statistical equilibrium equations
XCOMX	width limit for CO-lines
TLARGE	WN-matrix calculation numerical control parameter
TSMALL	WN-matrix calculation numerical control parameter
WNJUNK	WN-matrix 'cleanup' parameter
AW	WN-matrix integrated diagonal
MATRIX	WN-matrix inversion and generation control parameter
WNJUNK	WN-matrix 'junk' parameter
MSKIP	WN-matrix (spherical) ray selection parameter
NTAN	WN-matrix (spherical) ray selection parameter
WORLDLY	WORLD dump control switch
NCL	XCOL length
NDR	XDR length
K	XI length
KB	XIBLU length
KBT	XIBLUT length
KBTMAX	XIBLUT length limit
KR	XIRED length
KRT	XIREDT length
KRTMAX	XIREDT length limit
KS	XISYM length

KST	XISYMT length
KSTMAX	XISYMT length limit
KMMAX	XIFUL length limit
INK	XINK length
KK	XK length
KXLYM	XK-table, Lyman, augmentation switch
LG	XMU length
TAUCL	XXC parameter (partial redistribution)
XCL	XXC parameter (partial redistribution)
N	Z length
NKA	ZALBK length
ITKZA	Z-augmentation (diffusion calculation) iteration limit
MAUX	ZAUX index
LZA	ZAUX length
NZE	ZECL length
JZATMO	zero-print mode switch for ATMOSPHERE
JZATOM	zero-print mode switch for ATOM
CPRESS	Z-from-mass calculation parameter
WPRESS	Z-from-mass calculation parameter
WZM	Z-from-mass calculation weight
WZ	Z-from-TAUKIN calculation weight
FZION	ZION multiplier (ambipolar diffusion)
ZXMIN	ZION parameter (ambipolar diffusion)
NGRL	Z-scale limit for graphs
NGRR	Z-scale limit for graphs
JZOPT	Z-scale option for absorption/emission contributions graphs
IZOPT	Z-scale option for graphs
ZGM	Z-table for DGMZ (HSE)
ZECL	Z-table for eclipse continuum calculation

(Section 5 – last revised: 2007 Apr 13)

Section 6: **Program Options**

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Many features of PANDORA may be enabled or disabled, as desired. Some of these optional features are controlled by assigning particular values to certain input parameters; all others are controlled through the following two input statements:

"**DO (** OPTION_1 OPTION_2 OPTION_3 ... OPTION_n **)** ",

i.e. `DO ( ADDCOPR EPSW )` , and

"**OMIT (** OPTION_1 OPTION_2 OPTION_3 ... OPTION_n **)** ",

i.e. `OMIT ( FELE SCOPRNT QSFEDIT )` ,

where OPTION_i is the alphanumeric code name, to be described below, of a particular processing or output feature of PANDORA. Options appearing in **DO** statements will be enabled, those appearing in **OMIT** statements will be disabled. Only the OPTIONs appearing in the following table are valid. There may be any number of **DO** and/or **OMIT** statements, and a particular OPTION may appear several times – however, only the status resulting from its last appearance will prevail. Every OPTION not mentioned in **DO** and/or **OMIT** statements will retain its default setting.

All OPTIONS are listed and defined on the following table. This list is in alphabetical order by option name; the default settings are given in parentheses. After this table of definitions there follows an alphabetized listing of keywords and descriptive phrases for each OPTION – this last list should be consulted when an OPTION's significance or function are only vaguely known, and its name is sought. After the OPTION name has been located in the keywords list, the complete definition can then be found in the first part of this section.

Notes

See next page for important information about automatic options adjustments.

Note:

After all **DO** and/or **OMIT** statements have been read, and before the printout OPTIONS is produced, some options are reset automatically as follows, in the sequence shown:

- If PHASE2 is off: LIGHT, ECLIPSE and EMERINT are turned off;
- If FINITE is off: REFLECT is turned off;
- If FINITE and INCRFRNT are both off: INCIDNT is turned off;
- If SPHERE is on: SPHOUT, GDS, ENHANCE, HSE, INCIDNT and INCIFRNT are turned off;
- If USETRIN is off: CSWITCH is turned off;
- If ORT is on: GDS is turned off;
- If SPECSAV is on: CONSAV and PROSAV are turned on.
- If SPHERE and PRODMP are both on: ECLIDMP and LINTDMP are turned on.

ACSFPRNT (off):
print abbreviated results of continuum source function calculation (used only if CSFPRNT is on).

ADDCOPR (off):
print continuum data for additional wavelengths.

ADN1DMP (off):
print details of "sepcial N1" calculation (used only when ADN1PRNT is on).

ADN1PRNT (on):
print "special N1" calculation results (used only if AMBPRNT is on).

AEDIT (off):
replace negative final A-values (frequency integration weights) with zero.

AHSEPRNT (off):
print abbreviated results of HSE calculation.

AINDPRNT (off):
print abbreviated version of INPUT listing (used only when INDAPRNT is on).

AINTPRNT (off):
print abbreviated frequency integrations data.

ALL (off):
provide complete printout for all overall iterations, not just the last one.

ALLY (off):
provide complete Lyman and HSE printouts for every iteration, not just the last one.

ALSFPRNT (off):
print abbreviated results of Line Source Function calculation.

ALUPRNT (off):
print Aluminum populations and departure coefficients.

ALYMPRNT (off):
print abbreviated results of Level-$\mathcal{N}$-to-Continuum transfer calculation.

AMBPRNT (on):
print data from ambipolar diffusion calculations, (used only when AMDIFF is on).

AMDDMP (off):
print details of ambipolar diffusion calculations, (used only when AMBPRNT is on).

AMDIFF (off):
include ambipolar diffusion (only in Hydrogen or Helium runs).

AMDN1 (on):
use "special N1" calculation for ambipolar diffsuion, (used only when AMDIFF is on). Caution: AMDN1 should **not** be turned off (this switch is provided for testing only).

ANALYSIS (off):
print details of line absorption profile calculations (note input parameters NANAL1, NANAL2).

AOPTPRNT (off):
print abbreviated version of OPTIONS listing (used only when OPTPRNT is on).

APHICOPR (on):
print continuum data for additional photoionization wavelengths.

APHIPRNT (off):
print results and details of generalized additional photoionization calculation.

APOPPRNT (off):
print abbreviated populations of the ion-of-the-run.

APRFPRNT (off):
print abbreviated line profile calculation results.

ARHODMP (off):
print detailed sets of 'transition terms' (uses input parameter LDINT).

ATMOPRNT (on):
print ATMOSPHERE input data listing.

ATOMPRNT (on):
print ATOM input data listing.

ATOMSAV (off):
save computed default atomic model parameters in output file.

AVCON (off):
calculate the average of the continuum intensity.

AVELOP (off):
use Averaged Line opacities.

AVOPRNT (on):
print Averaged Line opacities data table as used in this run (also uses the value of LWNT).

BDCALC (off):
departure coefficients calculated from all level equations, rather than from the continuum equation.

BDGRAF (on):
print graphs of departure coefficients.

BDMP (off):
print details of departure coefficients calculation.

BDPRNT (off):
print complete sets of BDR, BDJ, BDS, and S* from 'RHO + RBD' calculation (only if RHBPRNT is on).

BEDIT (off):
edit departure coefficients.

BLENDMP (off):
print Voigt function details for each blended line component, (used only when ANALYSIS is on).

BRATDMP (off):
print details of b-ratios calculation (uses input parameter LDINT).

BSMOOTH (off):
do "alternate" sequential smoothing for departure coefficients (note input parameter ASMCR).

CALCOOL (off):
calculate net cooling rates.

CALHEAT (off):
calculate net heating rates.

CALPRNT (off):
print Calcium populations and departure coefficients.

CARPRNT (off):
print Carbon populations and departure coefficients.

CEFACTS (off):
update CE-enhancement factors where possible and needed.

CHEXLO (off):
use lower-level charge exchange.

CHEXLOL (off):
use LTE hydrogen number density for lower-level charge exchange.

CHEXUP (off):
use upper-level charge exchange.

CHKGRAF (on):
print graphs of CHECKs for all iterations.

CHKPRNT (on):
print Consistency CHECKs from 'RHO + RBD' calculation.

CHXDMP (off):
print details of upper-level charge-exchange calculation.

CHXPRNT (on):
print results of upper-level charge-exchange calculation (used only when CHX-CNG is on).

CIJPRNT (off):
print the bound-bound collision rates CIJ (for 'minimal' printout, see input parameter IRATE).

CLNORM (on):
compute H Lyman lines normalization factors.

CNFLXDMP (off):
print debug dump output from continuum flux calculation.

COCLIPSE (off):
calculate emergent continuum eclipse intensities for CO lines wavelengths.

COCOPR (off):
print continuum data for CO-lines opacity wavelengths.

COCRID (off):
print details of CO-lines cooling rate wavelength integration.

CODMP (off):
print details of CO-lines absorption calculation.

COLHPRNT (on):
print calculated rates for collisions with Hydrogen atoms.

COLTEMP (off):
calculate color temperatures.

COMCRID (off):
print details of Composite Lines cooling rates wavelength integration.

COMOPAN (off):
Composite Line Opacity analysis.

COMPCOPR (off):
print continuum data for Composite Line Opacity wavelengths.

COMPRK (off):
print comparison RKs.

CONFLUX (off):
calculate continuum flux.

CONSAV (off):
write continuum spectrum data in Special Spectrum Save File, (this option will be turned on automatically when SPECSAV is on).

COOLCO (off):
calculate CO-lines cooling rate, (used only when CALCOOL is on).

COOLCOM (on):
calculate Composite Lines cooling rate, (used only when CALCOOL is on).

COOLINT (off):
calculate integrated net heating and cooling rates, (used only when CALCOOL is on).

COOLXRAY (on):
calculate X-rays cooling rate, (used only when CALCOOL is on).

COOLSAV (off):
write cooling and heating rates in a save file.

CPSW (on):
adjust total Hydrogen density to give constant pressure, (used only when HSE is off).

CSF (on):
use calculated background continuum source function when calculating line source function.

CSFB (off):
set BC in line source function calculation = min(CSF, B), instead of = CSF, (used only when CSF is on).

CSFDMP (off):
print debug dump output for background continuum source function calculation.

CSFPRNT (on):
print results from background continuum source function calculation.

CSFGRAF (off):
print graphs of background continuum opacity and background continuum source function.

CSWITCH (off):
use TR (level 1), instead of TE, in the stimulated emission factor (BETA) for BC in the line source function calculation, (this option will be turned off automatically when USETRIN is off).

DELABORT (on):
try to read all the input before stopping because of error(s).

DIDHC (off):
print dI/dh for emergent continuum intensities (see also input parameter ICDIT).

DIDHL (on):
print and save dI/dh for emergent line intensity profiles.

DIFFANA (on):
analyze results of diffusion calculations (used only if AMDIFF is on and/or VELGRAD is on) for radiative CRD transitions.

DOION (on):
do all the normal calculations pertaining to the ion-of-the-run.

DPDWPRNT (off):
print results of Doppler Width and Damping Paramater calculations.

DRDMP (off):
print debug details of PRD DR calculation for transition (MS/NS) at depth IDRDP and frequency KDRDP.

DSMOOTH (off):
smooth the calculated diffusion terms with the sequential smoothing procedure.

DUSTCOPR (on):
print continuum data for Dust opacity wavelengths, (used only when DUSTEMP is on).

DUSTDMP (off):
print debug dump output from Type-2 Dust temperature recalculation.

DUSTEMP (on):
calculate new values of TDST, (used only when DUSTYPE is on).

DUSTYPE (off):
use Type-2 version of Dust background continuum opacity.

ECLIDMP (off):
print debug dump output from Eclipse calculation.

ECLIGRAF (on):
print graphs of results of Line Eclipse calculation.

ECLIPSE (off):
calculate emergent continuum Eclipse intensities, (pertains to $\text{WAVES}_i < 0$ only).

ECLISAV (off):
write Eclipse emission data to an output file.

ELECPRNT (off):
print and plot results of electron density calculations.

EMERBACK (off):
calculate intensity and flux emerging from back face (far face) of finite atmosphere.

EMERINT (on):
calculate emergent continuum intensities for all wavelengths for which background continuum calculations were done.

EMIGRAF (off):
print graph of emitters.

EMINDMP (off):
print debug dump output from emergent continuum intensity calculations.

EMIPRNT (off):
print detailed analysis of the contributions to the background continuum emission.

EMISUM (off):
print an 'Emitters Summary'.

ENHANCE (off):
use R^2 source function enhancement factor in emergent intensity calculations, (used only when SPHERE is off).

ENL (off):
edit negative values out of tables of EP1 (Lyman Epsilon-1) by interpolating from neighboring positive values.

ENL2 (off):
edit negative values out of tables of EP1 (Lyman Epsilon-1) by shifting the entire EP1 and EP2 tables.

EPCOMP (off):
print comparison of the results obtained from the various methods for the Lyman EP1, EP2 calculations.

EPDMP (on):
print intermediate details of the Lyman EP1, EP2 calculations, (also uses the value of LDINT).

EPSNEDC (off):
eliminate negative values of EP1 (Lyman Epsilon-1) when using the CHAIN method.

EPSW (off):
replace any line-source-function-epsilons < -0.9999 by -0.9999.

EVERY (off):
print complete printout for all sub-iterations, not just the last one.

EXPAND (off):
the atmosphere is expanding.

FDBCOPR (off):
print continuum data for FDB (frequency-dependent line source function background) wavelengths.

FDBDMP (off):
print frequency-dependent background terms for FDB transitions.

FELE (off):
use results from fast electrons calculation.

FELEC (off):
calculate fast electrons.

FELEDMP (off):
print debug dump output from fast electrons calculation.

FELEPRNT (on):
print results of fast electrons calculations.

FEPRNT (off):
print Iron populations and departure coefficients.

FINITE (off):
the atmosphere is finite, instead of semi-infinite.

FLUXDMP (off):
print details of emergent continuum flux calculation at each wavelength, (also uses the value of IFXDS).

FLUXSAV (off):
write integrated flux quantities to an output file.

FLWBPRNT (off):
print component profiles of flow broadening.

FLWBROAD (off):
compute flow-broadened profiles, (used only when EXPAND is off).

GDMP (on):
print debug dump consisting of all 'geometric dilution matrices', (used only when GDS is on).

GDS (off):
calculate geometric dilution.

GDSDMP (off):
print geometric dilution terms, (used only when GDS is on).

GNVCALC (off):
compute the diffusion term GNV1 from the non-local N1 calculation, (used only when AMDIFF is on).

GTNSMTH (on):
smooth STIM when calculating GTN(u,l).

GTNSTIM (off):
use departure coefficients, instead of number densities, in STIM for GTN(u,l).

HBROAD (on):
in a Hydrogen run, use ion collision broadening for transitions above level 5.

HEABD (off):
calculate depth dependence of Helium abundance (used only when AMDIFF is on).

HELPRNT (off):
print Helium populations and departure coefficients.

HEL2PRNT (off):
print Helium-II populations and departure coefficients.

HENORM (on):
renormalize Helium number densities in the diffusion calculations.

HFFCOOLD (off):
print details of H free-free and H-minus free-free net cooling rates integrations.

HMS (off):
calculate H-minus departure coefficient.

HMSCOPR (off):
print continuum data for H-minus departure coefficient calculation wavelengths.

HMSJPRNT (off):
print values of mean intensity used in H-minus departure coefficient calculation.

HMSONLY (off):
use only continuum data pertaining to 'H-minus wavelengths' in the H-minus departure coefficient calculation.

HNPRNT (on):
print Hydrogen populations and departure coefficients.

HSE (off):
recalculate NE and NH via the hydrostatic equilibrium equation.

HSEDMP (off):
print debug dump output from the hydrostatic equlibrium calculation, (used only when HSE is on).

HSEV (on):
include mass motion velocity in the hydrostatic equilibrium calculations, (used only when HSE is on).

HSTSUMM (on):
print summary of calculation of Stark splitting of Hydrogen lines.

ILR (on):
calculate incident line radiation terms, (used only when INCIDNT is on).

INBED (off):
edit negative values out of tables of BDIJ values calculated from unfudged input RHO values.

INCIDNT (off):
there is external radiation shining upon the atmosphere, and it is shining on the back face (far face).

INCIFRNT (off):
the external incident radiation is shining upon the front face of the atmosphere, (used only when INCIDNT is on).

INDAPRNT (on):
print miscellaneous INPUT data listing.

INDPRNT (off):
print the input values of number density and departure coefficient of the ion of the run.

INDXDMP (off):
print debug dumps of the contents of the random-access scratch file indices.

INPEX (on):
extrapolate input tables to added depths, instead of just extending the end values.

INNBPRNT (on):
print input values of NK, ND and BD.

INPEXW (on):
print input table extrapolation warning messages.

INSCARD (on):
write the current iterates to the restart files for every iteration, not just for the last iteration only. (Note: the results for iteration $i+1$ will overwrite the results for iteration i.)

INTAPRNT (on):
print frequency integrations data for all radiative transitions.

INTEDIT (off):
use edited TE values instead of input.

INTGRAF (on):
print graphs of the results of emergent line profile calculations, and graphs of S and B *vs.* Z with the emergent line profile calculation.

INTRPRNT (on)
print input values of RHO, JBAR, CHI and AW.

IRHWED (on):
edit input values of RHOWT.

IRUNT (off):
print the most detailed execution performance and version description data.

ISCRS (on):
use 'in-memory' scratch I/O to the extent possible.

ITDMP (off):
print debug dump of 'Iterative Summary File' contents summary.

ITERB (on):
print Iterative Summary of values of departure coefficients.

ITERCHI (off):
print Iterative Summary of CHI.

ITERCHK (on):
print Iterative Summary of values of consistency checks.

ITERN (on):
print Iterative Summary of values of number densities.

ITERNE (on):
print Iterative Summary of values of electron density.

ITERNH (on):
print Iterative Summary of values of total Hydrogen density.

ITERRHO (on):
print Iterative Summary of values of net radiative bracket.

ITERRK (on):
print Iterative Summary of values of Lyman RK-1.

ITERRWT (off):
print Iterative Summary of values of RHO-weights.

ITERS (on):
print Iterative Summary of values of line source functions.

ITERTAU (off):
print Iterative Summary of values of line core optical depths.

ITERTD (on):
print Iterative Summary of values of TDST (Type-2 Dust temperature).

ITERZ (on):
print Iterative Summary of values of Z.

IVALICK (on):
check 'validity' of emergent intensity integrations.

IXSTA (on):
print performance statistics.

JBDNC (off):
bypass the calculation of unused Rhos and b-ratios.

JLYSAV (off):
save Lyman-continuum JNU (=JB).

JNTRPOL (off):
interpolate input values of PRD JNU to new Z-scale (instead of simply assigning values to the new Z-scale), in runs for which TAUKIN is specified.

JNUPRNT (off):
print values of mean intensity for PRD transitions, for each iteration.

JSTIN (off):
just read and check all the input, then stop.

KOMPRNT (off):
print Composite Line Opacity (Kurucz) data table, as used in this run (also uses the value of LWNT).

KROSSID (off):
print details of Rosseland mean opacity wavelength integration.

KSHLCOPR (off):
print continuum data for K-shell wavelengths.

KURPRNT (off):
print Statistical Line Opacity (Kurucz) data table, as used in this run (also uses the value of LWNT).

LBDPRNT (on):
print summary of line center background.

LFDPRNT (off):
print full arrays of values of Line Flux Distribution.

LIGHT (on):
calculate emergent line intensity and flux profiles.

LINECDMP (off):
print details of scattering albedo analysis (used only when LINECOMP is on).

LINECOMP (off):
compare results from Line Source Function and Composite Line calculations.

LINECOPR (off):
print continuum data for line core wavelengths.

LINTDMP (off):
print debug dump output from emergent line intensity calculation.

LNUMDMP (off):
print dump of number density calculations.

LONGNBM (off):
use the long, detailed version of the error message that is printed when a calculated value of BDIJ < 0.

LSCALE (off):
print graph of logs of TAU scales.

LSFFULL (on):
print full set of standard line source function calculation results (used only if the basic set of results is printed).

LSFGRAF (on):
print Line Source Function graphs for all transitions, not just for those with LSFPRINT = 1.

LSFPRNT (on):
print results of Line Source Function calculations for all transitions, not just for those with LSFPRINT = 1.

LTE (off):
calculate LTE versions of emergent line intensity and flux profiles.

LTEDATA (on):
print LTE values of S and FR, (used only when LTE is on).

LYMAN (off):
calculate Level-$\mathcal{N}$-to-Continuum transfer in detail (the 'Lyman' calculation).

LYMCOPR (off):
print continuum data for Level-$\mathcal{N}$-to-Continuum transfer calculation wavelengths, (used only when LYMAN is on).

LYMDMP (off):
print debug dump output from Level-$\mathcal{N}$-to-Continuum transfer calculation, (used only when LYMAN is on).

MAGPRNT (off):
print Magnesium populations and departure coefficients.

MAKIX (on):
insert place-markers in printout file, and generate the corresponding index file.

MCINPUT (on):
accept lower- and MiXed-case input statements, instead of UPPER-case only.

METPRNT (off):
print details of automatic Statistical Equilibrium Equation Method selection, (used only when METSW is on).

METSW (off):
try the other Statistical Equlibrium Equation methods whenever a value of line-source-function-epsilon < -0.9999.

MITPRNT (off):
provide only a bare minimum printout for each iteration, (used only when ALL is off or EVERY is off).

MONOTAU (off):
force all sets of calculated optical depths to increase monotonically.

NBPRNT (off):
print final, weighted values of number density and departure coefficient.

NEDIT (off):
edit number densities to insure positive line source functions.

NESWICH (on):
recalculate NE in detail, instead of setting NE = NP.

NHADJ (on):
adjust the calculated values of NH so that TAU5000 = 1 where Z = 0, (used only when HSE is on; will be turned off automatically when HSE is off).

NRSMOOTH (on):
smooth the nℓ/n1 ratios in the diffusion calculations.

NVOIT (on):
print Voigt function calculations execution statistics.

OPAGRAF (off):
print graph of absorbers.

OPANEG (on):
edit negative Line Opacity only to keep Total Opacity positive.

OPAPRNT (off):
print detailed analysis of the contributions to the background opacity.

OPASUM (off):
print an 'Absorber Summary'.

OPTHINL (off):
use the optically-thin-limit approximation.

OPTPRNT (on):
print OPTIONS listing.

ORIGIN (off):
provide 'long version' of analyses of regions of formation of values of emergent intensity.

ORSHORT (off):
provide 'short version' of analyses of regions of formation of values of emergent intensity, (used only when ORIGIN is on).

ORT (off):
radiation flows in the 'outward' direction only, instead of isotropically.

OXYPRNT (off):
print Oxygen populations and departure coefficients.

OXY2PRNT (off):
print Oxygen-II populations and departure coefficients.

OXY3PRNT (off):
print Oxygen-III populations and departure coefficients.

PARTPRNT (off):
print the tables of Ionization Potentials, Partition Functions and/or Partition Function ratios.

PARTVAR (on):
use depth-varying values of Partition Functions (instead of constant values).

PASSPRNT (on):
print results and details of line source function calculations for passive transitions.

PDCHECK (off):
print debug checksums.

PDETPRNT (on):
print details of BD and ND calculations, illustrated at depth # IBNVIEW (used only when POPPRNT is on).

PED (off):
print results and details of particle energy dissipation calculation.

PEDDMP (off):
print debug dump output from particle energy dissipation calculation.

PEGTNALL (on):
print GTN-editing messages for every iteration, not just the last one.

PERDMP0 (off):
print debug dump output from `PERSEUS` for transition (MS/NS): contents of data blocks, (see Note 59, Section 5).

PERDMP1 (off):
print debug dump output from `PERSEUS` for transition (MS/NS): but without details of frequency/angle summations, (see Note 59, Section 5).

PERDMP2 (off):
print debug dump output from `PERSEUS` for transition (MS/NS): details of frequency/angle summations, (see Note 59, Section 5).

PERDMP3 (off):
print debug dump output from `PERSEUS` for transition (MS/NS): PRD data arrays, (see Note 59, Section 5).

PESRJALL (off):
print S, RHO and JBAR editing messages in every iteration, not just the last one.

PHASE2 (on):
calculate emergent spectrum, and provide summary analyses.

PIJPRNT (off):
print the bound-free collision rates PIJ (for 'minimal' printout, see input parameter IRATE).

POPBSW (off):
set the departure coefficients for higher levels equal to those for the highest calculated level (instead of their LTE values), for 'population update ions' only.

POPGRAF (on):
print graph of number densities.

POPPRNT (on):
print results and details of the number densities calculations.

PRDCOPR (off):
print continuum data for PRD (partial redistribution profile points) wavelengths (see also input parameter **IPRDF**).

PRDITER (off):
print results of all PRD-iterations, not just the last one.

PRDMETH (on):
Use the Hubeny-Lites, instead of the Kneer-Heasley, formulation for PRD.

PRDPRNT (off):
print results and details of PRD calculations.

PROCPRNT (on):
print line profile-specific emergent continuum intensities.

PRODMP (off):
print debug dump output from emergent intensity calculations.

PROSAV (off):
write emergent line profile data in the Special Spectrum Save File, (this option will be turned on automatically when SPECSAV is on).

PTN (on):
edit negative values out of tables of TAU integrands.

QSFEDIT (on):
edit negative values out of tables of QSF (PRD modified source function).

RABDAT (on):
save data needed for separate RABD calculation.

RATEALL (off):
print complete details of rates integrations.

RATECOPR (off):
print continuum data for rates integrations wavelengths.

RATEFULL (on):
print details of the rates integrations.

RATEGRAF (on):
print graphs of the TR sets and JNU sets used in rates calculations.

RATEPRNT (off):
print results and details of the 'SETTUP' calculation, *i.e.,* rates calculation (for 'minimal' printout, see input parameter IRATE).

RATESUMM (off):
print rate integration summary for every level.

RCOMPRNT (on):
print details of recombination calculation.

REFLECT (off):
the plane-parallel atmosphere is symmetric about the lowest depth value.

RHBPRDT (on):
print details of 'RHO + RBD' calculation for each radiative transition (only if RHBPRNT is on).

RHBPRNT (on):
print Explanation, and Results (optional), of the 'RHO + RBD' calculations (see also options BDPRNT, RHBPRDT, RHBPRSM).

RHBPRSM (off):
print final sets of Rho and b-ratios from 'RHO + RBD' calculation (only if RHBPRNT is on).

RHEDIT (off):
edit the calculated values of RHO (net radiative bracket).

RHOFUDGE (off):
'fudge' RHO's as necessary for calculation of BDIJ, (to assure positive values of BDIJ).

RHOWOPT (on):
use the same 'artificial' set of TAU values for all transitions when computing RHO/W, instead of the line-core TAUs of each transition.

RIJPRNT (on):
print ratio of collision rates RIJ.

RKINCR (off):
artificial RK enhancement.

RSMOOTH (off):
smooth the calculated RHO sets using the sequential smoothing procedure.

RSQUARE (off):
use depth-varying (instead of constant) dilution factor, (used only when INCIDNT is on).

SCALE (off):
print collated TAU scales.

SDIRECT (off):
replace negative Line Source Function values in "Direct" calculations by interpolated positive ones.

SEBUG (off):
print intermediate details of the statistical equlibrium calculations for transition (MS/NS), (also uses the value of LDINT).

SECOMP (off):
print comparative analysis of the results from the different Statistical Equlibrium methods.

SEDIT (on):
edit negative values out of calculated sets of Line Source Functions obtained by the "Full" solution.

SEDITIF (off):
edit negative values out of frequency-dependent Line Source Functions used for intensity and flux profiles.

SEPRNT (off):
print results and details of Statistical Equilibrium calculations.

SETIME (off):
print timings for the different Statistical Equilibrium methods, (used only when SECOMP is on).

SILPRNT (off):
print Silicon populations and departure coefficients.

SLFGRAF (off):
print graph of SLF for transition (MS/NS).

SLFPRNT (off):
print SLF for transition (MS/NS).

SLFSAV (off):
save SLF in the Special Spectrum Save File.

SLYR (on):
smooth the calculated Lyman RK-$\mathcal{N}$ set.

SNUSHFT (off):
apply frequency-shift to PRD SNU in emergent profile calculations.

SOBDMP (off):
print debug dump output from Sobolev escape probability calculation.

SOBINT (off):
print Sobolev integration details, (used only when SOBDMP is on).

SODPRNT (off):
print Sodium populations and departure coefficients.

SPECSAV (off):
save all spectrum data in the Special Spectrum Save File, (this is equivalent to turning on both CONSAV and PROSAV).

SPECSUM (off):
provide a 'Spectrum Summary'.

SPHEGEOM (off):
print complete sets of all Z-dependent geometrical quantities, (used only when SPHERE is on).

SPHERE (off):
the atmosphere is spherically symmetric, instead of being plane-parallel and semi-infinite.

SPHETAU (off):
calculate optical depths along rays by quadratic integration, instead of by trapezoidal rule, (used only when SPHERE is on).

SPHOUT (off):
use spherically-symmetric geometry in computing emergent line and continuum flux, (used only in cases where the line source functions were calculated with plane-parallel coordinates).

SQSMDMP (off):
print details of sequential smoothing, (used only when SQSMPRNT is on).

SQSMPRNT (off):
print brief messages for all occurrences of sequential smoothing.

SSMOOTH (off):
do "alternate" sequential smoothing for S-from-number densities.

STANDARD (on):
print various basic numerical data.

STANCOPR (off):
print results of continuum calculations for standard background wavelengths.

STANPRNT (off):
print provisional depth-dependent input tables, before interpolation to the standard Z table of this run.

STAUREDM (on):
print short version of TAU-reduction error message from the WN-matrix calculation.

STIMPRNT (off):
print values of stimulated emission factors.

STKWATT (on):
attenuate Hydrogen line Stark splitting components outside the Doppler core at each depth.

SULPRNT (off):
print Sulphur populations and departure coefficients.

SUMGRAF (on):
print 'iterative summaries' in graphical, rather than in tabular, form, (used only when SUMMARY is on.

SUMMARY (on):
print 'iterative summaries,' and a fudging summary.

SUMTREND (on):
print Iteration Trends summary.

TANG (on):
include the ray tangent to the first depth (*i.e.* shell) in the angle integrations for spherical geometry, (used only when NTAN = 1, and only when SPHERE is on).

TAUDMP (off):
print debug dump output from all optical depth integrations (TAU calculations).

TAUPLOT (on):
print TAU scales for all transitions beneath the departure coefficient graphs.

TAUPRNT (off):
print results and details of the line-core optical depth calculations.

TAUSUM (off):
print a 'TAU Summary'.

TEGRAF (on):
print graph of temperature vs. optical depth.

TOPE (off):
save data for separate 'Continuum Plots' program.

TRANSAV (off):
save transitions data in special file (.tsf).

TRPRNT (off):
print computed effective radiation temperatures.

TRUECONT (off):
compute "true continuum" as needed for residual line profiles.

TRUECOPR (off):
print results of "true continuum" calculations needed for residual line profiles.

ULNORM (on):
use H Lyman lines normalization factors.

USENCJ (on):
calculate background continuum JNU directly, instead of from the source function.

USETRIN (off):
calculate values of the rates RK and RL with the 'old' method, which requires input values of TR.

USETSM (off):
eliminate TAU values smaller than TSM in emergent intensity and continuum mean intensity calculations.

USEWTAB (on):
use standard rates integrations wavelengths.

VELGDMP (off):
print details of velocity gradient terms calculation, (used only when VLGPRNT is on).

VELGRAD (off):
include velocity gradient terms in statistical equilibrium equations (only in Hydrogen or Helium runs).

VELS (off):
use calculated diffusion velocity in source function calculations.

VESCAPE (off):
use Voigt expression for the escape probability.

VLGPRNT (on):
print data from velocity terms calculation (used only when VELGRAD is on).

VSWITCH (off):
use two broadening velocity sets, instead of just one.

VTV (on):
set VT = V.

WATESTE (on):
use logarithmic style of weighting for Lyman EP1, EP2.

WATESTR (on):
use logarithmic style of weighting for all RHO sets.

WAVENUMB (off):
print results in wavenumber instead of wavelength units.

WAVEPRNT (on):
print Continuum Wavelengths summary table (also uses the value of LWNT).

WISFILE (off):
write an 'iterative studies' save file for transition (MS/NS).

WNDMP (off):
print debug dump output for all WN-matrix calculations.

WTABPRNT (off):
print standard rates integrations wavelengths.

XRAYCRID (off):
print details of X-ray cooling rates wavelength integration.

ZCOMP (off):
when mass is prescribed, adjust Z to match the input mass scale.

ZPRNT (off):
reprint input values of Z and TE to nine significant figures.

REFERENCE GUIDE

This is a listing of OPTION names, in alphabetical order by description. Once an OPTION's name has been identified by means of this list, its full specification can then be found in the main table at the start of this section.

ACSFPRNT	abbreviated continuum source function calculation printout
AHSEPRNT	abbreviated HSE calculation printout
AINDPRNT	abbreviated INPUT printout
APRFPRNT	abbreviated line profile calculation results
ALSFPRNT	abbreviated Line Source Function calculation printout
ALYMPRNT	abbreviated LYMAN calculation printout
APOPPRNT	abbreviated number densities printout
AOPTPRNT	abbreviated OPTIONS listing
APOPPRNT	abbreviated POPULATIONS printout
DELABORT	abort, delayed, during input reading
OPASUM	absorber summary printout
OPAGRAF	absorbers (background continuum opacity contributors) graph
OPAPRNT	absorbers (background continuum opacity contributors) printout
ANALYSIS	absorption profiles, line, details printout
HEABD	abundance, Helium, depth dependence
RABDAT	abundance ratio calculation data
APHICOPR	additional photoionization background continuum data printout
APHIPRNT	additional photoionization details printout
ADDCOPR	additional wavelengths continuum data printout
NHADJ	adjustment of NH (Hydrostatic Equilibrium)
CPSW	adjustment of NH (not Hydrostatic Equilibrium)
LINECDMP	albedo, scattering, analysis
LINECOMP	albedo, scattering, analysis
RATEALL	all integration data should be printed for Rates Integrations
BSMOOTH	'alternate' sequential smoothing procedure for departure coefficients
SSMOOTH	'alternate' sequential smoothing procedure for S-from-number density
ALUPRNT	Aluminum populations printout

DIFFANA	ambipolar diffusion, analysis of results
NRSMOOTH	ambipolar diffusion, smoothing of number density ratios
AMDIFF	ambipolar diffusion terms
AMDN1	ambipolar diffusion terms alternative
GNVCALC	ambipolar diffusion terms alternative
AMDDMP	ambipolar diffusion terms detail printout
AMBPRNT	ambipolar diffusion terms printout
COMOPAN	analysis of Composite Lines (Kurucz) opacity contribution
RHOWOPT	artificial TAU in RHO/W calculation
ATMOPRNT	ATMOSPHERE data printout
EXPAND	atmosphere stationary or expanding
ATOMPRNT	ATOM data printout
ATOMSAV	atomic model parameters in output file
STKWATT	attenuate Hydrogen lines Stark splitting components
AINTPRNT	A-values (frequency integration weights) printout
INTAPRNT	A-values (frequency integration weights) printout
AEDIT	A-values (frequency integration weights) editing
AVCON	averaged continuum intensity
AVELOP	Averaged Lines opacity
AVOPRNT	Averaged Lines opacity details printout
INTRPRNT	AW input values printing
CSWITCH	b-for-`PERSEUS` temperature selector
BDCALC	b from all level equations
BDCALC	b from continuum equation
JBDNC	b-ratios and RHO calculation bypass
BRATDMP	b-ratios calculation debug details
LONGNBM	b-ratios calculation error message
BDPRNT	b-ratios printout (complete)
EMERBACK	backface emergent spectrum
INCIDNT	backface incident radiation
LBDPRNT	background data (summary at line core wavelengths) printout
USEWTAB	background wavelengths (standard), for rates calculation
WTABPRNT	background wavelengths (standard), for rates calculation
STANDARD	basic numerical data printouts
CSF	BC (Line Source Function calculation option)
CSFB	BC (Line Source Function calculation option)

BDMP	BD calculations details
PDETPRNT	BD calculations trace, using IBNVIEW
BDGRAF	BD graph printout
INNBPRNT	BD input values printing
ITERB	BD iterative summary printing
LONGNBM	BDIJ calculation error message
BDGRAF	BDIJ graph printout
RHBPRDT	BDIJ printout
RHBPRNT	BDIJ printout
RHBPRSM	BDIJ printout
BDPRNT	BDIJ printout (complete)
BLENDMP	blended lines components dump
CIJPRNT	bound-bound collision rates CIJ printout
PIJPRNT	bound-free collision rates PIJ printout
HBROAD	broadening, ion (Hydrogen)
	broadening velocity = microturbulence velocity
VSWITCH	broadening velocities switch
JBDNC	bypass b-ratios and RHO calculation
JBDNC	bypass RHO and b-ratios calculation
CALPRNT	Calcium populations printout
CARPRNT	Carbon populations printout
CEFACTS	CE-enhancement factors, using and updating
CHXDMP	charge-exchange calculation dump
CHXPRNT	charge-exchange calculation printout
CHEXLO	charge-exchange, lower-level
CHEXLOL	charge-exchange, lower-level, Hydrogen populations
CHEXUP	charge-exchange, upper-level
IVALICK	check validity of emergent intensity integrations
CHKGRAF	CHECKs graphs, for all iterations
PDCHECK	checksums printing
INTRPRNT	CHI input values printing
ITERCHI	CHI iterative summary printing
CIJPRNT	CIJ printout control
CODMP	CO-lines absorption calculation details printout
COCLIPSE	CO-lines continuum eclipse calculation
COOLCO	CO-lines cooling rate calculation

COCRID	CO-lines cooling rate calculation details printout
COCOPR	CO-lines wavelengths continuum data printout
SCALE	collated TAU scales printout
CIJPRNT	collision rates, electrons, CIJ printout
PIJPRNT	collision rates, electrons, PIJ printout
RIJPRNT	collision rates, electrons, ratio RIJ printout
COLHPRNT	collision rates, Hydrogen atoms, printout
COLTEMP	color temperatures
LINECDMP	comparison of Line Source Function and Composite Line calculations
LINECOMP	comparison of Line Source Function and Composite Line calculations
EPCOMP	comparison of Lyman Epsilons methods
SECOMP	comparison of Statistical Equilibrium methods
SETIME	comparison of Statistical Equilibrium methods timing
COMPRK	comparison RKs
FLWBPRNT	component profiles (flow-broadened) printout
COOLCOM	Composite Lines cooling rate calculation
COMCRID	Composite Lines cooling rate calculation detail printout
COMOPAN	Composite Lines opacity analysis
KOMPRNT	Composite Lines opacity details printout
COMPCOPR	Composite Lines opacity wavelengths continuum calculations printout
LINECDMP	Composite Lines scattering albedo analysis
LINECOMP	Composite Lines scattering albedo analysis
ITERCHK	Consistency Checks iterative summary
CNKPRNT	Consistency Checks printout
CPSW	constant pressure NH adjustment
STANDARD	constants (physical) printout
OPAGRAF	continuum absorbers (continuum opcacity contributors) graph
OPAPRNT	continuum absorbers (continuum opcacity contributors) printout
TRUECONT	continuum calculation, “true”
APHICOPR	continuum data (additional photoionization) printout
ADDCOPR	continuum data (additional wavelengths) printout
COCOPR	continuum data (CO-lines)
COMPCOPR	continuum data (Composite Lines opacity wavelengths) printout
DUSTCOPR	continuum data (dust) printout
FDBCOPR	continuum data (FDB wavelengths) printout
HMSCOPR	continuum data (H-minus departure coefficient wavelengths) printout

KSHLCOPR	continuum data (K-shell wavelengths) printout
LINECOPR	continuum data (Line Core wavelengths) printout
LYMCOPR	continuum data (Lyman calculation wavelengths) printout
PRDCOPR	continuum data (PRD wavelengths) printout
RATECOPR	continuum data (rates calculations wavelengths) printout
STANCOPR	continuum data (standard background wavelengths) printout
LBDPRNT	continuum data (summary at line core wavelengths) printout
TRUECOPR	continuum data ("true continuum") printout
CONSAV	continuum emission special output
EMIGRAF	continuum emitters (Continuum Source Function) graph
EMIPRNT	continuum emitters (Continuum Source Function) printout
CONFLUX	continuum flux
CNFLXDMP	continuum flux debug printout
FLUXDMP	continuum flux detail printout
SPHOUT	continuum flux using spherical coordinates
EMERINT	continuum intensity
AVCON	continuum intensity, averaged
EMINDMP	continuum intensity debug printout
DIDHC	continuum intensity, dI/dh
PROCPRNT	continuum intensity, line profile-specific
CONIPRNT	continuum intensity, "true," printout
USENCJ	continuum JNU method selection
LYMAN	continuum (Lyman) transfer calculation
OPAGRAF	continuum opacity contributors (absorbers) graph
OPAPRNT	continuum opacity contributors (absorbers) printout
TOPE	'Continuum Plots' data
CSFGRAF	Continuum Source Function and opacity graph
ACSFPRNT	Continuum Source Function calculation printout
CSFPRNT	Continuum Source Function calculation printout
EMIGRAF	Continuum Source Function contributors (emitters) graph
EMIPRNT	Continuum Source Function contributors (emitters) printout
WAVEPRNT	Continuum Wavelengths summary printout
STANDARD	control parameters (numerical) printout
COOLCO	cooling rate, CO-lines
COOLCOM	cooling rate, Composite Lines
COOLXRAY	cooling rate, X-rays

COOLSAV	cooling rates calculation special output for plotting
COCRID	cooling rates debug printout, CO-lines
COMCRID	cooling rates debug printout, Composite Lines
HFFCOOLD	cooling rates debug printout, H and H-minus free-free
XRAYCRID	cooling rates debug printout, X-rays
CALCOOL	cooling rates (net radiative)
CSFDMP	CSF calculation debug printout
CSFPRNT	CSF calculation printout
DPDWPRNT	damping parameter printout
PDCHECK	debug checksums
AMDDMP	debug printout, ambipolar diffusion
BLENDMP	debug printout, blended lines components
BRATDMP	debug printout, b-ratios calculation
CHXDMP	debug printout, charge-exchange calculation
COCRID	debug printout, CO-lines cooling rate integration
COMCRID	debug printout, Composite Lines cooling rate integration
CNFLXDMP	debug printout, continuum flux calculation
CSFDMP	debug printout, CSF calculation
ECLIDMP	debug printout, eclipse calculation
EMINDMP	debug printout, emergent continuous intensity
FDBDMP	debug printout, FDB terms
GDMP	debug printout, geometrical dilution
HFFCOOLD	debug printout, H and H-minus free-free net cooling rates
HSEDMP	debug printout, hydrostatic equilibrium calculation
LINTDMP	debug printout, line intensity calculation
PRODMP	debug printout, line intensity calculation
PERDMP0	debug printout, Line Source Function calculation
PERDMP1	debug printout, Line Source Function calculation
PERDMP2	debug printout, Line Source Function calculation
PERDMP3	debug printout, Line Source Function calculation
LYMDMP	debug printout, Lyman continuum calculation
EPDMP	debug printout, Lyman Epsilons calculation
TAUDMP	debug printout, optical depth integrations
PEDDMP	debug printout, particle energy dissipation
PERDMP0	debug printout, `PERSEUS`
PERDMP1	debug printout, `PERSEUS`

PERDMP2	debug printout, `PERSEUS`
PERDMP3	debug printout, `PERSEUS`
DRDMP	debug printout, PRD DR calculation
INDXDMP	debug printout, random access files indices
KROSSID	debug printout, Rosseland-mean opacity integration
SQSMDMP	debug printout, sequential smoothing
SOBDMP	debug printout, Sobolev escape probability calculation
SOBINT	debug printout, Sobolev escape probability calculation
SEBUG	debug printout, statistical equilibrium calculation
VELGDMP	debug printout, velocity gradient terms
WNDMP	debug printout, weight matrix calculations
XRAYCRID	debug printout, X-rays cooling rates integration
ATOMSAV	default atomic model parameters in output file
DELABORT	delayed abort during input reading
BDMP	departure coefficients calculation details
BEDIT	departure coefficients editing
BDCALC	departure coefficients from all level equations
BDCALC	departure coefficients from continuum equation
BDGRAF	departure coefficients graph
TAUPLOT	departure coefficients graph
HMS	departure coefficients, H-minus
GTNSTIM	departure coefficients, instead of Ns, in STIM for GTN(u,l)
ITERB	departure coefficients iterative summary
POPBSW	departure coefficients, populations ions
RHOFUDGE	departure coefficients ratios calculation RHO fudging
BSMOOTH	departure coefficients smoothing
NBPRNT	departure coefficients supplementary printout
HEABD	depth-dependent abundance, Helium
ITERZ	depth scale recalculation iterative summary printing
RSQUARE	depth variation of dilution factor
AMDDMP	detail printout for ambipolar diffusion terms
CHXDMP	detail printout for charge-exchange calculation
FLUXDMP	detail printout for emergent continuous flux calculation
CODMP	detail printout for CO-lines absorption calculation
LINECDMP	detail printout for LINECOMP options
EPDMP	detail printout for Lyman Epsilons calculation

LNUMDMP	detail printout for number density calculation
RCOMPRNT	detail printout for recombination calculation
LINECDMP	detail printout for scattering albedo analysis
ADN1DMP	detail printout for "special N1" calculation
SEBUG	detail printout for statistical equilibrium calculation
VELGDMP	detail printout for velocity gradient terms calculation
DIDHC	dI/dh, emergent continuum
DIDHL	dI/dh, emergent line profiles
AMDIFF	diffusion, ambipolar
AMDN1	diffusion, ambipolar, alternative
DIFFANA	diffusion, ambipolar, analysis of results
AMDDMP	diffusion, ambipolar, detail printout
GNVCALC	diffusion, ambipolar, GNV1 method
HENORM	diffusion, ambipolar, He renormalization
AMBPRNT	diffusion, ambipolar, printout
DSMOOTH	diffusion, ambipolar, smoothing
NRSMOOTH	diffusion, ambipolar, smoothing of number density ratios
DIFFANA	diffusion analysis
VELS	diffusion velocity in Line Source Function
RSQUARE	dilution factor depth variation
SDIRECT	'direct' Line Source Function editing option
DPDWPRNT	Doppler width printout
DRDMP	DR (PRD) debug printout
DUSTDMP	dust calculation: print numerical details of temperature recalculation
DUSTEMP	dust calculation: recompute temperature
DUSTYPE	dust calculation: Type-2
ITERTD	dust temperature recalculation iterative summary printout
DUSTCOPR	dust temperature recalculation continuum data printout
ECLIDMP	eclipse calculation debug printout
ECLISAV	eclipse emission special output
ECLIPSE	eclipse intensity calculations
COCLIPSE	eclipse intensity calculations, for CO lines
ECLIGRAF	eclipse intensity graphs, for Lines
BEDIT	edit departure coefficients
OPANEG	edit GTN
INBED	edit input values of b-ratios

INTEDIT	edit input values of TE
OPANEG	edit Line Opacity
SDIRECT	edit Line Source Function
SEDIT	edit Line Source Function
EPSW	edit Line-Source-Function-epsilons
ENL	edit Lyman Epsilon-1
ENL2	edit Lyman Epsilons
EPSNEDC	edit Lyman Epsilons
OPANEG	edit negative Line Opacity
NEDIT	edit number densities to insure positive line source functions
QSFEDIT	edit QSF (PRD modified source function)
RHEDIT	edit RHO
IRHWED	edit RHOWT input values
SEDITIF	edit SLF
PTN	edit TAU integrands
PEGTNALL	editing messages from GTN calculation
PESRJALL	editing messages form S, RHO and JBAR calculation
TRPRNT	effective radiation temperature printout
ELECPRNT	electron density calculation details printout
NESWICH	electron density calculation switch
ITERNE	electron density iterative summary printing
EMERINT	emergent continuous intensity
EMINDMP	emergent continuous intensity debug printout
DIDHC	emergent continuous intensity, dI/dh
PROCPRNT	emergent continuous intensity, line profile-specific
SPECSAV	emergent intensity special output
CONSAV	emergent intensity special output
STIMPRNT	emission factors, stimulated, printout
EMISUM	emitter summary printout
EMIGRAF	emitters (Continuum Source Function contributions) graph
EMIPRNT	emitters (Continuum Source Function contributions) printout
CEFACTS	enhancement factors for CE, using and updating
RKINCR	enhancement factors for RK, artificial
ENHANCE	enhancement (R-squared) for emergent intensities
ENL	Epsilon-1 (Lyman) editing
EPSW	Epsilons (Line Source Function) editing

METSW	Epsilons (Line Source Function) for Statistical Equlibrium calculations
EPDMP	Epsilons (Lyman) debug printout
ENL2	Epsilons (Lyman) editing
EPSNEDC	Epsilons (Lyman) editing
EPCOMP	Epsilons (Lyman) methods comparison
LONGNBM	error message from BDIJ calculation
STAUREDM	error message from WN-matrix calculation
SOBDMP	escape probability (Sobolev) calculation dump
VESCAPE	escape probability (Sobolev) Voigt expression
IRUNT	execution statistics
IXSTA	execution statistics
NVOIT	execution statistics for Voigt function calculations
EXPAND	expanding atmosphere
HSEV	expansion velocity in hydrostatic equilibrium calculation
STANDARD	exponentials and exponential integrals control parameter printout
INPEX	extrapolate input tables
INPEXW	extrapolate input tables, warning messages
FELE...	fast electrons calculation options
FDBCOPR	FDB wavelengths continuum printout
ZPRNT	figures, significant, printed
REFLECT	finite atmosphere, reflective
FLWBPRNT	flow broadening
FLWBROAD	flow broadening
PHASE2	flux calculations
SPHOUT	flux calculations using spherical coordinates
CONFLUX	flux, continuum
CNFLXDMP	flux, continuum, debug printout
FLUXDMP	flux, continuum, detail printout
FLUXSAV	flux, integrated, to be saved
LIGHT	flux, Line
SEDITIF	flux, Line, edit SLF for
LTE	flux, Line, LTE
ORIGIN	formation regions of computed emergent intensities
ORSHORT	formation regions of computed emergent intensities
FDBDMP	frequency-dependent background terms printout
FDBCOPR	frequency-dependent background wavelengths continuum printout

	frequency-dependent line source function = SLF
AINTPRNT	frequency integrations data printout
INTAPRNT	frequency integrations data printout
AEDIT	frequency integrations weights editing
SNUSHFT	frequency shift for PRD SNU in emergent profile calculation
INCIFRNT	frontface incident radiation
RHOFUDGE	fudge RHOs
SUMMARY	fudging summary
BDPRNT	full b-ratios printout
GDS	geometrical dilution
GDSDMP	geometrical dilution canonical printout
GDMP	geometrical dilution debug printout
SPHEGEOM	geometrical Z-dependent quantities printout (spherical geometry)
STANDARD	geometrical Z-dependent quantities printout (spherical geometry)
VELGRAD	gradient, velocity
VELGDMP	gradient, velocity, dump printout
OPAGRAF	graph of absorbers (background continuum opacity contributors)
CHKGRAF	graph of CHECK, for all iterations
BDGRAF	graph of departure coefficients
TAUPLOT	graph of departure coefficients
CSFGRAF	graph of Continuum Source Function and opacity
EMIGRAF	graph of emitters (Absorption Source Function contributors)
ECLIGRAF	graph of Line eclipse results
LSFGRAF	graph of Line Source Function calculation results
LSCALE	graph of logs of TAU scales
POPGRAF	graph of number density
CSFGRAF	graph of opacity and Continuum Source Function
TEGRAF	graph of temperature vs. optical depth
RATEGRAF	graph of TR and JNU, from rates calculation
GTNSTIM	GTN calculation, formulation of STIM for
GTNSMTH	GTN calculation, smoothing of STIM for
OPANEG	GTN editing
PEGTNALL	GTN-editing messages
HFFCOOLD	H and H-minus free-free net cooling rate debug printout
CALHEAT	heating rates (net radiative)
HFFCOOLD	H-minus and H free-free net cooling rate debug printout

HMS	H-minus departure coefficient
HMSCOPR	H-minus departure coefficient continuum data printout
HMSONLY	H-minus integration continuum wavelengths selection
HMSJPRNT	H-minus JNU printout
HEABD	Helium abundance, depth dependent
HENORM	Helium populations renormalization (diffusion calculation)
HELPRNT	Helium-I populations printout
HEL2PRNT	Helium-II populations printout
AHSEPRNT	HSE printout option
ALLY	HSL iterations general printout frequency control
PRDMETH	Hubeny-Lites PRD formulation
COLHPRNT	Hydrogen atoms collision rates printout
ITERNH	Hydrogen density iteration summary
NHADJ	Hydrogen density recalculation adjustment (HSE)
CPSW	Hydrogen density recalculation adjustment (not HSE)
HBROAD	Hydrogen, ion broadening
HSTSUMM	Hydrogen lines Stark splitting summary
CLNORM	Hydrogen Lyman lines (background) normalization factors
ULNORM	Hydrogen Lyman lines (background) normalization factors
CHEXLOL	Hydrogen populations for lower-level charge exchange
HNPRNT	Hydrogen populations printout
STKWATT	Hydrogen Stark splitting components attenuation
HSE	hydrostatic equilibrium
HSEDMP	hydrostatic equilibrium calculation debug printout
HSEV	hydrostatic equilibrium (expansion velocity)
HSEV	hydrostatic equilibrium (mass motion velocity)
NHADJ	hydrostatic equilibrium NH adjustment
AHSEPRNT	hydrostatic equilibrium printout
PDETPRNT	IBNVIEW-illustrated trace of BD and ND calculations
ILR	incident Line radiation term
INCIDNT	incident radiation, backface
INCIFRNT	incident radiation, frontface
MAKIX	index file for printout file
INDXDMP	index (random access file) dumps
ISCRS	'in-memory' scratch I/O
INBED	input BDIJ (from unfudged RHOs) editing

AINDPRNT	INPUT data printout
INDAPRNT	INPUT data printout
JSTIN	'input only'
MCINPUT	input reading: accept mixed case statements
DELABORT	input reading: delayed abort
INPEX	input tables extrapolation
INPEXW	input tables extrapolation warning
INTEDIT	input TE values editing
ZCOMP	input values of mass, to be matched by adjusted Z values
INDPRNT	input values of ND (number density)
INNBPRNT	input values of NK, ND and BD
INTRPRNT	input values of RHO, JBAR, CHI and AW
MAKIX	insertion of printout place-markers
INSCARD	insurance restart data file
PTN	integrands (TAU) editing
FLUXSAV	integrated flux quantities to be saved
INTRPRNT	integrated mean intensity (JBAR) input values printing
COOLINT	integrated net radiative cooling and heating rates
IVALICK	integration (intensity) validity checking
AINTPRNT	integration, frequency, data printout
INTAPRNT	integration, frequency, data printout
AEDIT	integration, frequency, weights editing
TAUDMP	integrations debug printout for TAUs
SOBINT	integration (Sobolev) dump index
PHASE2	intensity calculations
EMERINT	intensity, continuum
PROCPRNT	intensity, continuum, line profile-specific
CONIPRNT	intensity, continuum, "true," printout
SPECSAV	intensity data save file
LIGHT	intensity, line
LINTDMP	intensity, line, debug printout
PRODMP	intensity, line, debug printout
SEDITIF	intensity, line, edit SLF for
INTGRAF	intensity, line, graphs, and S & B vs. Z graphs
IVALICK	intensity, line, integration validity checking
LTE	intensity, line, LTE

SPECSAV	intensity, line, special output
PROSAV	intensity, line, special output
ORIGIN	intensity, regions of formation
ORSHORT	intensity, regions of formation
CONIPRNT	intensity, "true" continuum, printout
JNTRPOL	interpolation of input JNU
HBROAD	ion broadening (Hydrogen)
INNBPRNT	ionized number density input values printing
DOION	ion-of-the-run
ISCRS	I/O, scratch
FEPRNT	Iron populations printout
MITPRNT	iterations minimum printout
WISFILE	iterative studies file
PHASE2	iterative summaries
SUMMARY	iterative summaries
SUMGRAF	iterative summaries in graph form
ITDMP	iterative summary file contents index printout
ITERCHI	iterative summary of CHI
ITERCHK	iterative summary of consistency checks
ITERB	iterative summary of departure coefficient
ITERNE	iterative summary of electron density
ITERNH	iterative summary of HND
ITERNH	iterative summary of Hydrogen density
ITERS	iterative summary of Line Source Functions
ITERN	iterative summary of ND
ITERNE	iterative summary of NE
ITERN	iterative summary of number densities
ITERTAU	iterative summary of optical depth
ITERRHO	iterative summary of RHO
ITERRWT	iterative summary of RHOWT
ITERRK	iterative summary of RK (Lyman)
ITERS	iterative summary of S
ITERTAU	iterative summary of TAU
ITERTD	iterative summary of TDST
ITERNH	iterative summary of total Hydrogen density
ITERZ	iterative summary of Z

SUMTREND	iterative trends summary
JLYSAV	JB (Lyman continuum) save switch
PESRJALL	JBAR editing message
INTRPRNT	JBAR input values printing
USENCJ	JNU (continuum) method selection
HMSJPRNT	JNU (H-minus) printing
JNTRPOL	JNU input (PRD) interpolation
RATEGRAF	JNU(level), TR summary and JNU summary graphs
JLYSAV	JNU (Lyman continuum) save switch
JNUPRNT	JNU (PRD) printing
RATEGRAF	JNU (rates calculation) graphs
PRDMETH	Kneer-Heasley PRD formulation
KSHLCOPR	K-shell calculation background continuum calculation printout
KOMPRNT	Kurucz Composite Line opacity details printout
KURPRNT	Kurucz Statistical Line opacity details printout
	Level-$\mathcal{N}$-to-Continuum transfer = Lyman
ANALYSIS	Line absorption profiles details printout
LBDPRNT	Line center, background (continuum) data summary printout
ECLIGRAF	Line eclipse calculation graphs
LIGHT	Line flux calculation
SPHOUT	Line flux profiles using spherical coordinates
PROSAV	Line flux special output
LTE	Line flux, LTE
KURPRNT	Line haze opacity (statistical line opacity) details printout
LIGHT	Line intensity and flux calculation
PROCPRNT	Line intensity and flux, emergent continuum for
LINTDMP	Line intensity debug printout
PRODMP	Line intensity debug printout
DIDHL	Line intensity, dI/dh
APRFPRNT	Line intensity printout
PROSAV	Line intensity special output
LTE	Line intensity, LTE
OPANEG	Line opacity editing
CSF	Line Source Function calculation BC option
CSFB	Line Source Function calculation BC option
PERDMP0	Line Source Function calculation debug printout

PERDMP1	Line Source Function calculation debug printout
PERDMP2	Line Source Function calculation debug printout
PERDMP3	Line Source Function calculation debug printout
LSFGRAF	Line Source Function calculation graph
ALSFPRNT	Line Source Function calculation printout
LSFFULL	Line Source Function calculation printout
LSFPRNT	Line Source Function calculation printout
VELS	Line Source Function calculation velocity (diffusion)
SDIRECT	Line Source Function editing
SEDIT	Line Source Function editing
PESRJALL	Line Source Function editing message
	Line Source Function, frequency-dependent = SLF
ITERS	Line Source Function iterative summary
NEDIT	Line Source Function, positive values, editing number densities
LINECOPR	line wavelengths background continuum calculations printout
LSCALE	logs-of-TAU-scales graph
LONGNBM	long error message from b-ratios calculation
MCINPUT	lower-case input statements
CHEXLO	lower-level charge-exchange calculation
CHEXLOL	lower-level charge-exchange calculation, Hydrogen populations
LTEDATA	LTE calculations printout
CHEXLOL	LTE Hydrogen populations for lower-level charge exchange
LTE	LTE Line intensity and flux
	Lyman = Level-$\mathcal{N}$-to-Continuum transfer
LYMCOPR	Lyman continuum background continuum calculations printout
LYMDMP	Lyman continuum calculation debug printout
JLYSAV	Lyman continuum JNU (=JB) save switch
LYMAN	Lyman continuum transfer calculation
EPDMP	Lyman Epsilons debug printout
ENL2	Lyman Epsilons editing
EPSNEDC	Lyman Epsilons editing
EPCOMP	Lyman Epsilons methods comparisons
WATESTE	Lyman Epsilons weighting method
ENL	Lyman Epsilon-1 editing
CLNORM	Lyman lines (Hydrogen) (background) normalization factors
ULNORM	Lyman lines (Hydrogen) (background) normalization factors

ALYMPRNT	Lyman printout
ITERRK	Lyman RK iterative summary printing
SLYR	Lyman RK smoothing
MAGPRNT	Magnesium populations printout
ZCOMP	mass, input values, to be matched by adjusted Z values
HSEV	mass motion velocity in hydrostatic equilibrium calculation
STANDARD	matrix calculations control parameters printout
INTRPRNT	mean intensity, integrated, (JBAR), printing
EPCOMP	methods comparison (Lyman Epsilons)
SECOMP	methods comparison (Statistical Equilibrium calculation)
USENCJ	methods switch for background continuum JNU
	microtrubulence velocity = broadening velocity
MITPRNT	minimum printout for each iteration
MCINPUT	mixed-case input statements
MONOTAU	monotonic TAU
EXPAND	moving atmosphere
STANDARD	MU integration weights printout
ZPRNT	9 significant figures
AMDN1	N1 calculation, diffusion calculation
ADN1DMP	N1 calculation, diffusion calculation, details printout
ADN1PRNT	N1 calculation, diffusion calculation, printout
LNUMDMP	ND calculations details
PDETPRNT	ND calculations trace, using IBNVIEW
POPGRAF	ND graph
INNBPRNT	ND input values printing
ITERN	ND iterative summary printing
POPPRNT	ND printing
NESWICH	NE calculation switch
OPANEG	negative GTN editing
OPANEG	negative Line Opacity editing
ITERNE	NE iterative summary printing
INTRPRNT	net radiative bracket (RHO) input values printing
CALCOOL	net radiative cooling rates
CALHEAT	net radiative heating rates
NHADJ	NH adjustment (Hydrostatic Equilibrium calculation)
CPSW	NH adjustment (without Hydrostatic Equilibrium calculation)

ITERNH	NH iterative summary
INNBPRNT	NK input values printing
DOION	'no ion'
CLNORM	normalization factors for background Hydrogen Lyman lines
ULNORM	normalization factors for background Hydrogen Lyman lines
LNUMDMP	number densities dump
NEDIT	number densities editing for positive line source functions
POPGRAF	number densities graph
INDPRNT	number densities input values printing
INNBPRNT	number densities input values printing
GTNSTIM	number densities, instead of BDs, in STIM for GTN(u,l)
ITERN	number densities iterative summary
APOPPRNT	number densities printout
POPPRNT	number densities printout
NRSMOOTH	number densities ratios smoothing, diffusion calculations
NBPRNT	number densities supplementary printout
STANDARD	numerical data printout
CSFGRAF	opacity and background continuum source function graph
AVOPRNT	opacity (Averaged Lines) details printout
KOMPRNT	opacity (Composite) details printout
KURPRNT	opacity (Statistical) details printout
SPHETAU	optical depth along ray by quadratic integration
TAUPRNT	optical depth calculation printout
TAUDMP	optical depth integrations debug printout
ITERTAU	optical depth iterative summary
MONOTAU	optical depth monotonicity
TAUSUM	optical depth summary printout
OPTHINL	optically-thin-limit approximation
AOPTPRNT	OPTIONS printout
OPTPRNT	OPTIONS printout
ORIGIN	origin regions of computed intensities
ORSHORT	origin regions of computed intensities
ORT	outward-only radiation
ALL	overall iterations general printouts frequency control
OXYPRNT	Oxygen populations printout
OXY2PRNT	Oxygen-II populations printout

OXY3PRNT	Oxygen-III populations printout
PED	particle energy dissipation calculation
PEDDMP	particle energy dissipation calculation details dump
PARTVAR	partition function, mode
PARTPRNT	partition function, printout
PASSPRNT	'passive transitions' source function printout
IRUNT	performance statistics
IXSTA	performance statistics
NVOIT	performance statistics
PERDMP0	`PERSEUS` calculation debug printout
PERDMP1	`PERSEUS` calculation debug printout
PERDMP2	`PERSEUS` calculation debug printout
PERDMP3	`PERSEUS` calculation debug printout
CSWITCH	`PERSEUS` calculation selector of temperature for b
APHICOPR	photoionization (additional), background continuum data printout
APHIPRNT	photoionization (additional), details printout
STANDARD	physical constants printout
PIJPRNT	PIJ printout control
MAKIX	place-markers in printout file
POPBSW	populations ions departure coefficients
PHASE2	post-processing
PRDCOPR	PRD background continuum data printout
DRDMP	PRD DR debug printout
PRDITER	PRD iterations printout control
JNTRPOL	PRD JNU input interpolation
JNUPRNT	PRD JNU printout control
PRDMETH	PRD method selector
QSFEDIT	PRD modified source function (QSF) editing
PRDITER	PRD printout
PRDPRNT	PRD printout
SNUSHFT	PRD SNU frequency shift for profile calculation
STANDARD	precalculated integration weights printout
MAKIX	printout file place markers
ALLY	printout frequency control for HSL iterations
ALL	printout frequency control for overall iterations
EVERY	printout frequency control for sub-iterations

MITPRNT	printout: minimum per iteration
SNUSHFT	profile calculation PRD SNU frequency shift
APRFPRNT	profile calculation printout
PROSAV	profile emission special output
FLWBPRNT	profiles, flow-broadened
FLWBROAD	profiles, flow-broadened
ANALYSIS	profiles, line, details printout
SEDITIF	profiles, line, edit SLF for
PROCPRNT	profile-specific emergent continuum intensity and flux
IRUNT	program version description
STANPRNT	provisional input tables printout
QSFEDIT	QSF editing
RABDAT	RABD calculation data
USETRIN	radiation temperatures used for rates calculation
ILR	radiation, incident
INCIDNT	radiation, incident
INCIFRNT	radiation, incident
ORT	radiation, outward only
TRPRNT	radiation temperature, effective, printout
CALCOOL	radiative cooling rates
CALHEAT	radiative heating rates
INDXDMP	random access file indices dumps
RATECOPR	rates calculation background continuum data printout
USETRIN	rates calculation, from TR
RATEPRNT	rates calculation printout
RATEGRAF	rates calculation TR and JNU graphs
RATEALL	rates integrations details printout
RATEFULL	rates integrations details printout
RATESUMM	rates integrations summary printout
USEWTAB	rates integrations wavelengths, standard
WTABPRNT	rates integrations wavelengths, standard
CALCOOL	rates (net radiative cooling)
CALHEAT	rates (net radiative heating)
RIJPRNT	ratios of collision rates RIJ printout
BDGRAF	ratios of departure coefficients graph
RHOFUDGE	ratios of departure coefficients RHO fudging

SPHETAU	ray-optical-depth by quadratic integration
DELABORT	reading input: delayed abort
RCOMPRNT	recombination calculation details printout
REFLECT	reflective finite slab
ORIGIN	regions of formation of computed intensities
ORSHORT	regions of formation of computed intensities
HENORM	renormalization of Helium populations (diffusion calculation)
INSCARD	restart file insurance
JBDNC	RHO and b-ratios calculation bypass
RHOWOPT	RHO calculation
RHEDIT	RHO editing
PESRJALL	RHO editing message
RHOFUDGE	RHO fudging for calculating ratios of departure coefficients
INTRPRNT	RHO input values printing
ITERRHO	RHO iterative summary printing
RHBPRDT	RHO printout
RHBPRNT	RHO printout
RHBPRSM	RHO printout
RSMOOTH	RHO smoothing (sequential)
WATESTR	RHO weighting method
ITERRWT	RHO weights iterative summary
RHOWOPT	RHO/W calculation
IRHWED	RHOWT input editing
RIJPRNT	RIJ printout control
RKINCR	RK enhancement factors
COMPRK	RK, Lyman, comparisons
ITERRK	RK, Lyman, iterative summary
SLYR	RK, Lyman, smoothing
KROSSID	Rosseland mean opacity integration details printout
RSQUARE	R-squared depth variation of dilution factor
ENHANCE	R-squared enhancement for emergent intensities
PESRJALL	S editing message
SSMOOTH	S-from-number density smoothing
ITERS	S iterative summary
INTGRAF	S & B vs. Z graphs, and intensity graphs (Phase 2)
ATOMSAV	save computed atomic model parameters

TOPE	save 'Continuum Plots' data
COOLSAV	save cooling rates data for plotting
FLUXSAV	save integrated flux quantities
JLYSAV	save Lyman-continuum JNU (=JB)
RABDAT	save RABD calculation data
TRANSAV	save transitions data in special file
ISCRS	scratch I/O
LINECDMP	scattering albedo analysis
LINECOMP	scattering albedo analysis
SQSMDMP	sequential smoothing details printout
SQSMPRNT	sequential smoothing messages
BSMOOTH	sequential smoothing of departure coefficients
DSMOOTH	sequential smoothing of diffusion terms
RSMOOTH	sequential smoothing of RHO values
SSMOOTH	sequential smoothing of S-from-number density values
RATEPRNT	SETTUP printout
RATEFULL	SETTUP, rates integrations details printout
STAUREDM	short error message from WN-matrix calculation
ZPRNT	significant figures printed, more
SILPRNT	Silicon populations printout
	SLF = frequency-dependent line source function
SEDITIF	SLF editing
SLFGRAF	SLF graph printing
SLFPRNT	SLF printing
SLFSAV	SLF saving in Special Spectrum Save File
BSMOOTH	smoothing of departure coefficients
DSMOOTH	smoothing of diffusion terms
SLYR	smoothing of Lyman RK values
NRSMOOTH	smoothing of number densities ratios, diffusion calculations
RSMOOTH	smoothing of RHO
SSMOOTH	smoothing of S-from-number density
GTNSMTH	smoothing of STIM for GTN(u,l)
SQSMDMP	smoothing, sequential, details printout
SQSMPRNT	smoothing, sequential, messages
SOBDMP	Sobolev escape probability solution details printout
SOBINT	Sobolev integration dump index

SODPRNT	Sodium populations printout
	source function: see also Line Source Function
SPHERE	source function calculations using spherical coordinates
ENHANCE	source function enhancement (R-squared) for emergent intensities
EPSW	source-function-epsilons printing
PASSPRNT	source function printout, passive transitions
AMDN1	"special N1" calculation
ADN1DMP	"special N1" calculation, details printout
ADN1PRNT	"special N1" calculation, printout
SPECSAV	special output, calculated spectra
CONSAV	special output, continuum intensity calculation
ECLISAV	special output, eclipse intensities
PROSAV	special output, profiles
PHASE2	spectrum calculations
SPECSAV	spectrum calculations save file
SPECSUM	spectrum summary
SPHOUT	spherical coordinates for line and continuum fluxes
SPHERE	spherical coordinates for source function calculations
TANG	spherical coordinates, use of tangent ray
SPHEGEOM	spherical coordinates, Z-dependent quantities printout
STANDARD	spherical coordinates, Z-dependent quantities printout
USEWTAB	standard background wavelengths
WTABPRNT	standard background wavelengths
STANCOPR	standard background wavelengths continuum data printout
STKWATT	Stark splitting, Hydrogen, components attenuation
HSTSUMM	Stark splitting, Hydrogen, summary
EXPAND	stationary atmosphere
SEBUG	statistical equilibrium debug printout
SECOMP	statistical equilibrium methods comparison
METSW	statistical equilibrium methods selection
METPRNT	statistical equilibrium methods selection printout
SEPRNT	statistical equilibrium printout
SETIME	statistical equilibrium timing data
KURPRNT	Statistical Line opacity details
GTNSTIM	STIM for GTN(u,l), formulation of
GTNSMTH	STIM for GTN(u,l), smoothing of

STIMPRNT	stimulated emission factors printout
EVERY	sub-iterations printout frequency control
SULPRNT	Sulphur populations printout
PHASE2	summaries
SUMMARY	summary and fudging printout
OPASUM	summary printout, absorbers
WAVEPRNT	summary printout, continuum wavelengths
EMISUM	summary printout, emitters
SUMGRAF	summary printout, graphical form
HSTSUMM	summary printout, Hydrogen lines Stark splitting
ITDMP	summary printout, iterative summary records index
LBDPRNT	summary printout, line center background (continuum) data
RATESUMM	summary printout, rates integrations
SPECSUM	summary printout, spectrum
TAUSUM	summary printout, TAU
WAVEPRNT	summary printout, wavelengths (Continuum)
NBPRNT	supplementary number densities and departure coefficients printout
TANG	tangent ray in spherical coordinates
SPHETAU	TAU along ray by quadratic integration
PTN	TAU integrands editing
TAUDMP	TAU integrations debug printout
ITERTAU	TAU iterative summary
LSCALE	TAU (logs) graph
MONOTAU	TAU monotonicity
TAUPRNT	TAU printout
STAUREDM	TAU-reduction (WN-matrix calculation) error message
SCALE	TAU scales printout
TAUPLOT	TAU scales printout
TAUSUM	TAU summary printout
ITERTD	TDST iterative summary
DUSTEMP	TDST recalculation
DUSTDMP	TDST recalculation numerical details printout
INTEDIT	TE (input) editing
ZPRNT	TE printout, extra
TEGRAF	temperature vs. optical depth graph
CSWITCH	temperature selector for b (for `PERSEUS`)

SETIME	timing comparison of statistical equilibrium methods
ITERNH	total Hydrogen density iterative printout
PDETPRNT	trace of BD and ND calculations at depth # IBNVIEW
RIJPRNT	transition rates printout control
TRANSAV	transitions data, save in special file
RATEGRAF	TR graph
TRPRNT	TR printout
TRUECONT	"true continuum" calculation
TRUECOPR	"true continuum" calculation printout
CONIPRNT	"true continuum" intensity printout
USETRIN	TR used for rates calculation
USETSM	TSM use control
VTV	turbulent pressure velocity default
DUSTYPE	Type-2 dust opacity calculation
MCINPUT	upper-case input statements
CHEXUP	upper-level charge-exchange calculation
CHXDMP	upper-level charge-exchange calculation dump
CHXPRNT	upper-level charge-exchange calculation printout
USETSM	use TSM
IVALICK	validity checking of intensity integrations
	velocity, broadening = velocity, microturbulent
VSWITCH	velocity, broadening, switch
VELS	velocity, diffusion, in Line Source Function
VELGRAD	velocity gradient terms
DIFFANA	velocity gradient terms, analysis
VELGDMP	velocity gradient terms, details printout
VLGPRNT	velocity gradient terms, printout
	velocity, microturbulent = velocity, broadening
VTV	velocity, microturbulent pressure, defaults
IRUNT	version description
VESCAPE	Voigt expression for escape probability
NVOIT	Voigt function calculations execution statistics
VTV	VT default
WAVEPRNT	wavelengths (Continuum) summary printout
WAVENUMB	wavelengths printed in spectrum output
WAVENUMB	wavenumbers printed in spectrum output

WNDMP	weight matrix calculations debug printouts
NWRHO	weight (RHO) adjustment procedure
WATESTE	weighting method for Lyman Epsilons
WATESTR	weighting method for RHO
COOLXRAY	X-rays cooling rate calculation
XRAYCRID	X-rays cooling rate integration details printout
ZCOMP	Z adjustment to match input mass values
ITERZ	Z iterative summary printing
ZPRNT	Z printout, extra

Section 7: **Program Execution**

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PANDORA is written in Fortran; work on it began in 1966. It has run on various computers and operating systems, both at CfA and other places; currently at CfA it runs under Solaris (a flavor of Unix) on a SUN workstation.
PANDORA uses a large program address space, supplemented by a scratch disk file which can grow large (several Gbytes) depending on the run.
Internally, PANDORA refers to I/O files by Fortran unit numbers "nn." Externally, under Unix these files bear the generic names "`fort.nn`." I use a script called `schema` which supervises a `pandora` run and links variously-named I/O files to the proper Fortran units. While users are free to set up `pandora` runs and I/O file names as they wish, they are also free to use `schema`. In the listing overleaf, I give both the Fortran unit numbers and the specific file names or `schema`'s file "extension codes" by which I refer to these files.

I recommend that users make *their own copies* of `pandora`, of `schema` (if used), and of the commonly available data files (such as atomic model files, Line Opacity data files, etc). This insulates users from the changes I routinely make to these files *without prior warning*. Users can then choose to make fresh copies whenever convenient.

Section 99 is a tutorial introduction to PANDORA and how to set up the input files.

The **Input Files** are connected to the following units:

- 3 – general run-specific input (—.`dat`);
- 4 – atmosphere model (—.`mod`);
- 7 – atomic model (—.`atm`);
- 8 – run-specific restart data (—.`res`);
- 9 – JNU restart values for a PRD run (—.`jnu`);
- 10 – required for Statistical Line opacity (`statistical`, see Section 9);
- 11 – required for Composite Line opacity (`composite`, see Section 9);
- 12 – required for Averaged Lines opacity (`average`, see Section 9).

Intermixed reading from files 3, 4, 7 and 8 is controlled by the **USE** statement. Part A of the input statements (see Section 3) must be in file 3 (—.`dat`); the very first occurrence of **USE** must also be in file 3 (—.`dat`).

The **Output Files** are connected to the following units:

- 15 – general printout (—.`aaa`, see Section 11);
- 16 – error messages and 'debug' data (—.`aer`, see Section 11);
- 19 – restart data, PANDORA input format (—.`rst`);
- 20 – restart data, mostly PANDORA input format (—.`msc`);
- 21 – restart data, PANDORA input format (—.`pop`);
- 22 – PRD JNU values, PANDORA input format (—.`jnr`);
- 23 – results from the emergent spectrum calculations (—.`spc`);
- 24 – calculated cooling rates (—.`coo`);
- 25 – continuum data, for use by separate programs (—.`csp`);
- 26 – sample matrices, for use by separate programs (—.`mat`);
- 27 – Source-Function-related data (transitions data) (—.`tsf`);
- 28 – `run_archive` (see below);
- 29 – journal file: copies of the input data statements as read (—.`jrl`);
- 30 – iterative studies data, for use by separate programs (—.`itr`);
- 31 – printout index (—.`aix`, see Section 11);
- 32 – checksums, for use by separate programs (—.`cks`).

The **Scratch File** is connected to unit 1 (—.`tmp`); it is a temporary file, used in direct access mode (see Section 5, Note 20).

The `run_archive` file is used to collect a 'performance data record' from each PANDORA run. This is a permanent file, opened for 'append access' as needed.

Notes

(Making a 'performance data record' depends on input parameter **IPERFA**.)

(Section 7 – last revised: 2003 Jul 30)

Section 8: **Output Files**

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Besides the printout files (described in Sections 7 and 11), PANDORA provides output in several additional files. Some of these contain data that can be used to restart the run (and may also contain data that is neither needed nor permissible for restarting – such files must be edited appropriately). Other files provide collections of data and results that are useful for various special purposes. See also Section 7.

Each of the four basic restart data files begins with the set of four "Run ID" lines (in the form of PANDORA comments), containing the run **HEADING**, program version number, two time stamps (one expressed in Smithsonian Days), and a summary of basic run data. Copies of the **HEADING** line also appear at various places in several files.

File `fort.19` contains general restart data, as follows:

• *Always* —
Run ID

• *Always* —
for all radiative transitions u, ℓ: $\mathbf{METSE}^{u,\ell}$ (*if* METSW *is on*), $\mathbf{RHO}_i^{u,\ell}$, $\mathbf{RHWT}_i^{u,\ell}$, $\mathbf{JBAR}_i^{u,\ell}$, $\mathbf{CHI}_i^{u,\ell}$, $\mathbf{AW}_i^{u,\ell}$

• *If option* LYMAN *is on* —
for level j = **KOLEV**: $\mathbf{IRKCOMP}^j = 0$, $\mathbf{RK}_i^j$, $\mathbf{RKWT}_i$, $\mathbf{IRLCOMP}^j = 0$, $\mathbf{RL}_i^j$, $\mathbf{EP1}_i$, $\mathbf{EP2}_i$

• *Always* —

$\mathbf{NK}_i$, $\mathbf{ND}_i^j$ for all levels j; $\mathbf{BD}_i^j$ for all levels j

• *Always* —
"**USE (INPUT)** "

File `fort.20` contains miscellaneous restart and other data, as follows:

• *Always* —
Run ID

• *Always* —
N, $\mathbf{Z}_i$, $\mathbf{TE}_i$

• *If* **POPUP** *is on but* ≠ `HYDROGEN` —
$\mathbf{NE}_i$, $\mathbf{ZME}_i$, $\mathbf{NC}_i$

• *If option* HSE *is on* —
$\mathbf{MASS}_i$, $\mathbf{PGS}_i$, $\mathbf{PTO}_i$, $\mathbf{TE}_i$, $\mathbf{VT}_i$, $\mathbf{VM}_i$, $\mathbf{GD}_i$, $\mathbf{T5000}_i$

• *If option* ATOMSAV *is on and default values of atomic parameters were computed* —
atomic model parameter values

• *If options* DUSTEMP *and* DUSTYPE *are both on* —
$\mathbf{TDST}_i$

• *If* **MH2N** = 1 —
$\mathbf{H2N}_i$

• *If* **MCON** = 1 —
$\mathbf{CON}_i$

• *If* **POPUP** = `HYDROGEN` *and* **MFONT** = 1 —
atmosphere model data tables for Juan Fontenla

• *If* **NAME** = `HELIUM2` —
N, $\mathbf{Z}_i$, $\mathbf{HE304}_i$

• *If this is a K-shell run* —
N, $\mathbf{Z}_i$, $\mathbf{QIN}_i$

• *If* **IRPUN** = 1 —
two sets of data for a separate program (CENSUS) which calculates abundance ratios of ions of the same element
(these data include **Z**, and FLVSL and FIONL, as they appear in the 'POPULATIONS' printout; if AMDIFF is on and this is a Helium run, then a second set of these data will appear)

• *If option* JLYSAV *is on* —

Notes

Level-$\mathcal{N}$-to-Continuum (Lyman) J-bar values

• *If option* USETRIN *is off and* **MTREF** = 1 — Effective Radiation Temperature values

• *If* **MDFV** = 1 *and* AMDIFF *is on* —
N, $\mathbf{Z}_i$, $\mathbf{TE}_i$, $\mathbf{VM}_i$, $\mathbf{VAMB}_i$, $\mathbf{VBMB}_i$, $\mathbf{VCMB}_i$, $\mathbf{VDMB}_i$, $\mathbf{VH}_i$, $\mathbf{VP}_i$, $\mathbf{VE}_i$, $\mathbf{V1}_i$, $\mathbf{V2}_i$, $\mathbf{V3}_i$

• *If* **MDFG** = 1 *and* AMDIFF *is on* —
$\mathbf{GVL}_i^j$, $1 \le j \le \mathbf{NL}$

• *If* **RHEAB** *was recomputed* —
N, $\mathbf{Z}_i$, $\mathbf{RHEAB}_i$

• *If* **NAME** = `HELIUM` *or* `HELIUM2` *and* AMDIFF *is on* —
N, $\mathbf{Z}_i$, and either: $\mathbf{PALBET}_i$, $\mathbf{PBETAL}_i$ if `HELIUM`; or $\mathbf{PGMBET}_i$, $\mathbf{PBETGM}_i$ if `HELIUM2`

• *If option* CHEXUP *is on and this is one of the 10 "charge exchange" ions* —
N, $\mathbf{Z}_i$, $\mathbf{XRKH}_i^j$, $\mathbf{XRLH}_i^j$, $4 \le j \le$ NPQMX

• *If* **MKURU** = 1 —
then data for Kurucz's spectrum programs

(these data comprise the computed departure coefficients of the ion-of-the-run plus, if this is a Hydrogen run, some atmosphere data tables)

• *If option* CALCOOL *is on* —
data for separate program to calculate new **TE** values

(these data include **NE**, **NH**, **TE**, SUM [which is called 'Total Rate' in the 'NET RADIATIVE COOLING RATES' printout], and, in a Hydrogen run, SUMSM [*i.e.,* smoothed values of SUM])

• *If option* FLUXSAV *is on* —
data for separate programs to calculate new **TE** values

(these data include **Z** and **TE**, and 'Integrated Flux', 'Integrated Derivatives' and 'Effective Temperature', as they appear in the 'CONTINUUM FLUX INTEGRALS' printout)

• *If option* ECLISAV *is on* —
results of eclipse emergent profile calculations

(these data include **R1N**, **Z** and **FRR**, and 'DL', 'ID' and 'IS', as they appear in the 'ECLIPSE INTENSITY AND FLUX' printout)

• *If option* CLNORM *is on and this run calculates H Lyman* α *and/or* β —
FNRMLA and **FNRMLB**

(used by PANDORA to adjust the simulated H Lyman α and β lines in the background)

File `fort.21` contains populations restart data as follows:

• *Always* —
Run ID

• *If option* HSE *is on, and* **POPUP** *is set, and* **NAME** = `HYDROGEN` —
$\mathbf{NE}_i$, $\mathbf{ZME}_i$, $\mathbf{NC}_i$

• *If option* HMS *is on* —
$\mathbf{BDHM}_i$

• *If option* AMDIFF *or option* VELGRAD *is on, and* VBMB $\neq 0$ —
$\mathbf{VBMB}_i$

• *If option* HSE *is on, or if option* HSE *is off and option* CPSW *is on* —
$\mathbf{NH}_i$

• *If* **POPUP** = `HYDROGEN` —
for all levels j such that $1 \le j \le 15$: $\mathbf{NP}_i$, $\mathbf{HN}_i^j$, $\mathbf{BDH}_i^j$,
plus all those 'population ions' populations tables (in the order shown just below)
for which there was at least some input

• *If* **POPUP** = `CARBON` —
for all levels j such that $1 \le j \le 8$: $\mathbf{CK}_i$, $\mathbf{CN}_i^j$, $\mathbf{BDC}_i^j$

• *If* **POPUP** = `SILICON` —
for all levels j such that $1 \le j \le 8$: $\mathbf{SIK}_i$, $\mathbf{SIN}_i^j$, $\mathbf{BDSI}_i^j$

• *If* **POPUP** = `HELIUM` —
for all levels j such that $1 \le j \le 13$: $\mathbf{HEK}_i$, $\mathbf{HEN}_i^j$, $\mathbf{BDHE}_i^j$

• *If* **POPUP** = `HELIUM2` —
for all levels j such that $1 \le j \le 8$: $\mathbf{HE2K}_i$, $\mathbf{HE2N}_i^j$, $\mathbf{BDHE2}_i^j$

• *If* **POPUP** = `ALUMINUM` —
for all levels j such that $1 \le j \le 8$: $\mathbf{ALK}_i$, $\mathbf{ALN}_i^j$, $\mathbf{BDAL}_i^j$

• *If* **POPUP** = `MAGNESIUM` —
for all levels j such that $1 \le j \le 8$: $\mathbf{MGK}_i$, $\mathbf{MGN}_i^j$, $\mathbf{BDMG}_i^j$

• *If* **POPUP** = `IRON` —
for all levels j such that $1 \le j \le 8$: $\mathbf{FEK}_i$, $\mathbf{FEN}_i^j$, $\mathbf{BDFE}_i^j$

Notes

• *If* **POPUP** = `SODIUM` —
for all levels j such that $1 \leq j \leq 8$: $\mathbf{NAK}_i$, $\mathbf{NAN}_i^j$, $\mathbf{BDNA}_i^j$

• *If* **POPUP** = `CALCIUM` —
for all levels j such that $1 \leq j \leq 8$: $\mathbf{CAK}_i$, $\mathbf{CAN}_i^j$, $\mathbf{BDCA}_i^j$

• *If* **POPUP** = `OXYGEN` —
for all levels j such that $1 \leq j \leq 14$: $\mathbf{OK}_i$, $\mathbf{ON}_i^j$, $\mathbf{BDO}_i^j$

• *If* **POPUP** = `OXYGEN2` —
for all levels j such that $1 \leq j \leq 8$: $\mathbf{O2K}_i$, $\mathbf{O2N}_i^j$, $\mathbf{BDO2}_i^j$

• *If* **POPUP** = `OXYGEN3` —
for all levels j such that $1 \leq j \leq 8$: $\mathbf{O3K}_i$, $\mathbf{O3N}_i^j$, $\mathbf{BDO3}_i^j$

• *If* **POPUP** = `SULPHUR` —
for all levels j such that $1 \leq j \leq 8$: $\mathbf{SK}_i$, $\mathbf{SN}_i^j$, $\mathbf{BDS}_i^j$

File `fort.22` contains special restart data as follows:

- *Always* —
Run ID
- $\mathbf{JNU}_{i,k}^{u,\ell}$ for all PRD transitions

File `fort.23` contains data from all emergent spectrum calculations, to make them available to various auxiliary programs; this file is written only if options SPECSAV, PROSAV and/or CONSAV are on.

(These data include much of the input for the continuous intensity and flux calculations, and for the line intensity and flux calculations – mostly labelled in the file. The various quatities in the file can be identified by comparing them with the detailed normal printout. Note that, for Continuum Flux, the value printed is $4\pi H$, while the value saved is H. Both continuous intensity and line intensity are given for each value of μ, as is obvious. Extra data are saved when there is incident radiation – again, this should be clear. *Note*: flow-broadened profiles are indicated by setting the value of the velocity table index $\mathbf{NVY} = 0$. *Note* the effect of options WAVENUMB and INCIFRNT)

File `fort.24` contains results of the cooling and heating rates calculations, for separate plotting programs; this file is written only when options CALCOOL and COOLSAV are both on.

(These data include almost all the quantities that appear in the two COOLING RATES and the two HEATING RATES printouts)

File `fort.25` contains data for separate programs to produce 'continuum data' plots; this file is written only when the option TOPE is on.

(These data include, for each wavelength, the complete 'Continuum Data Blocks' (which contain all the information that appears in complete 'CONTINUUM DATA' printouts), followed by, again for each wavelength, the computed continuous emergent intensities and intermediate results from those computations. Since these data are not normally accessible, they are provided in this special file.

File `fort.26` contains contains data for separate programs to analyze the performance of PANDORA's matrix inversion algorithms; this file is written only when the switch **SMATC** > 0 and qualifying matrices were encountered; (this file is only of use to me, as the program developer)

File `fort.27` contains final values of data from the line source function calculations for all radiative transitions, as they appear in the printout file; this file has them in a format intended to be more convenient for user-written analysis and plotting programs. This file is written when the option TRANSAV is on.

(These data include **Z** and **TE**, and then 'TAU', 'S', 'RHO', 'JBAR' and ST, the total source function as plotted)

File `fort.30` contains 'iterative studies' data for a separate program to analyze the performance of PANDORA's iterative procedures, and provides various graphical displays of the data.

(These data include **Z** and **TE**, and 'EPSILON', 'S', 'TAU' and 'JBAR', as they appear in the 'LINE SOURCE FUNCTION' printout, for transition (**MS**/**NS**) *only*, for every iteration)

File `fort.32` contains debug checksums, for separate program `RELAX` that compares checksum data files from different runs.

(This is not intended for routine use; it is a debugging aid for ongoing program development)

Section 9: **Background Line Opacities**

****

PANDORA's calculation of line source functions requires knowledge of the background opacity; this opacity is referred to casually as the "background continuum." Opacity from other lines may contribute to this background continuum for any given line. When such other lines are lines of the ion-of-the-run, then PANDORA's "blended line" mechanism is available to handle it. Some background lines due to H, He-II, and CO can be included explicitly (see the table printed by PANDORA as part of the ATMOSPHERE printout). In addition, general background line opacity can be included in three other ways: Statistical Line opacity, Composite Line opacity, and/or Averaged Line opacity; these are all added into the total background continuum.

This section describes the *control*, the *input* and the *data* requirements of these background absorbers. Note that the necessary input files are also mentioned in Section 7.

These three Background Line opacities are mutually exclusive: only one of them can be used at any given wavelength. Averaged Line opacity has highest priority: if it is used, then neither of the other two is used. Composite Line opacity has the next highest priority: if it is used, then Statistical Line opacity is not used; thus the latter is used only if neither of the others is used.

A) Scattering albedo

Each of these Background Line opacities is apportioned between an absorption part and a scattering part by means of an albedo table that is a function of depth. This table is obtained by interpolation from the input tables $\mathbf{ZALBK}_\ell$ and $\mathbf{ALBK}_\ell, 1 \leq \ell \leq \mathbf{NKA}$.

When $\mathbf{NKA} = 0$, then the scattering albedo $= 1/(1 + Q_i)$, where Q_i is a function of depth and wavelength

$$Q_i = X_i \left(1 + \mathbf{CLM}\frac{10^4}{LM}\right) + PNH \left(\frac{\mathbf{NH}_i}{\mathbf{NH}_N}\right),$$

and X_i is either

$$X_i = \frac{\mathbf{XNE}_i}{1.07 \times 10^{14}} \left(\frac{LM}{5000}\right)^3 \frac{1}{\mathbf{CQM}}, \qquad \mathbf{CQM} > 0,$$

or

$$X_i = \frac{\mathbf{XNE}_i}{1.07 \times 10^{14}} \left(\frac{LM}{5000}\right)^3 \frac{1}{\mathbf{CQA}(\mathbf{TE}_i)}, \qquad \mathbf{CQM} \leq 0.$$

Here LM is wavelength in Angstroms, and **CQM** and **CQA** (a tabulated function of $\mathbf{CQT}_k$, $1 \leq k \leq \mathbf{NCQ}$) are input parameters (see Section 5, Note *117). The default values of this tabulated parameter are:

CQT	**CQA**
4000	0.0001
5000	0.001
6000	0.01
7000	0.1
8000	1.0

B) Statistical Line opacities

PANDORA can use opacity distribution functions computed by Kurucz, as described in VAL II. Ten component opacity distributions, identified by $k = 1$ through $k = 10$, are given for 11×9 grids of temperature and electron density, at each of 53 wavelength grid points in the range 1269.80 – 8352.95 Å.

Temperature grid: log(TE) =

3.60 3.64 3.68 3.72 3.76 3.80 3.84 3.88 3.92 3.96 4.00

Density grid: log(NE) =

9.0 10.0 11.0 12.0 13.0 14.0 15.0 16.0 17.0

The necessary tabulated numerical data from Kurucz are in a special data file, "`statistical`," which must be connected to logical unit 10 (see Section 7). Using the actual input tables of $\mathbf{TE}_i$ and $\mathbf{NE}_i$, $1 \leq i \leq \mathbf{N}$, at the start of a run PANDORA constructs an array of $53 \times \mathbf{N}$ values of Statistical opacity, using the specified component distribution function. For ultimate control over the computed values of this array, a table of *ad hoc* multipliers, $\mathbf{FKUR}_\ell$, $1 \leq \ell \leq 53$, (*i.e.* one for each of the given wavelength values), can be specified in the input; normally all values of $\mathbf{FKUR} = 1$.
The input parameter **KURIN** is used to specify which component distribution should be used: $k =$ **KURIN**. (When the value of **KURIN** $= 0$, then no Statistical opacities are computed, and the data file need not be provided.) A subset of the available wavelength range can be selected by specifying a lower limit, **KURMI** (printed as LLMIN), and an upper limit, **KURMA** (printed as LLMAX).
When option KURPRNT is on then a printout and a graph appear. Values of Statistical opacity are printed for all **N** depths, at wavelength points # 1 and every **LWNT**'th wavelength point thereafter. Values of Statistical opacity are plotted for all 53 wavelengths, at five depths whose indices are:
KINMAX + **KININT**, **KINMAX**, **KINMAX** − 1×**KININT**, **KINMAX** − 2×**KININT**, and **KINMAX** − 3×**KININT**.
A dump of raw data (as read from `statistical`), at wavelength points # 1 and every **KUDNT**'th wavelength point thereafter, appears if **KUDNT** > 0.

C) Composite Line opacities

Kurucz has calculated the composite opacity due to all known atomic and molecular lines (*circa* mid-1989) as a function of temperature, pressure, velocity and wavelength, assuming local thermodynamic equilibrium. His opacities are given for 56 values of temperature, 21 values of pressure, 5 values of velocity, and 35093 wavelength grid points in the range 8.97666 – 9998.56236 nm.

Temperature grid: log(TE) =

3.32	3.34	3.36	3.38	3.40	3.42	3.44	3.46	3.48	3.50
3.52	3.54	3.56	3.58	3.60	3.62	3.64	3.66	3.68	3.70
3.73	3.76	3.79	3.82	3.85	3.88	3.91	3.94	3.97	4.00
4.05	4.10	4.15	4.20	4.25	4.30	4.35	4.40	4.45	4.50
4.55	4.60	4.65	4.70	4.75	4.80	4.85	4.90	4.95	5.00
5.05	5.10	5.15	5.20	5.25	5.30				

Pressure grid: log(P) =

-2.0	-1.5	-1.0	-0.5	+0.0	+0.5	+1.0	+1.5	+2.0	+2.5
+3.0	+3.5	+4.0	+4.5	+5.0	+5.5	+6.0	+6.5	+7.0	+7.5
+8.0									

Velocity grid: V (km/s) =

0.0	1.0	2.0	4.0	8.0

These $35,093 \times (56 \times 21 \times 5) = 35,093 \times 5,880 = 206,346,840$ opacity values have been written to six binary files, as follows:

File name	**# points**	**Range (nm)**
BSAMHE	4659	8.97666 – 22.78209
BSAMLY	6936	22.78377 – 91.16094
BSAMBA	6934	91.17535 – 364.62911
BSAMVI	6163	364.70183 – 1249.82029
BSAMIR1	6934	1250.0 – 4999.28118
BSAMIR2	3467	5000.0 – 9998.56236

PANDORA works with a reduced set of $1,750 \times 5,880 = 10,290,000$ opacity values at 1,750 wavelength grid points covering almost the same range, at the same temperatures, pressures and velocities. This reduction is done by `PROCURE`, a separate program; its output file, "`composite`," must be connected to logical unit

11 (see Section 7). (`CONCUR`, a second separate program, selects a specified, unreduced subset of Kurucz's data; its output file has the same format as that produced by `PROCURE`.) PANDORA cannot read Kurucz's original files—it only reads files produced by `PROCURE` (or `CONCUR`).

Reduction Procedure

1) The original set of 35,093 wavelengths is cut into 350 blocks of 100 consecutive "original" wavelengths each (the last 93 original wavelengths are ignored).

2) Such a block pertains to "original" wavelengths $W_j, 1 \leq j \leq 100$, and contains $100 \times 5,880$ opacity values.

3) "Nominal" wavelength values, $N_i, 1 \leq i \leq 5$, are computed such that $N_i = W_1 + (2 \times i - 1) \times (W_{100} - W_1)/10$.

4) In each original block the opacity values pertaining to a given (TE,P,V)-triple are treated as a separate table of opacity *vs.* W_j.

5) Such a table of 100 opacity values is sorted into increasing order. The 10^{th}, 30^{th}, 50^{th}, 70^{th} and 90^{th} entries of this ordered opacity table, together with their associated (original) values of W_j, are pulled out. These opacity values constitute the "reduced" opacity table.

6) The 5 selected opacity values are then ordered so that their associated (original) wavelengths W_j are in increasing order.

7) The 5 "nominal" wavelengths N_i are then assigned to these 5 (ordered) opacity values of the "reduced" table.

8) This is done for all 5,880 (TE,P,V)-triples, so that 5,880 "reduced" tables of 5 entries each are obtained.

9) In this manner, each original block of data pertaining to 100 "original" wavelengths is replaced by a reduced block of data pertaining to 5 "nominal" wavelengths, for all values of temperature, pressure and velocity.

A typical PANDORA run need not use all 1750 wavelengths of the reduced data set, since it uses only those that fall within the wavelength bands specified in the input. There are **NAB** such band(s), and Composite Line opacity will be computed at all those wavelengths W (in Å), arising in the context of a given PANDORA run, such that $\mathbf{BANDL}_\ell \leq \mathrm{W} \leq \mathbf{BANDU}_\ell$, $1 \leq \ell \leq \mathbf{NAB}$. (When $\mathbf{NAB} = 0$, then no Composite Line opacities will be computed, and the data file need not be provided.) Using the input tables of $\mathbf{TE}_i$ and $\mathbf{V}_i$, and a computed

table of P_i, $1 \leq i \leq \mathbf{N}$, PANDORA constructs an array of KOMP $\times$ **N** values of Composite opacity at the start of a run; here KOMP is the count of all the wavelength points of the input 'reduced' data set that are contained within the specified band(s).
PANDORA automatically computes 'continuum data' for these KOMP wavelength points. Values of the 'method control parameters' for the relevant Continuum Source Function calculations can be specified, for each band, using the input values of **BANDY**. Printout from these continuum calculations is controlled by option COMPCOPR.
When option KOMPRNT is on then a printout and a graph appear. Values of Composite opacity are printed for all **N** depths, at wavelength points # 1 and every **LWNT**'th wavelength point thereafter. Values of Composite opacity are plotted for all KOMP wavelengths, at five depths selected by **KINMAX** and **KININT** as with Statistical opacity, above.
A dump of raw data (as read from `composite`), at wavelength points # 1 and every **KODNT**'th wavelength point thereafter, appears if **KODNT** > 0.

Note: Kurucz's original data files (BSAMHE, etc) no longer exist; thus the reduction and extraction procedures described here are of historical interest only. We have used our "standard" reduced file `composite` for many years; it is the only data input file now available.

D) Averaged Line opacities

PANDORA can use arbitrary opacity distributions specified as functions of arbitrary grids of depth (in km, like the **Z** table) and of wavelength (in Å). These opacity sets are interpolated to the values of depth and wavelength that are needed for the calculation. If option AVELOP is on, then PANDORA expects a special data file, connected to logical unit 12 (see Section 7). If there is data in this file (*i.e.,* if a wavelength grid is specified), then Averaged Line opacity will be used at all wavelengths within the range of the wavelength grid.

This special data file is a binary file that PANDORA attempts to read as in the following quasi-Fortran code fragment:

```
- - - -
integer KWA, NT, NP, NZ
real*8 WAVES(KWA), ZGRID(NZ), AVOP(NZ)
- - - -
read (12) KWA, NT, NP, NZ
- - - -
if (KWA .gt. 0) then
      read (12) (WAVES(I), I = 1,KWA)
      read (12) (ZGRID(I), I = 1,NZ)
      - - - -
      do 999 J = 1,KWA
            read (12) (AVOP(I), I = 1,NZ)
            - - - -
999         continue
      end if
      - - - -
```

(The parameters `NT` and `NP` provide for possible future program additions; currently they should both be set = 0.)

As each set of `NZ` opacity values pertaining to a given value of the wavelength grid is read, the data are interpolated to the **Z** table of the run; this process produces a final data array of size `KWA` × **N**.

When option AVOPRNT is on then a printout and a graph appear. Values of Averaged opacity are printed for all **N** depths, at wavelength points # 1 and every **LWNT**'th wavelength point thereafter. Values of Averaged opacity are plotted

for all KWA wavelengths, at five depths selected by **KINMAX** and **KININT** as with Statistical opacity, above.

(Section 9 – last revised: 2006 Nov 02)

Section 10: **Element Data**

****

Numerical data pertaining to electron-contributing elements are required for the electron density (**NE**) calculations. These data comprise an 'element table,' of **NMT** rows and 9 columns, that is set up for the run. Each row of the table pertains to a different ion; the default value of **NMT** = 38. The columns are for: element symbol (M), atomic number (atno), abundance realtive to Hydrogen (AB), ionization potential (CHI), partition function U-I and U-II (UI and UII), logarithmic abundance on a scale such that Hydrogen = 12.0 (LAB), default value of logarithmic abundance (DEF), and an integer (k) identifying the source of the abundance value. The default element table is given at the end of this section. *Note* option MCINPUT.

Data other than the default values (listed below) can be input with **NEWELE** and **ELEMENT** statements, as follows:

NEWELE (*j M atno AB CHI UI UII LAB DEF k*)

where j (an integer quantity) is the index of a group of entries (*i.e.* a row) in the element table; M (an alphanumeric quantity) must be a valid chemical element symbol; and n and k (integer quantities) and *AB, CHI, UI, UII, LAB* and *DEF* (floating point quantities) will constitute the j^{th} row of the element table. These fields must be given in the order shown. A **NEWELE** statement provides all the data for element M, which will override the entire current contents of the j^{th} row.

ELEMENT ($M\ I_1\ I_2\ \ldots\ I_n$)

where M must be a valid chemical element symbol, and I_i is one or more phrases,

each consisting of a pair of input fields: A V. The field A must be alphanumeric and is an identifier; it can take on the values: `AB` (= abundance), `LAB` (= logarithmic abundance), `UI` (= partition function), `UII` (= partition function), `CHI` (= ionization potential), or `ATNO` (= atomic number). The field V is numeric, and must be integer for A = `ATNO`, but floating point otherwise. Upon reading the phrase $I = A\ V$, PANDORA will set the value of A for element M equal to V. Examples:

1) `ELEMENT ( FE AB 3.5E-5 CHI 7.87 UI 24. )`

specifies Iron, and sets the abundance, ionization potential and the partition function UI equal to 0.000035, 7.87 and 24.0, respectively.

2) `ELEMENT ( FE CHI 7.87 )`
`ELEMENT ( fe ui 24. ab 3.5e-5 )`

is one of many configurations equivalent to example (1).

Note that an **ELEMENT** statement is normally used to override single existing entries in the current element table. The **NEWELE** statement is provided to allow emergency wholesale changes in the built-in default element data; (the preferred way to make bulk permanent changes in this table is to modify the PANDORA source code). In general the **NEWELE** statement should be avoided since, during input reading, **ELEMENT** statements are checked much more carefully for correctness and consistency than **NEWELE** statements.

Notes

PANDORA sets the value of **NMT** to its default before Part B of the input is read, and sets up the default values for **NMT** rows of the element table before Part D of the input is read (see Section 3). This makes a number of things possible; for instance:

• If "`NMT ( 5 )` " occurs, then the element table of the run will contain only 5 rows, whose default data will be set equal to those contained in the first five rows of the default element table (see below).

• If "`NMT ( 39 )` " occurs, then the element table of the run will contain 39 rows; the default data for the first 38 rows will be equal to those contained in the default element table (see below), while the default entries of the 39^{th} row will all be blanks or zero, respectively. Note that the input value of **NMT** may not exceed 50.

• Any of the numeric entries in the element table may be changed from their default values by mentioning them explicitly in **ELEMENT** statements. For example, if only AB(Na) (*i.e.* the abundance of Sodium) needs to be changed, to 0.00001, then there need not be an **NMT** statement, and only "`Element ( NA AB 1.E-5 )` " would be needed in Part D of the input.

• If **NMT** is explicitly input as greater than 38, then additional ions, with their associated data, can be input with **ELEMENT** statements. When an **ELEMENT** statement is processed, its element symbol (M), is compared with those currently present in the element table. If there is no match, and if there is at least one empty row, then the new element symbol and its associated data will be accepted. Conversely, if an attempt is made to introduce more than **NMT** entries, then the run will be stopped. When a **NEWELE** statement is processed, it will override the contents of the j^{th} row, regardless.

Default Element Table

M	*atno*	*AB*	*CHI*	*UI*	*UII*	*LAB*	*DEF*	*k*
H	1	0	13.595	2.00	1.00	0	12.00	
HE	2	0	24.58	1.00	2.00	0	11.00	
HE2	2	0	54.403	2.00	1.00	0	11.00	
LI	3	0	5.39	2.09	1.00	0	1.05	3
BE	4	0	9.32	1.02	2.00	0	1.38	3
B	5	0	8.296	6.03	1.00	0	2.70	1
C	6	0	11.256	9.28	5.94	0	8.39	4
N	7	0	14.529	4.07	8.91	0	7.85	5
O	8	0	13.614	8.70	3.98	0	8.66	2
F	9	0	17.418	5.62	8.32	0	4.56	1
NE	10	0	21.558	1.00	5.37	0	7.84	3
NA	11	0	5.138	2.02	1.00	0	6.17	3
MG	12	0	7.644	1.01	2.01	0	7.53	3
AL	13	0	5.984	5.83	1.03	0	6.37	3
SI	14	0	8.149	9.26	5.82	0	7.51	3
P	15	0	10.474	4.46	8.12	0	5.36	3
S	16	0	10.357	8.12	4.16	0	7.14	3
CL	17	0	13.014	5.25	7.76	0	5.50	1
AR	18	0	15.755	1.00	4.89	0	6.18	3
K	19	0	4.339	2.18	1.00	0	5.08	3
CA	20	0	6.111	1.03	2.29	0	6.31	3
SC	21	0	6.538	12.0	22.9	0	3.05	3
TI	22	0	6.818	30.2	56.2	0	4.90	3
V	23	0	6.738	41.7	43.7	0	4.00	1
CR	24	0	6.763	10.3	7.24	0	5.64	3
MN	25	0	7.432	6.45	7.76	0	5.39	1
FE	26	0	7.896	24.5	39.2	0	7.45	3
CO	27	0	7.863	31.6	27.5	0	4.92	1
NI	28	0	7.633	28.8	10.0	0	6.23	3
CU	29	0	7.724	2.29	1.02	0	4.21	1
ZN	30	0	9.391	1.00	2.00	0	4.60	1
GA	31	0	5.997	5.37	1.00	0	2.88	1
GE	32	0	7.899	8.13	4.37	0	3.58	3

RB	37	0	4.177	2.29	1.00	0	2.60	1
SR	38	0	5.693	1.26	2.19	0	2.92	3
Y	39	0	6.377	12.0	15.1	0	2.21	3
ZR	40	0	6.835	33.9	45.7	0	2.59	3
BA	56	0	5.210	2.29	4.17	0	2.17	3

(The source citations identified by the value of the integer k appear in the PANDORA printout; these are built into the source code, and cannot be changed by **ELEMENT** or **NEWELE** statements.)

When input reading is finished, the 'element table' exists only in *provisional* form. It is converted into *final* form by the following sequence of steps:
1) Look at every row. If any AB > 0, then compute the corresponding LAB from it; if AB ≤ 0, then set LAB = DEF.
2) Look at every row. If any AB $= 0$, then compute it from the corresponding LAB; if AB ≤ 0, then set AB $= 0$ and LAB $= 0$. (AB < 0 is legitimate in **ELEMENT** and **NEWELE** statements.)
3) If **FABD** $\neq 0$, then look at every row *except* those of Hydrogen or Helium. Set the final value of AB = **FABD** $\times$ AB. If this final AB > 0, then compute LAB from it.
4) *Squeeze out* (eliminate) from the table every row whose AB $= 0$, and adjust the value of **NMT** accordingly.
5) If the Hamburg data (used to calculate depth-dependent partition functions when option PARTVAR is on) has usable `CHI` values for any of the ions in the final table, then such Hamburg values will replace the corresponding default or input values of `CHI` (regardless of the status of option PARTVAR).

(Section 10 – last revised: 2007 Feb 05)

Section 11: **Printout**

Initial PANDORA development occurred in a batch-oriented environment using a remote central computing system. Output was written to a file that was printed sometime after completion of the run. The printers were expected to use $11\times14\frac{7}{8}''$ fan-fold paper providing about 60 lines per page and 132-136 character positions per line. The resulting hardcopy was called "output" or "printout."
Things have changed. Now PANDORA runs on desktop workstations. (But it is not an interactive program—things have not changed that much.) The user still deals with output files and normally waits for a run to finish before doing so. Complete output files are no longer routinely printed but are stored on disk to be displayed and examined on CRT screens. Nevertheless, in this writeup we retain the old terms "output" and "printout" to refer to PANDORA's output files and their contents.
PANDORA has been revised to limit the lengths of lines in the output files to no more than 128 characters.

This Section consists of two parts. Part A has general information about output files and their use while Part B has detailed information about how to control their contents.

A) Printout Files

The 'general printout' file is connected to unit 15, and the 'error printout' file may be connected to unit 16; see Section 7.

The 'general printout' file is the main output file of the run. Its normal contents, while to some extend fixed, can generally be controlled by various switches and options (see Part B, below). In addition, PANDORA also prints various 'debug' data and/or error messages, and these are written to the 'error printout' file. Normally the general printout file and the error printout file are *both* connected to unit 15, so that normal and error printouts appear in one file, in a single, *merged* sequence. (A merged arrangement preserves the context of error messages.)

However, the **OUTPUT** statement can be used to make PANDORA connect the error printout file to unit 16. Thus the two types of output can be *split*. This makes for cleaner normal output, which may be especially desirable in those situations where various error messages are considered inconsequential. (But note that a 'split' arrangement tends to obscure the context of error messages.)

The general printout file can be very large—this can make it difficult to scan it interactively with an editor. Option MAKIX has been provided to help with this. When MAKIX is on, then a 'printout index' file (connected to unit 31; see Section 7) will be generated, as follows:

Every 'major' printout section in the general printout file will be preceded by a unique 'identifier line'. These indentifier lines, and these lines only, will also appear in the 'printout index' file. Having in hand a copy of this index, the user can decide which printout sections to examine, and can use the unique identifier string as an unambiguous target for a string-search.

`LOOKAT`

A separate program `LOOKAT` helps to display the 'general printout' file on a screen, and to select portions to be printed. It works best when the associated 'printout index' file is also available (see above). `LOOKAT` is intended to be self-contained,

self-explanatory, and easy to use.

B) Printout control

Most sections of PANDORA's output can be enabled or suppressed at will. The various program 'options' (*i.e.* those mentioned in **DO** and **OMIT** statements) provide most of the control facilities for this purpose, but some other input parameters (especially those that control various 'debug dumps' and 'details dumps') also can affect the amount of printout.
There follows a list of every 'section' of PANDORA's printout, with descriptions of the conditions that determine whether or not that section appears. Many of these descriptions mention 'subsections' of major 'parent' sections. Such subsections are *not printed* if conditions are such that the parent section does not appear. Many parent sections contain stuff in addition to the subsections mentioned; some do not.

Besides the printout sections listed below, there are some debugging aid printouts that are under 'option' control; these options are listed in the TEST/DEBUG part of the printout section OPTIONS. The option MITPRNT controls whether or not even a minimum of information appears for all but the last iteration. Also, some error printouts appear invariably whenever certain problems are detected.

Printed Graphs. PANDORA produces many graphs of selected tables. The resolution is crude: character positions. Nevertheless, in many cases these convenient graphs provide adequate pictures of what is poing on. Before any graph image is actually printed, however, PANDORA determines whether it is "interesting" (*i.e.,* whether a 'sufficient' number of data points fall within, rather than on, the graph borders)—boring graphs are not printed. In such cases only a single print line, consisting of the graph title and the word "BORING," will appear.

Notes

The following **Notes** are referred to in the remainder of this Section:

Note A

This section appears for every overall iteration of a run in which any atmospheric model tables, involved in the calculations giving rise to this printout section, are being recomputed, *i.e.* if the option HSE is on, or if the **POPUP** switch has been set. However, if the option ALL is off, then this printout section appears only once, in any case.

Note B

If the option EVERY is off, then this printout section appears for the last sub-iteration only.

Note C

If the option ALL is off, then this printout section appears for the last overall iteration only.

Note D

If the option ALLY is off, then this printout section appears for the last HSL-iteration only.

Output from PHASE 0**: Input and Initialization**

PROVISIONAL INPUT
appears if STANPRNT is on, and if at least one value of **LZA** > 0.

STATUS OF OPTION
appears if OPTPRNT is on. (An abbreviated version of this listing appears if AOPTPRNT is on.)

INPUT NOTES
appears always.

CO LINES
appears when CO line absorption is included and CODMP is on.

ATMOSPHERE
appears if ATMOPRNT is on. When ZPRNT is on this printout has two sections, ATMOSPHERE-1 and ATMOSPHERE-2; the second section gives **Z**, **TE**, etc., to nine figures.

INPUT NUMBER DENSITY AND DEPARTURE COEFFICIENT
appears if INNBPRNT is on.

ATOM
appears if ATOMPRNT is on.

DEPTH-DEPENDENT TRANSITIONS DATA
appears if INRBPRNT is on.

ELEMENTS
appears always.

BACKGROUND
appears always.

INPUT
appears if INDAPRNT is on. (An abbreviated version of this printout appears if AINDPRNT is on.) Many diverse parameters may be printed here. The first page is a bit of a grab bag; the remaining input values are grouped in various subsections dealing with specific topics, shown in the headings. Still, some input parameters could equally well have been included in several of these groups, so, which group a given parameter is printed with may seem somewhat arbitrary. Subsections are printed as needed.

CONSTANTS
appears if STANDARD is on.

HYDROGEN and H2
appear if HNPRNT is on (note input parameter **MOPRNT**).

CARBON
appears if CARPRNT is on (note input parameter **MOPRNT**).

SILICON
appears if SILPRNT is on (note input parameter **MOPRNT**).

HELIUM
appears if HELPRNT is on (note input parameter **MOPRNT**).

HELIUM-II
appears if HEL2PRNT is on (note input parameter **MOPRNT**).

ALUMINUM
appears if ALUPRNT is on (note input parameter **MOPRNT**).

MAGNESIUM
appears if MAGPRNT is on (note input parameter **MOPRNT**).

IRON
appears if FEPRNT is on (note input parameter **MOPRNT**).

SODIUM
appears if SODPRNT is on (note input parameter **MOPRNT**).

CALCIUM
appears if CALPRNT is on (note input parameter **MOPRNT**).

OXYGEN
appears if OXYPRNT is on (note input parameter **MOPRNT**).

OXYGEN2
appears if OXY2PRNT is on (note input parameter **MOPRNT**).

OXYGEN3
appears if OXY3PRNT is on (note input parameter **MOPRNT**).

SULPHUR

appears if SULPRNT is on (note input parameter **MOPRNT**).

DIRECTIONS
appears if SPHERE is off and STANDARD is on, and if either GRCONT or GRLINE is on.

SPHERE
appears if SPHERE is on, and if either STANDARD or SPHEGEOM is on.

PARTITION
appears if PARTPRNT is on.

STIMULATED EMISSION FACTORS
appears if STIMPRNT in on. BETA(TR) appears only if CSWITCH is on.

TABLES
appears if STANDARD is on.

INTEGRATION
appears if INTAPRNT is on. (An abbreviated version of this listing appears if AINTPRNT is on.)

DOPPLER
appears if DPDWPRNT is on, for every radiative transition u, ℓ for which $\mathbf{LSFPRINT}^{u,\ell} = 1$ or $\mathbf{PROF}^{u,\ell} = 1$.

CHARGE EXCH.
appears if CHXPRNT is on.

STATISTICAL

appears if KURPRNT is on (note input parameter **LWNT**). This is a parent section, with one subsection as follows:

• dump of unprocessed data: the value of **KUDNT** must be > 0.

COMPOSITE

appears if KOMPRNT is on (note input parameter **LWNT**). This is a parent section, with one subsection as follows:

• dump of unprocessed data: the value of **KODNT** must be > 0.

AVERAGED

appears if AVOPRNT is on (note input parameter **LWNT**).

STANDARD RATES INTEGRATION WAVELENGTHS

appears if both USEWTAB and WTABPRNT are on.

JNU

appears if there is at least one PRD transition, and if **JNUNC** > 0.

Output from PHASE 1**: Iterations**

ND, NK and BD

appears at the start of every overall iteration, if ALL is off and MITPRNT is on.

Z-SCALE

appears in a Hydrogen run if values of **TAUKIN** were provided, so that the values of **Z** had to be updated (see also Note A).

CONTINUUM DATA

may appear in every overall iteration of a run which recomputes any of the atmosphere model data needed for continuum calculations (JNU, etc.) — *i.e.* if option HSE is on, if the **POPUP** switch has been set, and/or if **Z** must be updated. In other runs continuum calculations need to be done (and this printout can appear!) in the first overall iteration only. (If such a run has **IOMX** > 1 and option ALL is off, this printout will not appear!)

This is a major parent section whose subsections are related to the various contexts in which continuum calculations arise, as follows:

- for line core wavelengths: LINECOPR or LBDPRNT must be on (when LINECOPR is on, LBDPRNT is superfluous here) (see also Notes A and C);
- for transition rates integrations: RATEPRNT and RATECOPR must both be on and USETRIN must be off (see also Notes A and C);
- for standard background wavelengths: USEWTAB and STANCOPR must both be on (see also Notes A and C);
- for H-minus calculations: HMS and HMSCOPR must both be on (see also Notes A and C);
- for dust opacity wavelengths: DUSTYPE, DUSTEMP, and DUSTCOPR must all be on (see also Notes A and C);
- for 'additional wavelengths': ADDCOPR must be on;
- for additional photoionization: RATEPRNT and APHICOPR must both be on (see also Notes A and C);
- for Composite Line Opacity data wavelengths: appears only if these data are actually used, and if COMPCOPR is on (see also Notes A and C);
- for K-shell wavelengths: KSHLCOPR must be on (see also Notes A and C);
- for FDB wavelengths: FDBCOPR must be on (see also Notes A and C);

***** *Notes A, B, C, D are explained on page 11.4* *****

• for CO-lines absorption wavelengths: COCOPR must be on (see also Notes A and C);
• for every wavelength whose corresponding context OPTION is off: output *will* appear if that wavelength occurs in the **SCOW** table.

More control information on next page.

***** *Notes A, B, C, D are explained on page 11.4* *****

These Continuum Data printouts, from all contexts, are grouped as one batch and appear in order of increasing wavelength.

The printout for any particular wavelength consists of several parts, each of which appears only if the appropriate option is on, as follows:

absorbers printout	OPAPRNT
emitters printout	EMIPRNT
CSF printout	CSFPRNT (note option ACSFPRNT)
absorbers graph	OPAGRAF
emitters graph	EMIGRAF
CSF graph	CSFGRAF
summary graph	CSFGRAF

RATES
is a major parent section; a summary explanation of the calculations, and the printouts available from them, always appears. Substantive printouts appear if RATEPRNT is on. This section may appear both in the first and the last iteration of some runs. The amount of information printed depends on options RATEALL and RATEFULL. It has subsections as follows:
- for CHKI and CHIJ: COLHPRNT must be on;
- for upper-level charge exchange: CHEXUP and CHXPRNT must be on;
- for CIJ: CIJPRNT must be on;
- for PIJ: PIJPRNT must be on;
- for RIJ: RIJPRNT must be on;
- for additional photoionization: APHIPRNT must be on;
- for fast electrons: FELEPRNT must be on.

Note the extensive explanatory text in the regular printout.

RATES GRAPHS
appears if RATEGRAF is on.

AMBIPOLAR DIFFUSION

appears if RATEPRNT is on and if either AMBPRNT or VLGPRNT is on.
Note: this printout occcurs near the end of the regular RATES printout, if one or both of the options AMDIFF or VELGRAD are on. Options ADN1DMP, AMDDMP, DIFFANA, and VELGDMP affect this printout.

DIELECTRONIC RECOMBINATION

appears if RCOMPRNT is on.

H MINUS

appears if HMS is on (see also Notes A and C). This is a parent section, with one subsection as follows:

• for JNU: HMSJPRNT must be on.

DUST

appears if DUSTEMP and DUSTYPE are both on (see also Notes A and C).

***** *Notes A, B, C, D are explained on page 11.4* *****

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Start of Line Source Function printout *groups* (if any).

Printout can appear if there is at least one radiative transition. At least some part of the printout group for transition u, ℓ appears if $\mathbf{LSFPRINT}^{u,\ell} = 1$, or if option LSFPRNT is on, or if option LSFGRAF is on. (*Note:* $\mathbf{LSFPRINT}^{u,\ell}$ and option LSFPRNT are different beasties, but they work together.)

STARTING NUMBER DENSITY AND DEPARTURE COEFFICIENT
appears for the first iteration if default values were computed.

DAMPING
appears if DPDWPRNT is on (see also Notes A and C). It will *not* appear if a) HSE is on and this is not the last overall iteration, or b) HSE is off and this is not the last overall iteration but this is a Hydrogen run.

ANALYSIS
appears if ANALYSIS is on (see also Notes A and C).

LINE (U/L)
always appears; it contains a summary explanation of the various printouts related to the line source function calculations for radiative tramsitions.

STIM, and TAU
appear if TAUPRNT is on (see also Note B). (See also option PEGTNALL.)

STATISTICAL EQUILIBRIUM
is a major parent section which has three subsections as follows:
• for timing data: SETIME must be on;
• for PE, FE, *etc.*: SEPRNT must be on;
• for methods comparison: SECOMP or METPRNT must be on.
Note: option DIFFANA also affects this printout (see also Note B).

PRD

Printouts related to PRD calculations appear, for all PRD transitions, if option PRDPRNT is on. The amount of output depends on input parameters **IPRDF** and **IPRDD**. Tables of JNU are printed if option JNUPRNT is on. Printouts from PRD-related background (continuum) calculations, for wavelengths (frequencies, XI-values) selected by **IPRDF**, appear if option PRDCOPR is on (and/or for every PRD wavelength occurring in the **SCOW** table). For the purposes of PRD these "continuum printouts" have been split into two separate parts, but they have the standard format used for 'CONTINUUM DATA,' above, and use the same options for detailed control as described there. If iterations are used with the Hubeny-Lites formulation (i.e. option PRDMETH is on), then only the results of the last iteration are printed unless option PRDITER is on (see also Note B).

LINE SOURCE FUNTION

is a major parent section which has several subsections as follows:

• TNU-analysis is controlled by **KANTNU** (q.v.);

• for Line Source Function details for transition u, ℓ: $\mathbf{LSFPRINT}^{u,\ell} = 1$ or option LSFPRNT must be on (an abbreviated version of this printout appears if option ALSFPRNT is on); a part of this detail printout also depends on option LSFFULL;

• for source function graph for transition u, ℓ: $\mathbf{LSFPRINT}^{u,\ell} = 1$ or option LSFGRAF must be on;

• for radiative force for transition u, ℓ: $\mathbf{LFLUX}^{u,\ell} = 1$, (the full computed Line Flux Distribution appears if LFDPRNT is on).

Note: See also option PESRJALL (see also Note B).

Note: The section 'LINE SOURCE FUNCTION' (if not a PRD transition) will appear twice in a diffusion run with DIFFANA on, concluding with a summary graph comparing the results with and without diffusion terms.

End of Line Source Function printout *groups* (if any).

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LOG PLOT OF TAU SCALES
appears if there is at least one radiative transition and if LSCALE is on, in the very last sub-iteration only.

COLLATED TAU SCALES
appears if there is at least one radiative transition and if SCALE is on, in the very last sub-iteration only.

RHO AND RBD
is a major parent section. An explanation of the available printouts always appears. Substantive results appear if RHBPRNT is on, and subsections may appear as follows:
• for details of each radiative transition: RHBPRDT must be on;
• for details of BDQ calculation: BDQPRDT must be on;
• for complete sets of BDR, BDJ, BDS, and S*: BDPRNT must be on;
• for final sets of Rho and b-ratios: RHBPRSM must be on.
Note that the results printed by RHBPRSM are also printed by RHBPRDT; thus it is not normally necessary to turn both on; (RHBPRSM is intended to provide "minimal" printout).

CONSISTENCY CHECKS
appears if CHKPRNT is on, and is controlled by EVERY (see also Note B).

POPULATIONS
is a major parent section which appears here if LYMAN is on (see also Note D). See detailed description below.

CONTINUUM DATA FOR LYMAN
appears if LYMAN is on, and if either LYMCOPR is on or for every wavelength that occurs in the **SCOW** table (see also Note D). Detailed control of the print-out parts for each Lyman wavelength is as for other 'CONTINUUM DATA', described above.

LYMAN
is a major parent section which appears if LYMAN is on (see also Note D). (An abbreviated version of this major parent section is printed if ALYMPRNT is on.) It has three subsections as follows:
• for EP methods comparison: EPCOMP must be on;
• for RK comparison: COMPRK must be on;
• for PIJ: HSE must be off and this must not be the last iteration.

POPULATIONS
is a major parent section which appears here if HSE is on (see also Note D). See detailed description below.

NE
appears if HSE and NESWICH are both off and **POPUP** has been set.

HSE
appears if HSE is on (see also Note D). (An abbreviated version of this section is printed if AHSEPRNT is on.)

MODEL DATA
is a major parent section which appears if HSE is on (see also Note D); it is a continuation of the HSE section. It has subsections as follows:
• for absorbers at 500 nm: OPAPRNT must be on;
• for HYDROGEN: this always appears;
• recalculated Z-scale appears if values of **TAUKIN** were provided, or if values of **ZMASS** were provided and ZCOMP is on;
• for electrons calculations results (with graphs): ELECPRNT must be on (appears in the last iteration only).

***** *Notes A, B, C, D are explained on page 11.4* *****

GAS

appears if HSE is off and **POPUP** equals `HYDROGEN` (see also Note D).

POPULATIONS

is a major parent section controlled by ALL (see also Note D). An explanation of the various controls for this section always appears. Substative printout appears if either POPPRNT or POPGRAF are on. There are five subsections as follows:

• for NE results: **POPUP** must equal `HYDROGEN` and POPPRNT must be on;

• for the full tables: POPPRNT must be on, (the supplementary printout appears if NBPRNT is on), (an abbreviated version of the full tables appears if APOPPRNT is on);

• for graphs of ND: POPGRAF must be on (see Note D);

• for a trace of the Populations Calculations at depth # **IBNVIEW**: PDETPRNT must be on;

• for graph of BD vs. **Z**: BDGRAF must be on (the plots of TAU vs. **Z** appear only if TAUPLOT is on) (see Note D);

• for graph of BDIJ vs. **Z**: BDGRAF must be on and there must be at least one radiative transition (the plots of TAU vs. **Z** appear only if TAUPLOT is on) (see Note D);

• for graph of **TE** vs. log(TAU): TEGRAF must be on and there must be at least one radiative transition (see Note D).

UPDATED POPULATIONS DATA

is a major parent section, controlled by ALLY (see also Note D). Its various subsections are concerned with the various 'population-update ions,' as follows:

• for Hydrogen: HNPRNT must be on and **POPUP** must equal `HYDROGEN`;

• H2: **POPUP** must equal `HYDROGEN` and **NHTSW** > 0;

• for Carbon: CARPRNT must be on and **POPUP** must equal `CARBON`;

• for Silicon: SILPRNT must be on and **POPUP** must equal `SILICON`;

• for Helium: HELPRNT must be on and **POPUP** must equal `HELIUM`;

• for Helium-II: HEL2PRNT must be on and **POPUP** must equal `HELIUM2`;

• for Aluminum: ALUPRNT must be on and **POPUP** must equal `ALUMINUM`;

• for Magnesium: MAGPRNT must be on and **POPUP** must equal `MAGNESIUM`;

• for Iron: FEPRNT must be on and **POPUP** must equal `IRON`;

• for Sodium: SODPRNT must be on and **POPUP** must equal `SODIUM`;

• for Calcium: CALPRNT must be on and **POPUP** must equal `CALCIUM`;

• for Oxygen: OXYPRNT must be on and **POPUP** must equal `OXYGEN`;

• for Oxygen-II: OXY2PRNT must be on and **POPUP** must equal `OXYGEN2`;

• for Oxygen-III: OXY3PRNT must be on and **POPUP** must equal `OXYGEN3`;

• for Sulphur: SULPRNT must be on and **POPUP** must equal `SULPHUR`.

K-SHELL
appears if a K-shell ionization calculation has been requested in a Carbon run (see Note D).

CHARGE EXCHANGE
appears if upper-level charge exchange has been requested in a Hydrogen run and option CHXPRNT is on (see Note D).

RESTART VALUES OF JNU
appears in a PRD run when option JNUPRNT is on.

DAMPING
appears if PHASE2, PASSPRNT, and DPDWPRNT are all on, and if there is at least one passive transition for which the emergent profile calculation has been turned on.

ANALYSIS
appears if PHASE2, PASSPRNT, and ANALYSIS are all on, and if there is at least one passive transition for which the emergent profile calculation has been turned on.

TAU
appears if PHASE2, PASSPRNT, and TAUPRNT are all on, and if there is at least one passive transition for which the emergent profile calculation has been turned on.

PASSIVES
appears if PHASE2 and PASSPRNT are both on.

DAMPING and ANALYSIS
appear if PHASE2 is on, only for those transitions u, ℓ whose values of $\mathbf{BLCSW}^{u,\ell}$ require this and for which emergent profile calculations are requested. For DAMPING, DPDWPRNT must be on, for ANALYSIS, ANALYSIS must be on.

TAU
appears if PHASE2, TAUPRNT, LTE and LTEDATA are all on, only for those transitions for which emergent profiles calculations are requested.

LTE DATA
appears if PHASE2, LTE and LTEDATA are all on, only for those transitions for which emergent profiles calculations are requested.

ANALYSIS
appears if PHASE2, ANALYSIS, LTE and LTEDATA are all on, only for those transitions for which emergent profiles calculations are requested.

FREQUENCY-DEPENDENT LINE SOURCE FUNCTION
is a major section, which may appear for the (**MS**, **NS**) transition only. It has two subsections, as follows:
• for printout: SLFPRNT must be on;
• for graph: SLFGRAF must be on.

SCATTERING ALBEDO ANALYSIS
appears, for suitable transitions, if LINECOMP is on.

CONTINUUM DATA
appears for all wavelengthe needed for line profile calculations if FBDCOPR is on, or if TRUECONT and TRUECOPR are both on. Detailed control of the printout is as for other 'CONTINUUM DATA', described above.

WAVE SUMM 0
always appears.

WAVE SUMM 1
appears if WAVEPRNT is on. It provides a basic summary of the background (continuum) calculations at each wavelength.

WAVE SUMM 2
appears if WAVEPRNT is on and **IWSMD** = 1. It provides a basic summary of the contributors to the background (continuum) at each wavelength.

COMPOSITE LINE OPACITY ANALYSIS
appears if COMOPAN is on. (An abbreviated version of this printout appears if **KCOAA** is set = 1.)

COOLING
appears if CALCOOL is on. This is a parent section, with one subsection as follows:
• for integrated rates: COOLINT must be on.

HEATING
appears if CALHEAT is on. This is a parent section, with one subsection as follows:
• for integrated rates: COOLINT must be on.

HEATING/COOLING SUMMARY
appears if CALCOOL and CALHEAT are both on.

FUDGERS
appears as needed.

A-TROUBLES
appears as needed.

CHECKS GRAPHS
appears if there is at least one radiative transition and CHKGRAF is on.

ITERATIVE SUMMARIES
is a major parent section which appears as needed and if SUMMARY is on. An Explanation of the various controls for this section appears if either SUMMARY or SUMTREND is on. Its various subsections are controlled by separate options, and are related to various calculated quantities which are obtained by iterative improvement; they appear only in those cases where more than one iterate has been saved so that comparison among successive iterates is possible, as follows:
• for CHECKs: ITERCHK must be on;
• for $S^{u,\ell}$: ITERS must be on, and u, ℓ must be a radiative transition;
• for $RHO^{u,\ell}$: ITERRHO must be on, and u, ℓ must be a radiative transition;
• for $CHI^{u,\ell}$: ITERCHI must be on, and u, ℓ must be a radiative transition;
• for $TAU^{u,\ell}$: ITERTAU must be on, and u, ℓ must be a radiative transition;
• for RK: ITERRK must be on;
• for ND: ITERN must be on;
• for $RHOWT^{u,\ell}$: ITERRWT must be on, and u, ℓ must be a radiative transition;
• for BD: ITERB must be on;
• for NE: ITERNE must be on;
• for Z: ITERZ must be on;
• for TDST: ITERTD must be on.
Iterative Summaries appear in tabular and/or in graphical from, depending on option SUMGRAF and input parameter **ISMSW**.

ITERATION TREND SUMMARY
may appear if there is at least one radiative transition and SUMTREND is on.

Output from PHASE 2**: Spectrum and Summaries**

None of these sections appear if PHASE2 *is off.*

EMERGENT CONTINUOUS INTENSITY

appears if EMERINT is on. This is a parent section, with subsections as follows:
• for depths-of-formation: ORIGIN must be on (see option ORSHORT);
• for dI/dh: DIDHC must be on (see also input parameter **ICDIT**;
• for color temperatures: COLTEMP must be on;
• for average continuum intensities: AVCON muts be on.
Note the effect of option WAVENUMB.

CONTINUOUS FLUX

appears if CONFLUX is on. This section includes the integrated flux quantities, and the Rosseland means. It has one subsection as follows:
• for details at each wavelength: FLUXDMP must be on; (which specific details are printed depends on the value of **IFXDS**).
Note the effect of option WAVENUMB.

CONTINUUM ECLIPSE INTENSITIES

appears if EMERINT and ECLIPSE are both on, only for those 'additional wavelengths' and Composite Line Opacity wavelengths for which this was requested explicitly, and for CO lines wavelengths if COCLIPSE is on. Calculations for selected beams of specified widths are done when **NZE** > 0.
Note the effect of option WAVENUMB.

VELOCITIES

appears if LIGHT is on and **LPVEL** $= 1$, but only if there are non-zero velocity tables worth printing. (The corresponding mass-loss rates are printed only if **LPVEL** and **LPMLR** both $= 1$.)

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Start of Emergent Line Profile printout *groups* (if any).

These appear, if option LIGHT is on, for every transition (u, ℓ) for which the input parameter $\mathbf{PROF}^{u,\ell} > 0$.

BACKGROUND INTENSITY
computed continuum intensities amd flux needed for residuals calculation will be printed if option PROCPRNT is on.

GRAPH OF S, B VS. Z
appears if LIGHT and INTGRAF are both on, only for those transitions for which emergent profiles calculations were requested. These graphs do not appear if graphs were printed earlier in the LINE SOURCE FUNCTION section.

EMERGENT LINE PROFILES
shows the various versions of the emergent intensity profiles for a given transition, for all values of lookangle (μ), velocity, and viewing position (front-face (always), back-face (if requested); followed by the flux profiles computed from the intensity profiles. (A somewhat abbreviated version of this printout appears if APRFPRNT is on.) This parent section has subsections as follows:
• for profile analyses other than those printed earlier: ANALYSIS must be on;
• for depths-of-formation: ORIGIN must be on (*note* also option ORSHORT);
• for dI/dh: DIDHL must be on;
• for location analysis graph: LOGAS must be > 0;
• for FNRMLA, FNRMLB: CLNORM must be on in a Hydrogen run.
Note the effect of option WAVENUMB.

GRAPH OF RESIDUAL INTENSITY PROFILE
appears if LIGHT and INTGRAF are both on, only for those transitions for which emergent profiles calculations were requested.
Note the effect of option WAVENUMB.

GRAPH OF ABSOLUTE INTENSITY/FLUX PROFILE
appears if LIGHT and INTGRAF are both on, only for those transitions for which emergent profiles calculations were requested.
Note the effect of option WAVENUMB.

ECLIPSE
appears if LIGHT is on, only for those transitions u, ℓ for which $\mathbf{ECLI}^{u,\ell} > 0$.
Note the effect of option WAVENUMB.

End of Emergent Line Profile printout *groups* (if any).

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SPECTRUM SUMMARY
appears if SPECSUM is on and if either LIGHT or EMERINT is on.

CONTINUUM CONTRIBUTIONS SUMMARIES
is a major parent section which appears if EMERINT is on. It has three subsections as follows:

- for absorbers: OPASUM must be on;
- for emitters: EMISUM must be on;
- for TAU: TAUSUM must be on.

Performance Data, and Program Version Description

SCRATCH I/O SUMMARY
appears when **IRUNT** > 0.

TIMING SUMMARY
appears when **IXSTA** > 0.

VERSION DESCRIPTION
appears always (amount of detail depends on **IRUNT**).

(Section 11 – last revised: 2007 Feb 05)

Section 12: **Source Functions**

***

PANDORA has three methods for calculating the weight matrices needed for source function calculations:

• **QR** –
the quadratic representation method, which requires an input parameter, Y, the 'damping parameter' (see: SAO Special Report No. 303);

• **RT** –
the ray tracing method, with analytic angle integration (see: E. H. Avrett's program specification '[7/1/71] New Subroutine for Weighting Coefficients');

• **GR** –
a general ray tracing method based on an integral equation approach, with numerical angle integration (see: E. H. Avrett's program specification '[81 Feb 27] Expansion Velocity in the Source Function Calculations').

When the **QR** method is used for the Line Source Function calculation (where **KS** or KF weight matrices are required) or for the Level-$\mathcal{N}$-to-Continuum (*i.e.* Lyman) Source Function calculation (where **KK** weight matrices are required), then it can be used in one of two flavors: 'QR-direct' or 'QR-mapped.'

When 'QR-direct' is specified, weight matrices (as functions of TNU, mono-chromatic optical depth) are computed directly as needed.

When 'QR-mapped' is specified, a 'standard weight matrix' is computed once (using the standard TAU table **TS**, of length **M**, and the standard value of the damping parameter **YPRE**); the required weight matrices (which are functions of **KS**, KF, or **KK** different TNU tables) are obtained from the standard matrix by an interpolation procedure. *Note*: the purpose of the mapping procedure is to save time; it is less accurate than the direct method. In cases where the **QR** method is chosen, mapping might be appropriate for the early iterations of a calculation, switching to direct calculation of weight matrices when homing in on the final solution.

The input values of the various 'method control parameters' MCP are used to specify which method to use for the various source function calculations to be performed. A value of MCP is interpreted as follows:

$0 \leq$ MCP $\leq +1$ means: **QR**-direct;
MCP $= -2$ means: **QR**-mapped;
MCP $= -1$ means: **RT**;
MCP $= -3$ means: **GR**.

Note: When MCP selects **QR**-direct, then the value of MCP is also used as the required 'damping parameter' Y = MCP.

Note: **GR** is used automatically for all source function calculations when options SPHERE and/or EXPAND are on.

Note: **RT** is the default method for stationary plane-parallel cases.

Remember the following input parameters: **TMS**, which affects **RT** and **GR**; **TBAR**, which affects **QR**-mapped only; **TLARGE**, which affects **QR** and **QR**-mapped; and **TSMALL**, which affects all except **GR** (see Section 5).

(*Note* added 2006 Aug 30: The decision to use a single floating point input parameter combining the values of MCP and Y dates from the ancient past. I have long wanted to undo it in favor of using two separate quantities. Today such a

change would require a great deal of work because this ancient convention so pervades PANDORA. It is now much too late for that.)

The following list recapitulates the names of the various method control parameters (single values, or tables – see Section 5) used to select the weight matrix method to be used for the various types of source function calculations:

• **YPRE** – for **QR**-mapped, as discussed above;

• **YLINE** – for Line Source Function;

• **YL** – for Level-$\mathcal{N}$-to-Continuum (Lyman) source function;

• **YCONT** – for Continuum Source Function at the wavelengths of the cores of radiative transitions;

• **YWAVE** – for Continuum Source Function at 'additional' wavelengths;

• **YRATE** – for Continuum Source Function at the wavelengths specified for the rates integrations;

• **YHM** – for Continuum Source Function at the wavelengths specified for the H-minus calculation;

• **YLDT** – for Continuum Source Function at the wavelengths specified for the Type-2 Dust Temperature calculation;

• **YLYM** – for Continuum Source Function at the wavelengths specified for the Level-$\mathcal{N}$-to-Continuum (Lyman) transfer calculation;

• **YCR** – for Continuum Source Function at the wavelengths at which incident coronal radiation is specified;

• **YKR** – for Continuum Source Function at the wavelengths for which additional photoionization is specified;

• **BANDY** – for Continuum Source Function at Composite Line opacity wavelengths in a particular band;

• **YRATS** – for Continuum Source Function at standard rates integrations wavelengths;

• **YCOL** – for Continuum Source Function at CO-lines absorption wavelengths.

Section 13: **Auxiliary Depth Tables**

***

PANDORA deals with many depth-dependent quantities. When these exist in tabular form, they are specified as functions of the set of discrete geometrical depth values that constitute the standard kilometer depth table $\mathbf{Z}_i, 1 \leq i \leq \mathbf{N}$. However, it may happen that when such a quantity is to be input to PANDORA, it is known only as a function of a different set of depth values. When that is the case, such a different set of depth values may be input as an auxiliary depth table. Upon reading tables corresponding to that auxiliary Z table, PANDORA will perform, *during the input reading process*, the interpolations necessary to convert such tables to functions of the actual **Z**-scale of the run. After input reading is finished, and before beginning the actual calculations, PANDORA discards the auxiliary Z tables.
The remainder of this section discusses in detail how to introduce and use auxiliary Z tables.

Every auxiliary Z table, **ZAUX**, has a unique identifier m, $1 \leq m \leq 50$.
By definition, the value $m = 0$ refers to the standard kilometer depth table of the run, **Z**.
To introduce an auxiliary Z table, it is only necessary to specify its length, $\mathbf{LZA}_m$, in an `LZA` statement in Part B of the input (see Section 4), and then the table itself, $\mathbf{ZAUX}_i^m, 1 \leq i \leq \mathbf{LZA}_m$, in a `ZAUX` statement in a subsequent Section of the input file.

There are three ways of referring to (*i.e.* specifying) a depth table when specifying input values of depth-dependent quantities:
1) If none is referrenced explicitly, or if $m = 0$, then the standard kilometer depth table of the run, **Z**, is assumed.
2) The auxiliary depth table index **m** can be specified in the same input statement as the corresponding input quantity itself. Input statements of the Type **2***, **3*** and **5*** (see Section 2) have been provided for this purpose. When the value of m is specified in this manner, then it affects *that input statement only.*
3) A global value of auxiliary depth table identifier m can be specified as the input parameter **MAUX**. (The default value of **MAUX** = 0.) Upon encountering a `MAUX` statement, PANDORA assumes that all depth-dependent quantities that follow (except those that use input statement Types **2***, **3***, or **5***) correspond to the auxiliary depth table whose index was specified in that statement, and will perform the necessary interpolations mentioned above. A value of m as set by a `MAUX` statement remains in effect until countermanded by a subsequent `MAUX` statement.
The auxiliary depth table identifier value $m = 0$ is permitted in `MAUX` statements, but not in `LZA` or `ZAUX` statements.

Since the interpolation from **ZAUX** to **Z** is done during the reading of the input statements (as opposed to being done after all the input has been read), it is necessary that a given **ZAUX** table must have already occurred in the input before it is first referred to, and the **Z** table must already have occurred in the input before the first ZAUX-dependent input is read.

Note: It is normally possible (indeed, convenient at times) to use several distinct, non-contiguous input statements to specify the sequence of elements of an input array (using **I**, the explicit facility for specifying the index of the 'array member currently being read into'; see Section 2).
This is not possible with arrays that are functions of auxiliary Z tables.
For such arrays (even when PANDORA only needs to 'go through the motions' of interpolation), all elements must be specified in *one* input statement.

Note

Many years' experience with auxiliary Z tables has shown that their use causes

confusion; it seems best only to use them as temporary expedients.

(Section 13 – last revised: 1998 Sep 17)

Section 15: **Partial ReDistribution**

***

PANDORA uses either "complete redistribution" (CRD, the default) or "partial redistribution" (PRD, selected by input switch $\mathbf{SCH}^{u,\ell}$) to compute the line source function of transition (u, ℓ). PRD can be done by one of two methods, depending on the option PRDMETH. When PRDMETH is on, PANDORA uses a procedure based on the formulation of Hubeny & Lites as discussed in ApJ., **455**, 376. When PRDMETH is off, PANDORA uses a simplified procedure based on the formulation of Kneer & Heasley as discussed in Appendix A of Vernazza, Avrett & Loeser (1981), Astrophys.J.Suppl. **45**, 635, and in a paper by Avrett & Loeser (1984) appearing in *Methods in Radiative Transfer*, Kalkofen, ed., pp. 341–379. Note that PRDMETH selects the method for all PRD-transitions in a run.

Input Parameters

Set $\mathbf{SCH}^{u,\ell} = 1$ when PRD is to be used for transition (u, ℓ) (see also Note 47 of Section 5), and set option PRDMETH for the desired procedure. The input parameters $\mathbf{GMMA}^{u,\ell}$ and **IGMSW** control the calculation of γ and are always required.

When PRDMETH is on the other input parameters are **ITPRD**, **PRDCV** and **IGII**. The iterations limit **ITPRD** and the convergence criterion **PRDCV** control the (JNU : S) iterations. **IGII** determines how the function RII is computed: **IGII** = 1 selects the fast approximations developed by Gouttebroze, while **IGII**

= 2 selects the more accurate calculation of Adams, Hummer & Rybicki.

15.2

When PRDMETH is off the other input parameters are: $\mathbf{XC}^{u,\ell}$, $\mathbf{XP}^{u,\ell}$, $\mathbf{XR}^{u,\ell}$, $\mathbf{DDR}_k$ and $\mathbf{XDR}_k$ for $0 \leq k \leq$ **NDR**, **XCL**, **TAUCL**, **LMDL2**, **LMDL3**, and **DRLIM**, used to compute DR. Note that values of $\mathbf{XC}^{u,\ell}$, $\mathbf{XP}^{u,\ell}$, and $\mathbf{XR}^{u,\ell}$ can be specified for each PRD transition; but there is only one table of **DDR** vs. **XDR** values, used by all PRD transitions of a run, and only one pair of **XCL** and **TAUCL** values.

The remainder of this section relates to Gamma(γ) and to DR.

Gamma

$\gamma_i^{u,\ell}$ is the degree of coherent scattering in the wings of the (u,ℓ) line. γ is defined in equation (73) of Avrett & Loeser (1984). γ depends on depth (index i) and is very close to unity for low densities. PANDORA provides three ways of specifying $\gamma_i^{u,\ell}$, selected by the value of input parameter $\mathbf{GMMA}^{u,\ell}$.

When $\mathbf{GMMA}^{u,\ell} = -1$ (the default value), then $\gamma_i^{u,\ell} = \mathbf{CRD}^{u,\ell}/DP_i^{u,\ell}$, where the input parameter $\mathbf{CRD}^{u,\ell}$ is the radiative damping parameter and $DP_i^{u,\ell}$ is the computed total (radiative and collisional) damping parameter.

When $\mathbf{GMMA}^{u,\ell} < 0$, but > -1, (say, $\mathbf{GMMA}^{u,\ell} = -.99$), then the smaller of ($|\mathbf{GMMA}^{u,\ell}|$, $\mathbf{CRD}^{u,\ell}/DP_i^{u,\ell}$) is used as the value of $\gamma_i^{u,\ell}$.

When $\mathbf{GMMA}^{u,\ell} > 0$, then $\gamma_i^{u,\ell} = \mathbf{GMMA}^{u,\ell}$ (*i.e.* that constant value at all depths), disregarding $\mathbf{CRD}^{u,\ell}/DP_i^{u,\ell}$.

When **IGMSW**= 1, then the alternate formulas specified in the writeup dated [05 Feb 18] are used for $\gamma^{2,1}$ and $\gamma^{3,1}$ (Lyman alpha and beta) in Hydrogen runs.

DR

When PRDMETH is off one must specify the function $DR(x)$, which describes the change from zero coherent scattering in the Doppler core to partial coherent scattering in the wing. $DR(x)$ is the function $f(x)$ defined by equation (78) of Avrett & Loeser (1984).
PANDORA provides three options for computing values of $DR(x)$, selected by the value of input parameter $\mathbf{XC}^{u,\ell}$.

1) When $\mathbf{XC}^{u,\ell} < 0$, then $DR(x)$ is obtained by interpolation from the input table $\mathbf{DDR}_k$ vs. $\mathbf{XDR}_k$, $1 \leq k \leq \mathbf{NDR}$. The default values of this input table are the same as Table 33 of Vernazza, Avrett & Loeser (1981).

2) When $\mathbf{XC}^{u,\ell} > 0$, PANDORA uses

$$DR(x) = \begin{cases} 1, & x \leq x_c, \\ \exp\left[-\left(\dfrac{x - x_c}{x_c}\right)^p\right], & x > x_c. \end{cases} \tag{1}$$

(*c.f.* equation (78) in Avrett & Loeser (1984)). Here $x_c = \mathbf{XC}^{u,\ell}$ and $p = \mathbf{XP}^{u,\ell}$. Moreover, when $DR(x)$ is computed in this way it may not be less than $drlim^{u,\ell}$ (see below).

3) When $\mathbf{XC}^{u,\ell} = 0$, $DR(x)$ is computed from equation (1) but with XXC_i in place of x_c. XXC_i depends on the depth-dependent Voigt function parameter a_i; on the mean optical depth of the line

$$TAUM_i = 10^5 \int_{Z_1}^{Z_i} (GTN_i + KPC_{i1}) dz\,;$$

and on the input parameters **XCL** (default = 3.5) and **TAUCL** (default = 10^4) as follows. For $TAUM_i \leq \mathbf{TAUCL}$, $XXC_i = \mathbf{XCL}$. For $TAUM_i \geq 10^6$, $XXC_i = FXC_i$ where

$$FXC_i = \left(\frac{4a_i TAUM_i}{\pi}\right)^{0.3333}.$$

For $\mathbf{TAUCL} < TAUM_i < 10^6$, linear interpolation is used, so that

$$XXC_i = \frac{(6 - \log_{10} TAUM_i)XCL + (\log_{10} TAUM_i - \log_{10} TAUCL)FXCC_i}{6 - \log_{10} TAUCL}$$

where

$$FXCC_i = \left(\frac{4a_i 10^6}{\pi}\right)^{0.3333}.$$

However, whenever XXC_i is less than **XCL**, it is replaced by **XCL**. Again, when $DR(x)$ is computed in this way it may not be less than $drlim^{u,\ell}$ (see below).

DR limit

The value of $DR(x)^{u,\ell}$ computed from equation (1) above is not allowed to be less than the specified limit $drlim^{u,\ell}$ for that transition. There are two procedures for obtaining the value of $drlim^{u,\ell}$: a) the general case, and b) Hydrogen $(u,1)$ transitions, *i.e.*, the Hydrogen Lyman lines. These procedures use the input parameters $\mathbf{XR}^{u,\ell}$, **DRLIM**, **LMDL2**, and **LMDL3**.

a) General case

If $\mathbf{XR}^{u,\ell} \neq -1$, then

$$drlim^{u,\ell} = \mathbf{XR}^{u,\ell}\,;$$

but if $\mathbf{XR}^{u,\ell} = -1$, then

$$drlim^{u,\ell} = \mathbf{DRLIM}\,.$$

b) Hydrogen Lyman lines

If $\mathbf{XR}^{u,1} \neq -1$, then

$$drlim^{u,1} = \mathbf{XR}^{u,1}\,;$$

but if $\mathbf{XR}^{u,1} = -1$, then

if $u = 2$, *i.e.* the Lyman-α line, then

$$drlim^{2,1} = \mathbf{LMDL2}\,,$$

if $u = 3$, *i.e.* the Lyman-β line, then

$$drlim^{3,1} = \mathbf{LMDL3}\,,$$

but if $4 \leq u \leq 15$, then

$$drlim^{u,1} = \frac{\sum_{k=2}^{u-1} A^{u,k}}{A^{u,1} + \sum_{k=2}^{u-1} A^{u,k}}\,,$$

the branching ratio equation, where the $A^{i,j}$ are the computed Einstein A coefficients (see Section 19).

(Section 15 – last revised: 2005 Jun 15)

Section 16: **Velocities**

***

PANDORA uses several velocity tables, for various purposes. A velocity table may be specified in the input either as a tabulated function of depth (like other input tables), or by means of parameters appearing in the equation used to generate velocity tables as functions of depth.
This section 1) describes the various velocities, by exhibiting instances of their use in the program, 2) describes input procedures and post-read defaults, and 3) lists additional information about how PANDORA uses these velocities. The descriptions given here are rather sketchy (full information can be found in E. H. Avrett's program specifications and explanatory memoranda); the descriptions and equations appearing in this section are only meant to be illustrative, not exhaustive.
All the velocities treated in this section are arrays of length **N**.

1) Descriptions of Velocities

a) Broadening velocities **V** *and* **VR**

PANDORA uses two "broadening velocities" to compute doppler widths, depending on the option VSWICH. When VSWICH is off, then one velocity is used: $\mathbf{V}_i$ (in km/s), called the "broadening" velocity or "microturbulent" velocity. When VSWICH is on, then two velocities are used: $\mathbf{V}_i$ (in km/s), called the "tangential" broadening velocity and $\mathbf{VR}_i$ (in km/s), called the "radial" broadening velocity.
The doppler width DW is computed from:

$$DW_{im} = \alpha\sqrt{\beta \times \mathbf{TE}_i + \mathcal{V}_{im}^2} \quad ,$$

(where α and β are terms specified elsewhere). When VSWICH is off:

$$\mathcal{V}_{im}^2 = \mathbf{V}_i^2 \quad ,$$

but when VSWICH is on:

$$\mathcal{V}_{im}^2 = \mathbf{VR}_i^2 MU_m^2 + \mathbf{V}_i^2(1 - MU_m^2) \quad ,$$

where MU_m is cosine of the angle between the direction m and the outward normal.

b) Expansion velocities **VXS** *and* **VX**

Two "expansion velocities" may be specified: $\mathbf{VXS}_i$ (in km/s, positive outwards), called the "Source Function" expansion velocity, and various tables of $\mathbf{VX}_i^m$, $1 \leq m \leq \mathbf{NVX}$ (in km/s, positive outwards), called "additional" expansion velocities. **VXS** describes differential mass motion in the atmosphere and is used together with option EXPAND. "Expansion" affects the line source function calculation in fundamental ways: a whole-profile solution must be done (see also Section 18); and WN-matrices (*i.e.,* Λ-operators) must be computed with the general ray tracing method, which uses numerical (explicit) angle integration, in place of the other methods,which use analytic angle integration (and require much less computing). (*Note* that, for study and testing purposes, $\mathbf{VXS}_i = 0$ is allowed when option EXPAND is on; this forces PANDORA to use the general ray tracing method even in a stationary atmosphere.)

The effect of velocity on the calculated line profile can be studied approximately but economically by computing the line source function statically and then calculating not only the corresponding static line profile but also one or more additional profiles using "additional" expansion velocities **VX**.
(**Important:** tables of **VX** are used *only* for the line profile calculations, *not* for source function calculations; however, their use does cause all line source function calculations to be whole-profile solutions; see Section 18.)
Line absorption profiles are given by the Voigt function

$$\phi_{ik}^{jm} = \frac{a_i}{\pi^{3/2}} \int_{-\infty}^{+\infty} \frac{\exp(-x^2)dx}{a_i^2 + (U_{ik}^{jm} - x)^2} \quad ,$$

where $a_i = DP_i/DW_i$ (the doppler width DW_i is given in section (1a) above), and DP_i is the damping parameter. The damping parameter for transition (u, ℓ) is computed from:

$$DP_i^{u,\ell} = \mathbf{CRD}^{u,\ell} + \mathbf{CVW}^{u,\ell} \left(\frac{\mathbf{HN}_i^1}{10^{16}}\right) \left(\frac{\mathbf{TE}_i}{5000}\right)^{0.3} + \mathbf{CSK}^{u,\ell} \left(\frac{\mathbf{NE}_i}{10^{12}}\right)^{\mathbf{PW}} + \mathbf{CRS}^{u,\ell} \left(\frac{\mathbf{ND}_i^1}{10^{16}}\right) + HDP_i^{u,\ell} \quad ,$$

where HDP is the ion broadening term (upper levels of Hydrogen only).
The parameter U is computed from

$$U_{ik}^{jm} = \frac{(DL_k + DV_i^m) - \mathbf{DDL}^j \, \mathbf{FDDL}_i}{DW_i} \, ,$$

where DL_k is wavelength offset ("delta Lambda") computed from $\mathbf{XI}_k$, DV_i^m is the wavelength shift due to velocity, and $\mathbf{DDL}^j$ is the offset of the jth component of a blended line (most transitions are not "blended lines" and have $\mathbf{LDL} = 1$ and $\mathbf{DDL}^1 = 0$.)
The wavelength shift due to velocity is given by

$$DV_i^m = VP_i^m \, (\lambda^{u,\ell}/c) \times 10^5 \, ,$$

where VP^m is the velocity projected along direction m, $\lambda^{u,\ell}$ is the "core" wavelength of transition (u, ℓ), and c is the light speed (in cm/s). The projected velocity is given by

$$VP_i^m = MU^m \times (\mathcal{V}_i - \mathcal{V}^*) \, ,$$

where MU^m is the cosine of the angle between direction m and the outward normal, $\mathcal{V}^* = 0$ in the restframe but $\mathcal{V}^* = \mathcal{V}_I$ in the frame comoving with point I, and $\mathcal{V} = \mathbf{VXS}$ or $\mathcal{V} = \mathbf{VX}$, as the case may be.

PANDORA provides two types of **VX**: "general **VX**" and "shock **VX**." This distinction (described below) arises from the different generating formulas used to generate tables of $\mathbf{VX}_i$ when such tables were not explicitly given in the input.

c) Flow-brodadening velocities, $VXFB$, for profiles

When option FLWBROAD is on, a special set of velocities is generated and used to compute a set of line profiles; these profiles are averaged to yield a "flow-broadened" profile. These flow velocities, $VXFB$, enter the profile calculations just like the "additional" expansion velocities, **VX**, discussed above.

d) Sobolev velocity **VSB**

The "Sobolev" velocity $\mathbf{VSB}_i$ (in km/s, positive outwards) is needed when the moving escape probability (*i.e.* Sobolev) solution is selected for one or more transitions. The Sobolev formula for the net radiative bracket is

$$RHO_i^{\text{Sobolev}} = G_i \left(1 - \frac{J_i}{S_i}\right) \quad ,$$

$$G_i = \int_0^1 f_i(x)dx \quad ,$$

$$f_i(x) = \frac{1 - \exp[-H_i(x)]}{H_i(x)} \quad ,$$

$$H_i(x) = \frac{FXI_i}{x^2 \mathbf{VSB}_i' + (1-x^2)RV_i} \quad ,$$

where $\mathbf{VSB}_i'$ is the derivative of **VSB** with respect to **Z**. In the plane-parallel case: $RV_i = 0$; but in the spherical case:

$$RV_i = \frac{\mathbf{VSB}_i}{(\mathbf{Z}_N - \mathbf{Z}_i) + \mathbf{R1N}} \quad .$$

e) Mass motion velocity **VM**

The "mass motion" velocity $\mathbf{VM}_i$ (in km/s, positive inwards) is needed when the option VELGRAD is on and is further explained in section (2b) below. The mass motion velocity can also be introduced into the hydrostatic equilibrium calculations, depending on the option HSEV. This is illustrated next, in the description of the use of **VT**.

f) Turbulent pressure velocity **VT**

VT is the "turbulent pressure" velocity (in km/s), (note that when option VTV is on then, if no values of $\mathbf{VT}_i$ were specified in the input, $\mathbf{VT}_i$ will be set equal to $\mathbf{V}_i$). **VT** is used in the hydrostatic equilibrium calculations in the equation for the total pressure.
The hydrostatic equilibrium equation is

$$dp/dx = g\rho\,,$$

where p is the total pressure, x is the distance from the outer boundary (in cm), and the density ρ is given by

$$\rho_i = m_{\rm H}\,\mathbf{NH}_i\,\left(1 + \frac{m_{\rm He}}{m_{\rm H}}\frac{NHE_i}{\mathbf{NH}_i}\right)\,,$$

where NHE_i is the Helium density. The total pressure is given by

$$p_i = (1+\gamma)P_i^{\rm gas} + P_i^{\rm turb} + P_i^{\rm exp} \quad .$$

γ is the input constant **RMAGP** that can be used to simulate the effect of magnetic pressure; $P_i^{\rm gas}$ is the gas pressure

$$P_i^{\rm gas} = (NHA_i + NHE_i + \mathbf{NE}_i - NH2_i)\,k\,\mathbf{TE}_i$$

where NHA_i is the atomic Hydrogen density and $NH2_i$ is the molecular Hydrogen density; $P_i^{\rm turb}$ is the turbulent pressure

$$P_i^{\rm turb} = 1/2\rho_i(\mathbf{VT}_i \times 10^5)^2 \quad ;$$

and $P_i^{\rm exp}$ is the expansion pressure

$$P_i^{\rm exp} = \rho_i(\mathbf{VM}_i \times 10^5)^2$$

only when the option HSEV is on; when the option HSEV is off, then $P_i^{\rm exp} = 0$ (note that option HSEV is on by default). Here **VM** is the mass motion velocity, further explained in section (2b) below.

2) Establishing and checking velocity values

After all the input has been read, the values of **V**, **VR**, and **VT**, are accepted as they stand (but note that option VTV is relevant).

a) Values of **VSB**, **VXS**, and "general" $\mathbf{VX}^n$ may either be input directly as simple arrays, or by means of their corresponding generating parameters **CVSB**, **CVXS**, and $\mathbf{CVX}^n$, from which the input tables are computed. "General" **VX** are computed when $\mathbf{ISSV}^1 = 0$; for "shock" **VX**, see below. (Values of $VXFB$ cannot be input as simple arrays but can only be obtained with generating parameters; see below.)
Such values of velocity $\mathcal{V}_i$ are computed from the corresponding generating parameter $\mathcal{C}$ as follows:

$$\mathcal{V}_i = \frac{\mathcal{C} \times 10^{10} \times TERM_i}{\mathbf{NH}_i} \times \frac{FMV_i}{FFRS_i^2}$$

(see E. H. Avrett's program specifications "Use of the continuity equation for the fluid velocity," dated 8/9/88, and "Depth-dependent helium abundance," dated 12/31/90, and the further modifications dated 1/25/93 and 4/26/95). Here

$$TERM_i = \frac{(1 + \mu \times a^*)}{(1 + \mu \times a_i)},$$

where $\mu = m_{\rm He}/m_{\rm H}$, $a_i = ABD_{\rm He} \times \mathbf{RHEAB}_i$, and a^* is a reference value of a_i determined as specified in [12/31/90].
The multiplier FMV_i is used to set $\mathcal{V}_i = 0$ deep in the atmosphere and is obtained as follows:

$$FMV_i = 0, \qquad t_i < \mathbf{FMVLIM},$$

or

$$FMV_i = t_i, \qquad t_i \geq \mathbf{FMVLIM},$$

where

$$t_i = \frac{1}{2}[1 - \tanh(x_i)],$$

and

$$x_i = (\mathbf{Z}_i - \mathbf{CVZ})/\mathbf{CDZ}, \qquad \mathbf{CDZ} \neq 0,$$

or

$$x_i = 1, \qquad \mathbf{CDZ} = 0.$$

CDZ (default = 1 km) and **CVZ** (default = the smallest value of $\mathbf{Z}_i$ for which $\mathbf{NH}_i > 10^{11}$), and **FMVLIM** (default = 10^{-4}), are input parameters.

The term $FFRS_i$ is required when spherical geometry has been selected. Thus, when the option SPHERE is off, $FFRS_i = 1$; but when the option SPHERE is on,

$$FFRS_i = \frac{(\mathbf{R1N} + \mathbf{Z_N}) - \mathbf{Z}_i}{(\mathbf{R1N} + \mathbf{Z_N}) - Z^*} ,$$

where $Z^* = \mathbf{Z}_1$ when $\mathbf{NH}_1 > 10^{10}$; $Z^* = \mathbf{Z_N}$ when $\mathbf{NH_N} < 10^{10}$; but otherwise is obtained by interpolation in the **Z** and **NH** tables so that $\mathbf{NH}(Z^*) = 10^{10}$.

Shock velocity

When input parameter $\mathbf{ISSV}^1 > 0$, then tables of "shock" velocity values $\mathbf{VX}_i^m$, $1 \leq m \leq \mathbf{NVX}$, are generated from other input parameters as follows: $\mathbf{VX}_i^m = \mathbf{SCVB}$ when $i > \mathbf{ISSV}^m$, but

$$\mathbf{VX}_i^m = -\mathbf{SCVA} \exp[(\mathbf{Z}_i - \mathbf{Z_{ISSV}}^m)/\mathbf{SCVS}]$$

for $i \leq \mathbf{ISSV}^m$. Here **ISSV** is the shock velocity depth index, **SCVA** is the velocity amplitude, and **SCVS** is the velocity scale height.

Flow-broadening velocities, $VXFB$

$VXFB$s consist of two groups: the $2 \times \mathbf{NFB}$ isotropic velocities generated with **CVXM**, and the 2 mass-conserving flow velocities generated with **CVXF**. The generating procedure discussed above does not produce proper values of the isotropic velocities, which are intended to represent ubiquitous "random" flows in the Sun's upper chromosphere and lower transition region. So these isotropic velocities are edited, after computation, to insure that they are nowhere smaller than values obtained by interpolation from the input table **FNH** (a function of **HNDF**). These $VXFB$ effectively constitute the **VX**-set for this run (with **NVX** determined by the program); when option FLWBROAD is on no other types of "additional" expansion velocities are allowed (and the run will be aborted if an input value of $\mathbf{NVX} > 0$ is provided).

b) Values of **VM** may either be input directly as a simple array, or by means of the generating parameters **CFH** or **CFHE**. These are used to compute **VM** by a procedure that is intimately related to how **VM** is used in the diffusion calculations when the option VELGRAD is on, as follows.
In a Hydrogen run:

$$\mathbf{VM}_i = 10^{-5} \left(\frac{\mathbf{CFH}}{\mathbf{NH}_i} - RS_i \times \mathbf{VBMB}_i \right) \times \frac{FMV_i}{FFRS_i^2} \,,$$

while in a Helium run:

$$\mathbf{VM}_i = 10^{-5} \left(\frac{\mathbf{CFHE}}{NHE_i} + RH_i \times \mathbf{VBMB}_i \right) \times \frac{FMV_i}{FFRS_i^2} \,;$$

where

$$RS_i = \mu \times HEND_i / (\mathbf{NH}_i + \mu \times HEND_i) \,,$$

while

$$RH_i = \mathbf{NH}_i / (\mathbf{NH}_i + \mu \times HEND_i) \,;$$

where again $\mu = m_{\rm He}/m_{\rm H}$ and NHE_i, FMV_i and $FFRS_i$ are as in section (2a), above.

c) When values of velocity tables are established by these procedures, then the following three remarks apply:
1) whenever the input value of a generating parameter $\mathcal{C} \neq 0$, then the corresponding $\mathcal{V}$ will be computed from it, regardless of whether or not an input table of values was provided;
2) whenever one velocity table is set equal to another (see just below), then the corresponding generating parameters are set equal as well; and
3) whenever NH_i is recomputed during a run, those velocity tables whose corresponding generating parameters are $\neq 0$ are recomputed as well.

d) After these procedures have been applied as needed during post-read input processing, the tables of **VM**, **VXS** and **VSB** are checked for reasonableness and consistency, as follows:
First, the values **VM** are checked. They may = 0, but they must be $\neq 0$ if VELGRAD is.
Next, the values of **VXS** are set up. When there are input values of **VXS**, they are accepted and named VXI (*i.e.* the " original input" values of **VXS**). The values of VXI must = 0 when EXPAND is off; they may be ≥ 0 when EXPAND is on. [*NOTE: the values of* **VXS** *that are used in the line source function calculations (and the emergent profile calculations) are redetermined from time to time, as needed;* normally*, however,* **VXS** *is set* $= VXI$.] Then, when EXPAND is on, the following occcurs. If the values of **VM** $\neq 0$, then VXI is set = -**VM**. But if the values of **VM** = 0, then VXI retains its input values as read; note that these may = 0! After these rules have been enforced, **VXS** is set = VXI.
Last, the values of **VSB** are checked. If the values of **VM** $\neq 0$, then **VSB** is set = -**VM**. If the values of **VM** = 0 and the values of **VXS** $\neq 0$, then **VSB** is set = **VXS**. If the values of **VM** and of **VXS** both = 0, then **VSB** retains its input values as read. Note that **VSB** must $\neq 0$ if a Sobolev solution is requested!

3) More about how velocities are used

a) As part of every diffusion calculation (*i.e.* when options AMDIFF and/or VELGRAD are on), tables $VADD_i$, $VV1_i$, and $VV2_i$ are computed as follows:

$$VADD_i = VV1_i + VV2_i \quad ;$$

where, when AMDIFF is on in a Hydrogen run:

$$VV1_i = -VH_i \times 10^{-5} \quad ,$$

when AMDIFF is on in a Helium I run:

$$VV1_i = -V1_i \times 10^{-5} \quad ,$$

or, when AMDIFF is on in a Helium II run:

$$VV1_i = -V2_i \times 10^{-5} \quad ;$$

and, when VELGRAD is on:

$$VV2_i = -\mathbf{VM}_i \quad ;$$

(see E. H. Avrett's program specification "Use of diffusion velocities in emergent profile calculations," dated 10/25/89). Then, if the option VELS is on, the current values of **VXS** are replaced by the following:

$$\mathbf{VXS}_i = VXI_i + VV1_i \quad .$$

b) Emergent line profile calculations are done with as many velocity tables as possible. (These enter the calculation by way of the "doppler width" DW, given above). A "set" of velocity tables is assembled as follows:
The first velocity is either $\mathbf{VXS}_i$ or $\mathbf{VSB}_i$, depending on whether or not the Sobolev solution was used for this transition.
If $\mathrm{VADD}_i \neq 0$ and $\neq$ the first velocity, then VADD is added to the set as the second velocity.
Thereafter, the tables $\mathcal{V}_i^n = \mathbf{VX}_i^n + VADD_i,\ 1 \leq n \leq \mathbf{NVX}$, are added to the set, provided that $\mathcal{V}_i^n \neq 0$ and $\neq$ any of the preceding velocities. Recall that these **VX** are either "additional" expansion velocities (either of type "general" or of type "shock") or flow-broadening velocities.

(Section 16 – last revised: 2005 Aug 17)

Section 17: **Ion Abundances**

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For simplicity, PANDORA treats, in any one run, the levels of a single ionization stage together with the lowest level of the next higher stage. The sum of the populations of these two *ions* at depth i is $\mathbf{ABD} \times \mathbf{RABD}_i \times \mathbf{HND}_i$, where **ABD** is the *elemental* abundance relative to hydrogen, $\mathbf{HND}_i$ is the total hydrogen number density (*i.e.,* protons + neutral hydrogen atoms + 2 × hydrogen molecules), and $\mathbf{RABD}_i$ is the fraction of the elemental abundance in the two stages. By default, $\mathbf{RABD}_i = 1$ for all i.

In a hydrogen run, $\mathbf{ABD} = 1$, and $\mathbf{RABD}_i$ is automatically calculated to account for the atomic fraction relative to the total including molecules (input parameter **NHTSW**). In carbon and oxygen runs, $\mathbf{RABD}_i$ is automatically reduced to account for the portions of those elements that are in the form of carbon monoxide (input parameter **NCOSW**).

Diffusion may render invalid the assumption that **ABD** of a particular element is constant throughout the atmosphere (*i.e.,* the elemental abundance itself may be depth-dependent). When the options AMDIFF and HEABD are both on, PANDORA calculates the depth-dependence of the total helium abundance, $\mathbf{RHEAB}_i$. The product $\mathbf{ABD}_{\mathrm{He}} \times \mathbf{RHEAB}_i$ is then used in that run in place of the constant $\mathbf{ABD}_{\mathrm{He}}$ as appropriate. (By default, $\mathbf{RHEAB}_i = 1$ for all i.)

The quantities FION_i (the fraction of ions) and FLVS_i (the fraction representing the sum of bound-level populations), as they appear in the POPULATIONS printout, are included in output file `fort.20` (see Section 8). Note that $\mathrm{FLVS}_i + \mathrm{FION}_i = \mathbf{RABD}_i$. Sets of FION & FLVS values from the runs with different ionization stages can then be read by a separate program, called `CENSUS`, which

computes tables of $\mathbf{RABD}_i$ for the different ions. `CENSUS` is available for general use, as an auxiliary program for PANDORA.

For example, a He I run (He I levels plus the lowest level of He II) and a He II run (He II plus He III) could both be started with default values of **RABD**. The sets of FION & FLVS values obtained from both these runs are then used by `CENSUS` to compute a table of $\mathbf{RABD}_i$ values for He I and another table for He II. Values of the He I table will be less than unity because of the He III fraction, and values of the He II table will be less than unity because of the He I fraction. After those initial parallel He I and He II runs starting with $\mathbf{RABD}_i = 1$, it is then better to alternate between He I and He II runs, each followed by a `CENSUS` run to update the $\mathbf{RABD}_i$ values, instead of making He I and He II runs in parallel before using `CENSUS`.

The FION & FLVS data from PANDORA output file `fort.20` consist of the lines following the marker `[ CENSUS data start ]` and up to the marker `[ CENSUS data end ]`, exclusive (see Section 8). Note that each set includes the $\mathbf{Z}_i$ table, and a number specifying the stage of ionization.

The input file for `CENSUS` is `fort.91`. It should contain the FION & FLVS sets from the latest runs with all the ions of the element. The main `CENSUS` printout file is `fort.92`. There is also a data output file, `fort.93`, which contains tables of $\mathbf{RABD}_i$ for all the ions represented in the input, in the form of valid PANDORA input statements.

`CENSUS` can deal with the case of different $\mathbf{Z}_i$ tables in the various FION & FLVS sets. If the $\mathbf{Z}_i$ tables do differ (in length and/or by value), the program constructs an all-inclusive merged table, Z_m, interpolates all FION and FLVS input tables to Z_m, computes the various $\mathbf{RABD}_i$ tables to correspond to Z_m, and then writes out the individual $\mathbf{RABD}_i$ tables to correspond to the appropriate original input $\mathbf{Z}_i$ tables. This procedure can lead to unwanted results if the various FION & FLVS sets are intended to correspond to, say, identical $\mathbf{TE}_i$ tables, but the different PANDORA runs had assigned different **Z** values to the depth slots associated with that same $\mathbf{TE}_i$ table. (*Note* that PANDORA recomputes **Z** in HSE runs for which input values of $\mathbf{ZMASS}_i$ or $\mathbf{TAUKIN}_i$ were provided.) It is important to pay attention to this. The user may need to intervene and edit the data in the `CENSUS` input file to make sure that the FION & FLVS tables are associated with appropriate $\mathbf{Z}_i$ tables, and that inappropriate interpolations are avoided.

(Section 17 – last revised: 1997 Apr 08)

Section 18: **Frequency Tables**

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Tables of frequency values, ξ of length k, are needed —1) for the calculations performed for every radiative transition (u, ℓ) as follows: a) integration over frequency for the Line Source Function, b) integration over frequency for PRD terms (if needed), c) emergent line profile calculation; and —2) to capture simulated lines in the "background" (continuum). A frequency table can span either a half-profile (which then implies a symmetric whole profile), or a whole profile (which need not be symmetric).
Internally, PANDORA establishes separate complete sets of preliminary frequency tables for every transition (u, ℓ). Such a complete set consists of: a symmetric half-profile table, a blue-side half-profile table, and a red-side half-profile table. These tables will be set equal to *unique* transition-specific half-profile input tables if such were provided, otherwise to general-purpose *common* half-profile input tables.
Full-profile frequency tables are assembled from half-profile tables. However, for every transition (u, ℓ) that is a blended line, a composite full-profile frequency table is specially constructed by combining the full-profile tables of each of the component lines. Full-profile tables are augmented automatically to account properly for "background lines."

The remainder of this section describes the input, the defaults provided when no inputs are specified, how the full-profile table and the composite full-profile table (if needed) are constructed, and which tables are selected for the source function and emergent profile calculations.

Important Note

The lengths of the various input and constructed frequency tables should not exceed the limits explained below for **KMMAX**, and also in Section 5, Note 47.

Input

For historical reasons, *only half-profile frequency tables may be specified in the input.* All these tables must be specified with their values in ascending order, and each table's first value must = 0.

One may specify *unique* half-profile frequency tables for some or all transitions (u, ℓ), and/or one may specify *common* half-profile frequency tables to be used for all those transitions for which no unique sets are specified.

1) *Common* half-profile frequency tables:
The basic *common* half-profile frequency table is **XISYM** of length **KS**. (The defaults are given is Section 5, above.) A *common* blue-side half-profile table, **XIBLU** of length **KB**, and a *common* red-side half-profile table, **XIRED** of length **KR**, may also be specified. After PANDORA has read Part D of the input, defaults will be provided for unspecified tables: **XIBLU** will be set equal to **XISYM** if no values were input, and **XIRED** will be set equal to **XISYM** similarly.

2) *Unique* half-profile frequency tables:
[The transition-superscripts (u, ℓ) on names ending in 'T' are omitted in the next paragraph.]
The following half-profile frequency tables can be input for transition (u, ℓ): symmetric **XISYMT** of length **KST**, blue-side **XIBLUT** of length **KBT**, and red-side **XIREDT** of length **KRT**. After PANDORA has read Part D of the input, defaults will be provided for unspecified tables: The *unique* **XISYMT** will be set equal to *common* **XISYM** if no values were input; thereafter, **XIBLUT** will be set equal to **XISYMT** if no values were input, and **XIREDT** will be set equal to **XISYMT** similarly.
Note also the relevant input parameters **KSTMAX**, **KBTMAX**, and **KRTMAX**, which must be specified.

3) *Full-profile* frequency table:
[The transition-superscripts (u, ℓ) on names ending in 'T' are omitted in the next paragraph.]
After **XIBLUT** and **XIREDT** for transition (u, ℓ) have been established, a whole-profile frequency table XIFULT of length KFT is constructed by concatenating the values of **XIREDT** and the negatives of the values of **XIBLUT**: $\text{XIFULT}_1 =$

$-\mathbf{XIBLU_{KBT}}$, $\mathrm{XIFULT}_{\mathbf{KBT}} = 0.0$, $\mathrm{XIFULT}_{\mathrm{KFT}} = \mathbf{XIREDT_{KRT}}$, where $\mathrm{KFT} = \mathbf{KBT} + \mathbf{KRT} - 1$.

4) *Blended* line transitions:
A special composite full-profile frequency table XICMPT$^{u,\ell}$ of length KCT$^{u,\ell}$ is constructed by merging **LDL**$^{u,\ell}$ XIFULT$^{u,\ell}$ tables, each offset appropriately, with redundant points eliminated as much as possible.
Note: For storage allocation purposes, PANDORA estimates the value of the largest KCT$^{u,\ell}$ *before* any have been computed. This estimate may be much too large (in cases when many redundant points can be eliminated). Yet a run could be stopped if this estimate is larger than can be accommodated. The input parameter **KMMAX** has been provided for such a case: if **KMMAX** > 0 then, if it is larger than the estimate, **KMMAX** will be used for storage allocation purposes instead of an internal estimate; if **KMMAX** < 0 then, if $-$**KMMAX** is less than the estimate, $-$**KMMAX** will be used for storage allocation purposes instead. A run will still be stopped, however, if ultimately any KCT$^{u,\ell}$ $>$ |**KMMAX**|.

Uses

After all these preliminaries, PANDORA is ready to set up the frequency table ξ for each transition. The choice of table depends on whether the range of the Line Source Function frequency integration extends over the whole profile, or only over half a profile:

1) If option EXPAND is on, then full-profile integrations are done for all transitions.

2) If **NVX** > 0, then full-profile integrations are done for all transitions.

3) If **LDL**$^{u,\ell}$ > 1 (*i.e.,* if this is a blended line transition), then full-profile integration is used for transition (u, ℓ).

4) If **LSFFDB**$^{u,\ell}$ $= 1$ (*i.e.,* if frequency-dependent background is required for this transition), then full-profile integration is used for transition (u, ℓ). *Note* that PANDORA sets **LSFFDB**$^{u,\ell} = 1$ automatically for every PRD transition.

5) In **all other** cases, half-profile integrations are used.

Then, for every radiative transition (u, ℓ):

If half-profile integration is used for transition (u, ℓ), then $k^{u,\ell}$ is set equal to $\mathbf{KST}^{u,\ell}$ and $\xi^{u,\ell}$ is set equal to $\mathbf{XISYMT}^{u,\ell}$.

If full-profile integration is used for transition (u, ℓ) and this is a blended line, then $k^{u,\ell}$ is set equal to $\mathrm{KCT}^{u,\ell}$ and $\xi^{u,\ell}$ is set equal to $\mathrm{XICMPT}^{u,\ell}$.

If full-profile integration is used for transition (u, ℓ) and this is not a blended line, then $k^{u,\ell}$ is set equal to $\mathrm{KFT}^{u,\ell}$ and $\xi^{u,\ell}$ is set equal to $\mathrm{XIFULT}^{u,\ell}$.

Moreover, if a full-profile ξ-table has been selected:

PANDORA checks whether the centers of any simulated "background lines" occur in the wavelength band corresponding to the range ξ_1 to ξ_k. If yes, then the ξ-table is augmented with enough additional values to resolve such lines properly. The Hydrogen Lyman lines are handled as a special case. All other background lines cause all or part of a set of frequency values—obtained by constructing a full-profile frequency table from the input table **BXI** of length **KBX**—to be inserted in the ξ-table. (*Note*: **BXI** is also used for inserting "background line wavelengths" in the standard Rates Integrations wavelengths table constructed and used when option USEWTAB is on.)

Section 19: **Atomic Models**

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PANDORA uses the numeric parameters of a model of the ion-of-the-run to compute the line source functions and emergent line profiles of interest. The user must see to it that the minimum required set of atomic model parameters is specified in the input. Some of these atomic parameters (in the case of Hydrogen: most) can take on default values supplied by the program.
Over the years, and with the the help of many people, we have compiled and collected several dozen atomic model data sets. These data sets are known as "atomic model files" and are available for general use.

The purpose of this section is to provide some general guidance for setting up an atomic model and to describe the available defaults. Please refer to Section 5 for complete details about the various parameters mentioned here.
Note that PANDORA-supplied default parameter values are written to file `fort.20` (*i.e.,* `.msc`) when option ATOMSAV is on (see Section 8).

There now follow: 1) General Information; 2) Defaults For Ions Other Than Hydrogen; 3) Defaults for Hydrogen; and 4) More About Collision Rates.

1) General Information

An atomic model consists of a set of energy levels, a continuum level, specifications of the properties of levels, and specifications of the properties of transitions between levels and between levels and the continuum. (As well, PANDORA uses many other atomic model-related parameters that pertain to the details of various specific computational and organizational procedures.)

Levels

The number of energy levels ('regular levels') is **NL**, (**NL** ≥ 2). Additional higher levels can be included in the calculations in an approximate way as 'supplementary levels' by setting **NSL** $>$ **NL**. (Normally these are not used, and the program sets **NSL** $=$ **NL**.)
The principal quantum numbers n and ℓ for each level are specified by means of the **NLPAIR** statement. (Another parameter **QNL**, the "number of $n\ell$ electrons," must be specified for each level if default **CI** values [see below] are used.)
The value of $\mathbf{NU}^j, 1 \leq j \leq \mathbf{NSL}$, is the energy of level j in frequency units (in units of 10^{15} Hz); the convention $\mathbf{NU}^1 = 0$ is enforced. The value of **NUK**, similarly, is the energy of the continuum. If the higher level(s) of the ion model are 'autoionizing' level(s), then auxiliary continuum energies, $\mathbf{NUC}^j > \mathbf{NUK}$, can be specified (the default value of $\mathbf{NUC}^j = \mathbf{NUK}$).
Other parameter values needed for each level include: **P**, statistical weight; **CP**, photoionization cross-section; and values of **ELSYM** and **IONSTAGE** (e.g., for Mg-II, **ELSYM** = MG and **IONSTAGE** = 2).

The collisional ionization rate is $\mathbf{CI}_i^j \times \mathbf{NE}_i \times \exp(-h\,\mathbf{NU}^j \times 10^{15}/k\,\mathbf{TE}_i)$, where **CI** is the collisional ionization coefficient. Values of **CI** can also be provided in the input. **CI** can be given as functions of a specified short temperature table $\mathbf{TER}_k,\ 1 \leq k \leq \mathbf{NTE}$. When values of $\mathbf{CI}_i^j$ at particular depths i (*i.e.,* for particular values of $\mathbf{TE}_i$) are required as the calculation proceeds, they are then obtained by interpolation from these given tables of $\mathbf{CI}^j(\mathbf{TER}_k),\ 1 \leq j \leq \mathbf{NSL},\ 1 \leq k \leq \mathbf{NTE}$. When $\mathbf{NTE} = 1$, then the constant value $\mathbf{CI}^j$ is used for all temperatures.
However, **CI** can also be computed "on-the-fly" for the specific value of $\mathbf{TE}_i$ (and $\mathbf{NC}_i$ in a Hydrogen run) at every depth i; see (**4**), below.

Transitions between levels

PANDORA computes the collisonal transitions, both due to electrons and due to hydrogen, between all levels, and from all levels to the continuum (thus providing rates between levels via the continuum). However radiative transitions are computed only between specified pairs of levels $(u, \ell),\ u > \ell$. There are **NT** such pairs, which are specified by means of the **INPAIR** statement. The "radiative" transitions so specified, depending on how PANDORA should treat them, can be of five different types as indicated by the parameter $\mathbf{KTRANS}^{u,\ell}$: `RADIATIVE`, `PASSIVE`, `THICK`, `THIN`, and `2-PHOTON`. Note that `RADIATIVE` transitions can be designated as 'blended lines'; this is triggered by setting $\mathbf{LDL}^{u,\ell} > 1$ (see also input parameter **LDLMAX**).
Values of the Einstein parameter $\mathbf{A}^{u,\ell}$ are required for all `RADIATIVE` and `PASSIVE` transitions, and may be specified for `THICK` transitions. Values of the broadening parameters $\mathbf{CRD}^{u,\ell}$ (radiative), $\mathbf{CVW}^{u,\ell}$ (van der Waals), $\mathbf{CSK}^{u,\ell}$ (Stark) and $\mathbf{CRS}^{u,\ell}$ (resonance) may be specified for `RADIATIVE` and `PASSIVE` transitions.

The collisional de-excitation rate is $\mathbf{CE}_i^{u,\ell} \times \mathbf{NE}_i \times (\mathbf{P}^u/\mathbf{P}^\ell)$, while the excitation rate is $\mathbf{CE}_i^{u,\ell} \times \mathbf{NE}_i \times \exp[-h\,(\mathbf{NU}^u - \mathbf{NU}^\ell) \times 10^{15}/k\,\mathbf{TE}_i]$; here **CE** is the excitation coefficient. Values of **CE** may also be provided in the input. **CE** can be given as functions of the short temperature table $\mathbf{TER}_k,\ 1 \le k \le \mathbf{NTE}$, mentioned above. When values of $\mathbf{CE}_i^{u,\ell}$ at particular depths i (*i.e.,* for particular values of $\mathbf{TE}_i$) are required as the calculation proceeds, they are then obtained by interpolation from these given tables of $\mathbf{CE}^{u,\ell}(\mathbf{TER}_k),\ 2 \le u \le \mathbf{NL},\ 1 \le \ell < u,\ 1 \le k \le \mathbf{NTE}$. When $\mathbf{NTE} = 1$, then the constant value $\mathbf{CE}^{u,\ell}$ is used for all temperatures.
However, **CE** can also be computed "on-the-fly" for the specific value of $\mathbf{TE}_i$ (and $\mathbf{NC}_i$ in a Hydrogen run) at every depth i; see (4), below.

Minimum input

Values for at least the following atomic model parameters are required in order to be able to do anything at all: **NL**, **NU**, **NUK**, **P**, **CP**, **NT**, **A**, and values of **CI** and **CE** for one value of **TER** (for, say, the default value 4000 K).

2) Defaults For Ions Other Than Hydrogen

a) Unspecified values of $\mathbf{CI}^j(\mathbf{TER}_k),\ 1 \le j \le \mathbf{NSL},\ 1 \le k \le \mathbf{NTE}$ are replaced by computed ones. Three different methods are available; the (set of) method(s) to be used can be specified in a CIMETHOD statement. The CIMETHOD statement lists methods by codename as follows:
`CLARK`: Clark, Abdallah, and Mann (1991), ApJ **381**, 597;
`AR`: Arnaud and Rothenflug (1985), A&A **60**, 425;
`VORONOV`: Voronov (1997), Atomic Data and Nuclear Tables **65**, 1.
`AR` and `VORONOV` can only be used for level $j = 1$, of some ions; `CLARK` can be used in all cases.
The default methods set is: `AR` for $j = 1$ if possible, and `CLARK` otherwise.

b) Unspecified values of $\mathbf{KTRANS}^{u,\ell}$, for all (u, ℓ) pairs mentioned in **INPAIR**, are set equal to `RADIATIVE`.

c) If **CP** is not specified, then for level 1 a default value is computed according to Verner *et al.* (1996), ApJ, **465**, 487 if they list data for this ion. If not, and for other levels, default values are obtained from the hydrogenic approximation.

d) Unspecified values of $\mathbf{CE}^{u,\ell}(\mathbf{TER}_k),\ 2 \le u \le \mathbf{NL},\ 1 \le \ell < u,$ $1 \le k \le \mathbf{NTE}$ are replaced by computed ones. Two different methods are available; the (set of) method(s) to be used can be specified in a CEMETHOD statement. The CEMETHOD statement lists methods by codename as follows:
`SEATON`: Seaton (1962), Proc.Phys.Soc. **79**, 1105;
`VREGE`: van Regemorter (1962), ApJ **136**, 906.
`SEATON` can only be used for transitions with nonzero **A**-values, of neutral atoms; `VREGE` can be used for all cases. The `VREGE` method needs **A**-values. If $\mathbf{A}^{u,\ell} = 0$ then theoretical values of $\mathbf{A}^{u,\ell}$ for such 'forbidden' transitions are computed assuming that the oscillator strength of the transition is given by the parameter **FROSCE** (whose default value = 0.01).
The default methods set is: `SEATON` for neutral atoms, and `VREGE` otherwise.

e) Unspecified values of $\mathbf{CRD}^{u,\ell}$, $\mathbf{CVW}^{u,\ell}$, and $\mathbf{CSK}^{u,\ell}$ are updated with computed ones. The calculation of **CRD**-vales uses all available **A**-values.

f) If all values of **RRCP** for any level are unspecified, default sets for such levels are computed either according to Verner *et al.* (see (c), above), or using $1/\nu^3$.

3) Defaults For Hydrogen

a) Unspecified values of $\mathbf{NU}^j$, $\mathbf{P}^j$ and $\mathbf{CP}^j$, $1 \leq j \leq \mathbf{NSL}$, and of **NUK** are replaced by computed ones.

b) Unspecified values of $\mathbf{CI}^j(\mathbf{TER}_k)$, $1 \leq j \leq \mathbf{NSL}$, $1 \leq k \leq \mathbf{NTE}$ are replaced by computed ones. Five different methods are available; the (set of) method(s) to be used can be specified in a CIMETHOD statement. The CIMETHOD statement lists methods by codename as follows:
`CLARK`: Clark, Abdallah, and Mann (1991), ApJ **381**, 597;
`AR`: Arnaud and Rothenflug (1985), A&A **60**, 425;
`JOHNSON`: Johnson (1972), ApJ **174**, 227;
`VS`: Vriens and Smeets (1980), Phys.Rev.A **72**, 940;
`SHAH`: Shah, Elliott, and Gilbody (1987), J.Phys.B **20**, 3506.
`AR` and `SHAH` can be used for level $j = 1$ only; the others can be used in all cases.
The default methods set is: `SHAH` for $j = 1$, and `CLARK` otherwise.

c) Unspecified values of $\mathbf{CE}^{u,\ell}(\mathbf{TER}_k)$, $2 \leq u \leq \mathbf{NL}$, $1 \leq \ell < u$, $1 \leq k \leq \mathbf{NTE}$ are replaced by computed ones. Six different methods are available; the (set of) method(s) to be used can be specified in a CEMETHOD statement. The CEMETHOD statement lists methods by codename as follows:
`SEATON`: Seaton (1962), Proc.Phys.Soc. **79**, 1105;
`VREGE`: van Regemorter (1962), ApJ **136**, 906;
`SCHOLZ`: Scholz *et al.* (1990), MNRAS **242**, 692;
`PB`: Przybilla and Butler (2004), ApJ **609**, 1181;
`AGGRWL`: Aggarwal *et al.* (1991), J.Phys.B **24**, 1385;
`VS`: Vriens and Smeets (1980), Phys.Rev.A **22**, 940;
`JOHNSON`: Johnson (1972), ApJ **174**, 227.
`SCHOLZ` can be used for transition (2/1) only; `PB` works for all transitions (u, ℓ), $u \leq 7$; `AGGRWL` works for all transitions (u, ℓ), $u \leq 5$; the others can be used for all cases.
The default methods set is: `AGGRWL` for all transitions it works for, and `JOHNSON` otherwise.

d) Unspecified values of $\mathbf{A}^{u,\ell}$, for all (u, ℓ) pairs mentioned in **INPAIR**, are computed according to Johnson (1972), ApJ **174**, 227 (uses 'lowering of the ionization potential when $\mathbf{IXNCS} = 1$). All unspecified values of $\mathbf{KTRANS}^{u,\ell}$, for all

(u, ℓ) pairs mentioned in **INPAIR**, are set equal to `RADIATIVE`.

e) Unspecified values of $\mathbf{CRD}^{u,\ell}$, $\mathbf{CVW}^{u,\ell}$, $\mathbf{CSK}^{u,\ell}$, and $\mathbf{CRS}^{u,\ell}$ are updated with computed ones. The calculation of **CRD**-values uses all available **A**-values; the calculation of **CSK**-values uses the method of Sutton (1978), JQSRT **20**, 233.

4) More About Collision Rates

When PANDORA computes values of **CI** and/or **CE**, as described in (2) and (3) above, such raw computed values are modified before use, as follows:

$$CI^j_{default} = ACI^j + MCI^j \times CI^j_{raw}$$

$$CE^{u,\ell}_{default} = ACE^{u,\ell} + MCE^{u,\ell} \times CE^{u,\ell}_{raw}$$

(The default values of the input parameters **ACI** and **ACE** are all 0, and of the input parameters **MCI** and **MCE** are all 1.)

Before any input or computed **CI** and **CE** values are used in the calculations, they are all multiplied by input parameter **RFAC** (default = 1).

When option CEFACTS is on and any values of $\mathbf{PCE}^{u,\ell} > 0$, then sets of $\mathbf{FCE}^{u,\ell}_i$ are computed and adjusted to prevent $S^{u,\ell}_i \leq 0$. Such **FCE** values are saved for use in restart runs.

If `ONTHEFLY` was specified for **CI** in a CIMETHOD statement, and/or for **CE** in a CEMETHOD statement, then the tabulated values in the ATOM printout section are for information only. Actual values of **CI** and/or **CE** will be computed at every depth as needed.
In a Hydrogen run computed default **CI** and **CE** values using `JOHNSON` or `VS` also depend on **NC** when the value of the input parameter **IXNCS** = 1 (the default is **IXNCS** = 0, *i.e.* the **NC**-dependent factor is set = 1). When the **NC**-dependent factor is computed explicitly it is intended to account for the 'lowering of the ionization potential.'

A comparison of the various default **CI** and **CE** values appears in the printout section INPUT NOTES. These sample values are computed using $\mathbf{TE}_i$, where i is the input parameter **INCEI**.

(Section 19 – last revised: 2007 Apr 18)

Section 20: **Statistical Equilibrium Equations**

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This section supplements the derivation and discussion given in the paper "Iterative Solutions of Multilevel Transfer Problems" by Avrett & Loeser in *Numerical Radiative Transfer*, ed. W. Kalkofen (Cambridge University Press, 1987), pp. 135–161.

The single-rate and net-rate statistical equilibrium equations are equations (10) and (14), respectively, in the paper cited above. To change from a net rate to a single rate for the u, ℓ transition, $u > \ell$, $\rho_{u,\ell}$ is replaced by $1 + (\overline{J}_{u,\ell}/\alpha_{u,\ell})$ where $\alpha_{u,\ell} = 2h\nu^3_{u,\ell}/c^2$, and $A_{u,\ell}(\overline{J}_{u,\ell}/\alpha_{u,\ell})(p_u/p_\ell)$ is added to the collisional excitation rate $C_{\ell,u}$. (Here $A_{u,\ell}$ is the Einstein emission coefficient and p_u/p_ℓ is the ratio of statistical weights.) These equations are written in terms of the bound-level number densities n_m. The continuum number density was eliminated by the use of equation (2).

Equation (10) or (14) for $m = 2, 3, \cdots, M$ when divided by n_1 each form a set of $M - 1$ equations for $n_2/n_1, n_3/n_1, \cdots, n_M/n_1$ given the $\overline{J}$ values in the first case and the ρ values in the second. (Here M, the number of bound levels, corresponds to the input parameter **NL**.) These equations can be expressed in terms of the departure coefficient ratios $b_2/b_1, b_3/b_1, \cdots, b_M/b_1$ if the rate coefficients are multiplied by γ_m/γ_1 where $\gamma_m = p_m \exp(-h\nu_{m1}/kT)$.

If we specified all transitions as "single," PANDORA would use the set of equations (10) to obtain "b-ratios from $\overline{J}$." If we specified all transitions as "net," PANDORA would use equations (14) to obtain "b-ratios from ρ." When PANDORA starts a calculation from scratch with no input ρ values (*i.e.,* all input $\mathbf{RHO}^{u,\ell}_i = 0$) and no input $\overline{J}$ values (*i.e.,* all input $\mathbf{JBAR}^{u,\ell}_i = 0$) the "b-ratios

from ρ" equations are used regardless of any transitions specified as "single." We include a "b-ratios from $\bar{J}$" calculation in each iteration mainly as a consistency check regardless of transitions specified as "net."
Otherwise, transitions are consistently treated as net or single according to the input transition rate selector $\mathbf{KRATE}^{u,\ell} = 1$ or $\mathbf{KRATE}^{u,\ell} = 2$, respectively. Some experimentation may be required in any given situation to determine which rate selector value to use for which transitions; we have found that best results are obtained by choosing 1 for strong lines and 2 for weak lines.

(Section 20 – last revised: 1996 Apr 02)

Section 21: **The Hydrogen Lyman Lines in the Continuum Calculations**

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1. Theory

The Hydrogen Lyman lines are transitions between any upper level U and the lower level $L = 1$. The absorption coefficient for a line transition between levels U and 1 is

$$\kappa_\nu = n_1 \frac{h\nu_{U1}}{4\pi} \mathcal{B}_{1U} \frac{\phi(a,x)}{\Delta\nu_D} \tag{1}$$

where n_1 is the number density of the lower level,

$$\phi(a,x) = \frac{a}{\pi^{3/2}} \int_{-\infty}^{+\infty} \frac{\exp^{-z^2}}{a^2 + (z-x)^2}\,, \tag{2}$$

and where $x = \Delta\nu/\Delta\nu_D$, $\Delta\nu = \nu - \nu_{U1}$, and $a = \delta/\Delta\nu_D$. In equation (1) we have ignored stimulated emission since it is negligible at Lyman line wavelengths. Here ν_{U1} is the line-center frequency, and the Doppler width $\Delta\nu_D$ is given by

$$\Delta\nu_D = \frac{\nu_{U1}}{c} \sqrt{\frac{2kT}{M} + V^2} \tag{3}$$

where M is the mass of the atom and V is the line-broadening or microturbulent velocity.
The damping parameter is the sum

$$\delta = \delta_{\rm Nat} + \delta_{\rm Res} + \delta_{\rm Stark} + \cdots \tag{4}$$

and here we consider only the natural, resonance and Stark components

$$\delta_{\rm Nat} = \frac{1}{4\pi} \sum_{k=1}^{U-1} A_{Uk} \tag{5}$$

and

$$\delta_{\rm Res} = \frac{1}{4\pi} \frac{3e^2}{m} \sqrt{\frac{g_L}{g_U}} \frac{f_{1U}}{\nu_{U1}} n_1 \,, \tag{6}$$

and

$$\delta_{\rm Stark} = 7.06 \times 10^{-6}\, \mathbf{PMSK}\, a^{U1} \frac{U^4}{U^2-1} \left(\frac{NE}{10^{12}}\right)^{2/3} \tag{7}$$

where

$$a^{U1} = \begin{cases} 0.642 & \text{if } U = 2 \\ \\ 1.0 & \text{otherwise} \end{cases} , \tag{8}$$

and **PMSK** is an input parameter (default = 1). This expression for Stark damping is from Sutton, K., 1978, J.Q.S.R.T., 20, 333. (Including $\delta_{\rm Stark}$ is optional in PANDORA; see below.)
In equation (6) n_1 represents the number density of perturbing atoms of the same ionization stage. The Einstein coefficients in equations (1) and (5) are related by the equations $A_{U1} = (2h\nu_{U1}^3/c^2)\mathcal{B}_{U1}$ and $g_U\mathcal{B}_{U1} = g_1\mathcal{B}_{1U}$, where g_U and g_1 are the statistical weights of the upper and lower levels. A_{U1} and the oscillator strength f_{1U} are related by

$$A_{U1} = \frac{g_1}{g_U} \frac{8\pi^2 e^2 \nu_{U1}^2}{mc^3} f_{1U} \tag{9}$$

where e and m are the electron's charge and mass, respectively.
When $a = 0$ in equation (2) the profile function reduces to

$$\phi(0, x) = \frac{1}{\sqrt{\pi}} \exp^{-x^2} \,. \tag{10}$$

For x larger than 3 (typically), and $a > 0$,

$$\phi(a, x) \rightarrow \frac{a}{\pi x^2} \,, \tag{11}$$

or

$$\frac{\phi(a, x)}{\Delta\nu_D} \rightarrow \frac{\delta}{\pi(\Delta\nu)^2} \,. \tag{12}$$

Thus in the line wings we can write equation (1) as

$$\kappa_\nu = n_1 \frac{h\nu_{U1}}{4\pi^2} \mathcal{B}_{1U} \frac{\delta_{\rm Nat} + \delta_{\rm Res} + \delta_{\rm Stark}}{(\Delta\nu)^2} \,. \tag{13}$$

In PANDORA we use equation (1) to determine κ_ν in the line core and equation (13) for larger $\Delta\nu$ in the line wings.
In the line core the source function is the frequency-independent line source function

$$S_{U1} = \frac{2h\nu_{U1}^2/c^2}{\frac{g_U}{g_1}\frac{n_1}{n_U} - 1} \,. \tag{14}$$

In the line wings, however, photons can be scattered (changing only their direction by the encounter with the atom) with no change in frequency, rather than being absorbed and the re-emitted with $\phi(a,x)$ frequency distribution. For those scattered photons the source function (i.e., the ratio of emission to absorption coefficients) is the mean intensity J_ν.
The transfer equation then is written as

$$\mu \frac{dI_\nu}{dz} = \kappa_\nu^{\rm abs}(I_\nu - S_{U1}) + \kappa_\nu^{\rm sct}(I_\nu - J_\nu) \,. \tag{15}$$

We introduce a scattering albedo α_ν and let

$$\kappa_\nu^{\rm abs} = (1 - \alpha_\nu)\kappa_\nu \,, \tag{16}$$

and

$$\kappa_\nu^{\rm sct} = \alpha_\nu \kappa_\nu \,. \tag{17}$$

We specify α_ν as a function of $x = \Delta\nu/\Delta\nu_D$. (Note that $\Delta\nu_D$, a function of T and V, varies with depth.) We define $(1 - \alpha_\nu) = DR(x)$, which is determined as described below. $DR(x)$ must not be less than the allowed lower limit which, for $3 \le U \le 15$ is given by the branching ratio equation

$$drlim^{u,1} = \frac{\sum_{k=2}^{U-1} A_{Uk}}{\sum_{k=1}^{U-1} A_{Uk}} \,. \tag{18}$$

Equation (13), which we use in the line wings (*i.e.*, when $x \ge XLIM$; see below), is written as

$$\kappa_\nu = \kappa_\nu^{\rm Nat} + \kappa_\nu^{\rm Res} + \kappa_\nu^{\rm Stark} \tag{19}$$

where

$$\kappa_\nu^{\rm Nat} = \begin{cases} n_1 \frac{h\nu_{U1}}{4\pi^2} \mathcal{B}_{1U} \frac{\delta_{\rm Nat}}{(\Delta\nu)^2} & \lambda < 142.5 \text{ nm} \\ \\ 0 & \lambda \geq 142.5 \text{ nm} \end{cases} \tag{20}$$

and

$$\kappa_\nu^{\rm Res} = \begin{cases} n_1 \frac{h\nu_{U1}}{4\pi^2} \mathcal{B}_{1U} \frac{\delta_{\rm Res}}{(\Delta\nu)^2} & U > 2 \\ \\ 10^{-17} n_1^2 \pi f_{12} r_{\rm el} F(\lambda, T) & U = 2 \end{cases} \tag{21}$$

(where $r_{\rm el} = 2.818 \times 10^{-13}$ cm is the classical electron radius), and

$$\kappa_\nu^{\rm Stark} = n_1 \frac{h\nu_{U1}}{4\pi^2} \mathcal{B}_{1U} \frac{\delta_{\rm Stark}}{(\Delta\nu)^2} \, . \tag{22}$$

We set $\kappa_\nu^{\rm Nat} = 0$ for $\lambda \geq 142.5$ nm in equation (20) since this is a component of the Rayleigh scattering opacity which we determine separately according to

$$\sigma_\nu^{\rm Ray} = \begin{cases} 0 & \lambda < 142.5 \text{ nm} \\ \\ n_1 R(\lambda) & \lambda \geq 142.5 \text{ nm} \end{cases} \, . \tag{23}$$

The values of $R(\lambda)$ are given by: M. Gavrila, 1967, Phys.Rev., 163, 147, Table I. The standard formula for $\kappa_\nu^{\rm Res}$ in equation (21) is used only for the $U > 2$ Lyman lines. For the wings of Lyman alpha we can use values of $F(\lambda, T)$ calculated by N. F. Allard (private communication, October 2002), based on general unified theory, including all the transitions contributing to Lyman alpha, taking into account the variation of the dipole moment during the collision, averaging over velocity. (HH potentials from: T. Detmer, P. Schmelcher, L. S. Cederbaum, 1998, J.Chem.Phys., 109, 9694; dipole moments from: I. Drira, 1999, J.Mol. Spectrosc., 198, 52.) $F(\lambda, T)$ has been tabulated for two values of temperatures, $T = 5000$ K and $T = 8000$ K, and for the wavelength range $261.3429 \text{ nm} \geq \lambda \geq 110.1760$ nm (the actual values can be found in the listing of subroutine `reaper`; for example, $F(140.1269, 8000) = 9.7522 \times 10^{-11}$). We obtain any value of $F(\lambda, T)$ by linear interpolation/extrapolation between 4000 K and 10,000 K; we use $F(\lambda, 4000)$ for $T < 4000$ K and $F(\lambda, 10000)$ for $T > 10,000$ K. We set $F(\lambda, T) = 0$ for values of λ outside the tabulated wavelength range.

While we use equation (1) in the line core and equation (13) in the line wings for $1 \leq U \leq 15$, for $U > 15$ only the line core eqution is used. At wavelengths near the $U = \infty$ Rydberg limit (911.75347... Å) there are contributions from

many overlapping Lyman lines. As many of these contributions are computed and summed as seem significant.
For $U >$ **NQLYM** linear combinations of the Lyman line and Lyman continuum absorption coefficients and source functions can be used to avoid a discontinuity at the Rydberg limit; when **NQLYM** $= 0$, however, such linear combinations are not used (and **NQLYM** $= 0$ is the default).

2. Practice

A simulation of the H Lyman-α line has been used in PANDORA as one of the contributors to the background (or "continuum") absorption for a long time. (In the 1960s Yvette Cuny's work, revealing the enormous wings of this line, had shown this to be an important opacity in the sun.) From the beginning H Ly-α absorption and scattering have been treated separately. Recently further incremental additions were made to the treatment of background H Lyman lines simulations.

This incremental development has resulted in five different contributors to the background absorption and emission calculations, as shown in the printout section BACKGROUND:

11 — H Ly alpha Abs.	= H(2/1) Line absorption
16 — H Ly alpha Sct.	= H(2/1) Line scattering
34 — H Ly 3-15 Abs.	= H(u,1), $3 \leq$ u ≤ 15, Lines absorption
36 — H Ly 3-15 Sct.	= H(u,1), $3 \leq$ u ≤ 15, Lines scattering
37 — H Ly>15 Abs.	= H(u,1), u > 15, Lines absorption

(See printout section BACKGROUND for more information regarding these background contributors.)

The following input parameters control these calculations: **NLY**; $\mathbf{LMXX}_j$, $\mathbf{LMDR}_j$, $1 \leq j \leq$ **LLY**; **LMXC**, **LMXP**, **LMDL2**; **LMDL3**; **LMZ**, **LMH**; and **NQ-LYM**, **IFALL**, **JHLSK**, **PMSK**. These are briefly discussed below; their values for the run are listed in printput section INPUT, under the subheading "Hydrogen Lyman alpha opacity."

If the additional input parameter **LYODS** > 0, then extensive printouts of computational details, for every **LYODS**'th depth, will be printed for every wavelength for which dumps of the background calculation details have been turned on (input table **DWAVE**; see Section 5, Note 65).

For the lines $(u, 1), 2 \leq u \leq 15$, PANDORA's simulation needs values of $XLIM$ (the boundary beween core and wing) and of $DR(x)$ (which describes the change from zero coherent scattering in the Doppler core to partial coherent scattering in

the wings).

$$XLIM = \begin{cases} \mathbf{LMXC} & \mathbf{LMXC} > 0 \\ \mathbf{LMXX}_1 & \text{otherwise} \end{cases} .$$

$DR(x)$ is computed by the same procedure as that used for calculating PRD terms in PANDORA's detailed line source function calculations. (In many Hydrogen runs the $(2,1)$-line and the $(3,1)$-line are computed with PRD.) This calculation of $DR(x)$ is described in subsections (3.) and (4.) of Section 15. The input parameters **LMXC**, **LMXP**, **LMDL2**, and **LMDL3**, and the input tables $\mathbf{LMXX}_j$, $\mathbf{LMDR}_j$, $1 \le j \le \mathbf{LLY}$, are used for this. (Note that $\mathbf{LMXC} = 0$ is not allowed.)

When "H Ly 3-15" (the "higher Lyman lines") are simulated, the upper limit is the value of **NLY** (default = 15). "H Ly>15" (the "highest Lyman lines") are done only when $\mathbf{NLY} = 15$; in that case, as many of the converging lines are computed as "make a difference" to the total absorption (or emission) resulting from many overlapping line wings (this calculation uses the built-in upper limit 500).

Values of the contributions to the background absorption or emission due to the cores and wings of the Lyman-α and the higher Lyman lines are computed only at wavelengths less than **LMZ** Å(default = 1682); values of the highest Lyman lines are computed only at wavelengths less than **LMH** Å(default = 950). The lower wavelength limit for all these simulations is the head of the Lyman continuum (the Rydberg wavelength, ≈ 911 Å).

The Lyman-α line simulation can use N. F. Allard's experimental values of $F(\lambda, T)$, as mentioned earlier. These data are used only when $\mathbf{IFALL} = 1$ (the default); otherwise $F(\lambda, T) = 0$ is used.

Stark broadening can be included in the simulations, as mentioned earlier. This is done only when $\mathbf{JHLSK} = 1$ (the default). **PMSK** is a parameter for computing Stark damping.

NQLYM controls the provision for avoiding absorption and emission discontinuities at the Lyman continuum edge.

(Section 21 – last revised: 2004 Nov 09)

Section 99: **Tutorial — How to Run PANDORA**

***

This section describes the input files and output files for four PANDORA demonstration runs. I hope that first-time users will find this helpful. By way of background: when we first began work on PANDORA, we envisioned a 'Dial-an-Atom' program; thus PANDORA's original *raison d'être* was the coupled line source function calculation, and the statistical equilibrium calculations required for them, with arbitrary model ions. Over the years the program has grown to do many more and different things, but PANDORA's primary purpose remains the calculation of line source functions and emergent line profiles. **Before reading this section**: be sure you have become familiar with the main body of this handbook, what kind of information it contains, and how it is organized.

Any PANDORA run requires input from four 'logical data Groups': 1) atmosphere model data; 2) atom (ion) model data; 3) levels- and transition-related restart data (*i.e.,* partially-converged solutions) from the preceding run (which may be omitted for runs starting from scratch); and 4) run-specific numeric and control data. Items from any of these 'groups' may/will occur in each of the four major structural parts of PANDORA's input: Parts B, D, F and H. Also, all runs require a run-specific **HEADING** line as the first line of the input file. (PANDORA runs that use PRD for one or more transitions may also require JNU restart values.)

A basic minimum of Group-1 data and Group-2 data normally *must* be supplied, since there are no appropriate default values for them. Group-3 data normally are not supplied for runs beginning from scratch (*i.e.,* the defaults are used); however, sometimes it makes sense to supply output from a related run as input for a

new run. Restart runs normally use Group-3 data that were written in an output file (a 'restart' file) by the preceding run. Group-4 data need not be supplied (especially for runs beginning from scratch) since the automatic defaults should be applicable to a variety of situations. As a calculation progresses through a series of restarts, it should become clear what switch settings, option settings, alternative numerical methods, and numerical control parameter values are most appropriate for any particular case.

There are six Types of PANDORA runs: 1) population-update runs with Hydrogen; 2) population-update runs with ions other than Hydrogen; 3) regular runs; 4) no-ion runs; 5) continuum-only runs; and 6) input-only runs.
The distinction between population-update and regular runs arises from the following. PANDORA computes both 'line' absorption and 'continuum' (more properly: 'background') absorption. Many 'absorbers' can be included in the total computed 'continuum' opacity, including the bound-free absorption of H, He-I, He-II, C-I, Si-I, Al-I, Mg-I, Fe-I, Na-I, Ca-I, O-I, and S-I. The calculations of the contributions of these absorbers require values of number densities and departure coefficients as functions of depth; computed non-LTE values will be used *if they are provided*. (If none are provided, then LTE default values of number densities will be computed, and/or default values of departure coefficients will be computed from whatever values of number density are available.) Consider a run with, say, Si-I. At the end of every overall iteration, new values of the number densities and departure coefficients of the 'ion-of-the-run' (in this case, Si-I) are computed. These values *can* be used when the 'continuum' opacity is recomputed at the start of the next iteration (*i.e.,* PANDORA can be instructed that new values of number densities and departure coefficients for Si-I are available, and that therefore Si-I's contribution to the opacity must be recomputed). For this purpose, the new data must be copied from their 'ion-of-the-run' slots into the appropriate 'population-ion-data' slots (*i.e.,* into the 'Si-I-population-data' slots). PANDORA will do this 'updating' if the **POPUP** switch is set. (If the population-ion-data are not updated at the end of each overall iteration, then they will retain their initial values.) (These population ion data can be printed by turning on the appropriate population-ion-data print option – in this case, SILPRNT.) Moreover, when the **POPUP** switch is set, then the latest recomputed population-ion-data will be written in one of the restart files, for later use. Thus, any PANDORA run for one of the 12 ions listed above *may* be (but *need not* be) a population-update run. A run with a valid **POPUP** statement among

the input is a 'population-update' run; runs without the **POPUP** switch set are 'regular' runs. (In Type-4 and Type-5 runs the **POPUP** switch is not used.)

(The input table **RUNTOPOP** is important for population update runs. The parameters describing the built-in population-ion-models are printed as part of the population ion data for a particular population-update ion – *e.g.* with SILPRNT on. Note the input parameters **POPION**, **POPXLM**, and **POPRCP**, provided for emergency use.)

Hydrogen runs are special because PANDORA does certain things only when Hydrogen is the ion-of-the-run. These include: recomputation of **Z**, of **NH**, and of **NE**. Such recomputed tables will be written in restart files, and normally should be used in subsequent runs. (Population-update runs also recompute **NE** and write it out – however, we generally ignore such **NE** values, preferring to rely on those produced by Hydrogen runs.)

Type-5, continuum-only, runs are about as far removed from PANDORA's basic purpose as one can imagine. Only 'continuum' source functions, and emergent continuum emission (depending on specific option settings), are computed. This is done at specific wavelengths only, as controlled by the switch **JSTCN**.

Type-4, no-ion, runs resemble continuum-only runs in that no line transfer is computed. In any run with the option DOION off, all those things, but only those things, that specifically concern an ion-of-the-run are omitted. Thus a no-ion run does more things (such as, hydrostatic equilibrium calculation, Dust temperature recalculation) than a continuum-only run.

Type-6, input-only, runs are useful for checking whether the input data being supplied for a run are what they should be. An input-only run only reads and massages the raw input, and does some other input-related initializations, and then stops – *i.e.,* its output file (provided it ran to completion) exhibits the **Phase 0** output (see Section 11), and the input JNU values (if there were any). After this output has been inspected and found satisfactory, the statement
"DO (JSTIN) " can be removed from the input, and the run resubmitted as a normal run.

Tutorial Runs

DEMO1 is a type-1 run from scratch, using a single input file; DEMO2 is identical to DEMO1 except for using multiple input files; DEMO3 is a restart, with changes, of DEMO2; and DEMO4 is a type-3 run from scratch.

In this section I refer to the various files by the file "extension codes" used with `schema` (see Section 7). The complete file names of these demonstration runs are constructed with these extensions; thus: `demo1.dat`, `demo4.jnr`, etc.

(*Please note:* PANDORA's input provisions are very flexible, and users are free to adopt a variety of conventions for organizing input data. I will describe what I have found convenient; feel free to establish different procedures.)

DEMO1

This run uses a single input file, `.dat`. This file first contains the **HEADING** line (Part A); then Group-1 data, Group-2 data, and Group-4 data in Part B (before the first **GO**); then more Group-1 data, Group-2 data, and Group-4 data in Part D (before the second **GO**); Part F and Part H are empty (*i.e.,* defaults will be used).

Group-1, atmosphere model, data comprise the statements: **N**, **NVH**, **R1N**, **CGR**, **Z**, **TE**, **NH**, **NE**, and **BDHM**. The underlined ones constitute the basic minimum that *must* be provided; if any of these are missing, the run will fail. (However, as a special case, when **ZMASS**, **TE**, and **NE** are provided then **Z** and **NH** need not be.) (Note: I have to set **NVH** = 0 because I want to have **V** = 0.)

Group-2, atom model, data comprise the statements: **NL**, **NTE**, **NT**, **INPAIR**, **NAME**, **ELSYM**, **IONSTAGE**, **MASS**, **PART**, **ABD**, **PW**, **P**, **CP**, **TER**, **CI 1**, **CI 2**, **CI 3**, **CE 2 1**, **CE 3 1**, **A 3 2**, **CE 3 2**, **CRD 3 2**, **CVW 3 2**, **CSK 3 2**, and **CRS 3 2**. Again, the underlined ones represent the basic minimum that *must* be provided, or the run will fail (*Note:* see Section 19.) These model atom data constitute a basic three-level Hydrogen atom, with the (2,1) and (3,1) lines in detailed balance. A value of **PW** is provided because a **CSK** statement appears. If the temperature-dependence of **CI** and **CE** were not known, then **NTE** and **TER** would not appear, and only single, constant values of **CI** and **CE** would have to be provided. (But note that while the foregoing is true generally, there is much more to it for Hydrogen, which is a special case—see Section 19.) The **PART** statement is not really needed (since 0 is the default); I like to use it to remind me that depth-dependent partition functions will be used (the default state of PARTVAR is on).

Group-4 data comprise: **DO**, **OMIT**, **IOMX**, **POPUP**, **RUNTOPOP** and **TRN**. PANDORA provides defaults for all of them – but this run wants the val-

ues appearing in `.dat`. The **TRN** statements appear because the option USETRIN is on. The **POPUP** switch is on, for the purpose described earlier. **RUNTOPOP** appears because values other than the defaults are required in this case.

To execute this run, I submit the run-specific script `demo1`, which uses the general script `schema`. The main purpose of these scripts is to connect actual files to the files that Fortran I/O expects by default.

Between them, `pandora` and `schema` send a slew of messages to standard output (the screen; these messages can be redirected to a "log" file in the usual manner—it is useful to do that). These messages consist of 'computation progress reports,' relevant directory listings, and other information that is useful for the record. The last message that comes from `pandora` is "`PANDORA done`"; this is the *only* reliable indication that a run completed properly.

The main output file ('printout' file) from PANDORA is the file `.aaa`; here, `demo1.aaa`. A few of the printout sections in this output file always appear; the remaining printouts are controlled by option settings, as described in Section 11.

If option LSFPRNT = off in addition to $\mathbf{LSFPRINT}^{3,2} = 0$, then the printout headed "LINE (3/2)" would not have appeared, leaving only the subsequent "Plot of logs of ST ..." as a record of the line source function calculation. In a converged solution the values of "S(n)" and "S" would be more nearly equal.

The printed values of "Consistency CHECKs," at the end of the printout "RHO AND RBD," look pretty good. If these tables do not have almost all values close to 1, then the calculation has not converged and needs to be iterated further.

The printout "LEVEL 1 TO K" appears because the option LYMAN is on and **KOLEV** = 1. The fact that the printed values of "Old/New" for RK-1 (on the page just before "NE") are rather far from unity is an indication that this calculation has not converged.

While the sections "WAVE SUMM 0" and "WAVE SUMM 1" can be turned off with option WAVEPRNT, I do not recommend doing that.

The various "Iterative Ratio" plots show significant changes from iteration to iteration, another strong indication that the calculation has not yet converged. NE has settled down in the outer half of the atmosphere.

"Execution Data" always appears (the amount of printout is controlled by option IRUNT). Before signing off, the program version identifies itself.

The remaining files produced by this run are `.msc`, `.pop` and `.rst`; their contents are described in Section 8. Most of these data are needed in order to restart this

run for additional iterations – DEMO3 is an example of such a restart.

DEMO2

This run uses the same input parameters as DEMO1, and thus produces the same output files — what is different is that the input, instead of being all contained in `.dat`, is now distributed over four files: `.mod`, `.atm`, `.res`, and `.dat`. (These four files correspond to the four 'logical data Groups' described earlier.)

I do this because I find this a convenient way to organize my data. My conventions are: `.atm` contains the data specifying the physical parameters of an atom or ion model; `.mod` contains the data specifying the physical parameters of a model atmosphere; `.res` contains the same data as the output file `.rst`, *i.e.,* the restart data for the line source function calculations, and the 'Lyman' calculation (if any); and `.dat` contains the heading and the various run-specific processing and numerological control parameters, *and the* **GO** *statements* that define the structure of the input.

PANDORA *always* begins reading from `.dat`; thereafter, **USE** statements tell it which file to read from next.

Input reading begins at the **HEADING** in `demo2.dat`. '`USE ( MODEL )` ' then switches reading to `.mod` (*i.e.,* `demo2.mod` – recall that `demo2` and `schema` set up this connection), and reading of Part B data then continues there until '`USE ( INPUT )` ' switches reading back to `.dat`. '`USE ( ATOM )` ' then immediately switches reading to `.atm` (*i.e.,* `atom2.atm`), and reading of Part B data then continues there until '`USE ( INPUT )` ' switches reading back to `.dat`. Reading of Part B data from `.dat` then continues until the first **GO**, which terminates Part B. Then reading is again switched to `.mod` and `.atm` for Part D data, and then to `.res` (*i.e.,* `demo2.res`) which, you will note, is *empty.* Thereupon the last of the Part D data are read from `.dat`, until the second **GO**, which terminates Part D. As with DEMO1, Part F is empty; and so is Part H, even though reading of Part H is switched to `.mod` (the reason why I do this may become clear with DEMO3).

When PANDORA first reads from a given file, it starts at the beginning of the file. When it reads from a partially-read file again, it resumes right after the last statement previously read.

The `.mod` files, in general, are convenient when you wish to calculate solutions for various ions in the same atmosphere – all those runs can be set up to use the same `.mod` file. The `.atm` files, in general, are convenient when you wish to cal-

culate solutions for the same ion in different atmospheres – all those runs can be set up to use the same `.atm` file. Over the years we have accumulated many `.atm` files for a variety of atom and ion models (*e.g.* there are many different Hydrogen models, using different numbers of levels and transitions; we also have various models of atoms and ions important in the Sun; plus some odds and ends). All these are available for general use.

DEMO3

This run shows how I go about setting up a restart of DEMO2.
DEMO3 needs the files: `.dat`, `.mod`, `.atm`, and `.res`. (Normally, the files for a restart of DEMO2 would have 'DEMO2-names' – these would be edited versions of the previous DEMO2 input files. However, for tutorial purposes, here I have given them new 'DEMO3-names'.) I obtained the DEMO3 input files from the input *and* output files of DEMO2 as follows:
`.res` is simply a copy of DEMO2's *output* file `.rst`. (If I were restarting DEMO2 'normally', without changing names from DEMO2 to DEMO3, I would: first delete `demo2.res`, and then change the name of `demo2.rst` to `demo2.res`.)
`.mod` is an edited copy of DEMO2's `.mod`, with the following changes:
• old values of **NE** were removed, and replaced by those in `demo2.pop`;
• values of **NP**, **HN** 1 ... **HN** 15 and **BDH** 1 ... **BDH** 15, from `demo2.pop`, were added after the second '`USE ( INPUT )` ' to Part H of `.mod`, where they will be read when the third occurrence of '`USE ( MODEL )` ' in `.dat` switches reading back to this `.mod` file. To alert PANDORA to the existence of these 'Hydrogen-population-data', I had to add '`NLH ( 15 )` ' near the beginning, in Part B of `.mod`. (If DEMO2 had calculated FNRMLA,FNRMLB, then I would have used the updated values of these tables, found in `demo2.msc`, to update any previous values in `demo2.mod`.)
I also introduced some further changes into Part D of this atmospheric model (*not* for restart purposes, but because I wanted to change the calculation):
• a set of values of **V** is added;
• the molecular Hydrogen abundance calculation is turned off (**NHTSW**);
• the He-II-lines and X-ray absorptions are turned off (**NABS**).
Atomic model data normally do not need to be changed for a *restart* run, and so `demo2.atm` could (and normally would) have been used for this run. However, I wanted a more elaborate atomic model for DEMO3, which I obtained by copying

`demo2.atm` and adding 'rates integrations' data: the **MR**, **WRAT** and **RRCP** statements. (Note: none for level 1 because the 'Lyman' calculation is done for level 1; starting values for the the level-1 rates **RL** 1 and **RK** 1 are in `.res`, having been computed by DEMO2.)

Finally, `.dat` for DEMO3 is a modified version of `demo2.dat`. Only one of these modifications is strictly for *restart* purposes: the **HEADING** line. The other modifications change the details of the calculation itself, and the contents of the 'printout' file:

- a value of **LF** that differs from the default;
- different option settings (note that the options PHASE2 and USETRIN now revert to their default settings, which are 'on' and 'off', respectively);
- the option IRUNT is changed to the 'prolix' setting;
- a value of $\mathbf{YLINE}^{3,2}$ that differs from the default;
- the emergent profile calculation for the (3,2) line is turned on (**PROF**);
- sets of values of **TRN** are omitted, since they are no longer needed;
- and the other parameter changes that you see there.

DEMO3 produces the same output files as DEMO2, but the contents differ. In `.aaa`, you will note the following (among others):

- "ATMOSPHERE" has different values of 'Electron density'; 'Broadening velocity' appears;
- "ND, NK, + BD" now has nonzero values (from `.res`);
- "ATOM" has different 'Line source function method' and 'Show computed line profile'; it no longer has 'Radiation Temperature';
- the list of contributors in "BACKGROUND" is different;
- "INPUT" has data for "Rates Integrations"; non-zero input values of **RKWT** 1, **EP1**, and **EP2** appear (from `.res`); "He II Lines Opacity data" is gone; data for "Spectrum Calculations" appears;
- "CONSTANTS" and "TABLES" are gone (why?);
- "HYDROGEN" population data now have input values, and no longer their approximate (*i.e.,* LTE) default values;
- "RATES" (through "RIJ") appears (option RATEPRNT), "Details of Recombination Calculation" is gone (why?);
- "Results of TAU Calculation, ..." appears (option TAUPRNT);
- "NE" and the printed tables in "POPULATIONS" are gone (option POPPRNT);
- "Old/New" for RK-1 are closer to unity, overall;

• "WAVE SUMM 0" shows that DEMO3 computed more continuum solutions than did DEMO2 (why?);
• "Iterative behavior ..." printouts are gone (why?);
• "Background Intensity" (for **LF** values of **MUF**) appears (why?, and why does "Background Flux" not appear?);
• "Profile of the 3/2 Line" (for **L**=**LF** values of **MU**) appears;
• "Scratch I/O ..." appears (option IRUNT);
• "Execution Data", and program version description, give more details (option IRUNT).

DEMO3's output files `.msc` and `.pop` contain the same amounts of data as those of DEMO2; `.rst` has a bit more (because $\mathbf{RHOWT}^{3,2}$ now has some non-zero values).

DEMO3 could now be restarted further, just as before. If this were the kind of Hydrogen run that produces new values of **Z** (say, because values of **TAUKIN** are specified), or of **NH** (say, because of option HSE), or of **BDHM** (option HMS), then these new sets would also have to be edited into `.mod`, to replace the old sets.

DEMO4

This is an Mg-II run, 'from scratch' like DEMO1, except that it is a 'regular' type of run and it is a PRD run.

The `.atm` file for this run contains a simple Mg-II model with two levels and one radiative transition. The `.atm` file does *not* contain the specifications of the PRD parameters, since this ion model does not *require* the PRD treatment. Instead, I consider the PRD parameters to be run-specific, and provide them in `.dat`. Since **JNUNC** is mentioned neither in `.mod` nor in `.dat`, it retains its default value 0, and a `.jnu` input file is not required.

(By the way, regarding $\mathbf{GMMA}^{2,1} = -0.999$: this value might put too severe a strain on a 'from scratch' calculation. One might instead begin with, say, $\mathbf{GMMA}^{2,1} = -0.8$ and then, through a series of restarts, gradually work up to the 'desired' value -0.999.)

The `.mod` file contains 8 levels worth of 'population-ion-data' for H, He-I, He-II, C-I, and Si-I. Values of departure coefficients are specified for levels 1 - 5 of H only; default values (see the 'printout') will be set up for everything else. `.mod` also contains five auxiliary depth tables and illustrates their use; note that `.mod`

does not contain **Z**, the depth table of the run (*cf.* Section 13). `.mod` also contains some **DO** statements affecting the 'printout' only; one can debate whether these belong here, or in `.dat`.

As with DEMO2, `.res` is empty (why?).

The `.dat` file is relatively simple; note that it contains the **N** and **Z** statements, these being run-specific in this case. Of course, there is no **POPUP** statement (that makes this a 'regular' run). The **YLINE** statement is superfluous (see next paragraph), but does no harm. (By the way, a `.dat` file for most runs—other than H runs—might contain a table of **RABD** or **RABDL** values [see Section 17]; a `.dat` file for a He-II run with diffusion might contain tables of **PALBET** and **PBETAL**.)

In the 'printout' file `.aaa`, note that "ATOM" now has 'Partial Redistribution' and several parameters for P.R.D.; moreover, '`Line source function method`' is '`(not used)`' because the '`Background source function method`' specification applies to both calculations. Output from rates integrations is short (RATEPRNT and RATESUMM are off), consisting of graphs only (RATEGRAF is on). The "LINE (2,1)" printouts here have only very abbreviated PRD calculation results, because PRDPRNT and PRDCOPR are both off, and only JNUPRNT is on. Notice that the 'normal' line source function calculation output states (between the lines of dashes) that this is a '`Solution with partial redistribution`'. (Note option PRDMETH; often it makes sense to use PRDMETH off initially, until the solution is nearly converged, and then use PRDMETH on.) No "Consistency Checks" are computed for a 2-level ion model.

Since **LF** is greater than 1, a line flux profile was also computed from the calculated intensity profiles (however, with only two **MUF** values, this is not much of a calculation). Since this line is computed with PRD ($\mathbf{SCH}^{2,1} = 1$), a whole profile, rather than a half profile, was computed. Moreover, a PRD calculation computes the background continuum for every point in the line, and that is why the "Line-Free" continuum was also computed for every point in the line.

The other output files produced by this run are `.jnr`, `.msc`, and `.rst`; of course there is no `.pop` output file (why?).

Restarting this run is simple. Delete `.res`, and change the name of `.rst` to `.res`; change the name of `.jnr` to `.jnu` (first deleting the previous `.jnu`, if any). Update the **HEADING** in `.dat`, and make any other desired changes. Make sure that the value of **JNUNC** > 0 (Part D of the input, in `.dat`).

Again, this run only *uses*, but does not *affect*, the atmospheric model data. (At

least, not directly. In principle, values of **RABD** for a Mg-I run could be affected by these Mg-II results, and that would change the 'Mg-I-population-data' which are part of the atmospheric model — but DEMO4 treats Mg-I in LTE. For **RABD** see Section 17.)

(Section 99 – last revised: 2007 Feb 05)