

# ADAS406: Transient ionisation - process metastable populations and emission functions

The program calculates the fractional abundances of resolved metastable or unresolved stage populations of the ions of an element in transient ionisation or recombination in a thermal plasma of fixed electron temperature and electron density. It also evaluates the transient radiant energy excess (deficit) and line emission photon excess (deficit) generalised contribution functions.

## Background theory:

### The unresolved case:

Consider the evolution of populations of ions of an element in a plasma. For an element  $X$  of nuclear charge  $z_0$ , the populations of the ionisation stages are denoted by

$$N^{(z)} : z = 0, \dots, z_0 \quad 5.6.1$$

The time dependence of the ionisation stage populations is given by the equations

$$\begin{aligned} \frac{d}{dt} N^{(z)} = & N_e S_{CD}^{(z-1 \rightarrow z)} N^{(z-1)} \\ & - (N_e S_{CD}^{(z \rightarrow z+1)} + N_e \alpha_{CD}^{(z \rightarrow z-1)} + N_H C_{CD, \rho \rightarrow \rho'}^{(z \rightarrow z-1)}) N^{(z)} \\ & + N_e \alpha_{CD}^{(z+1 \rightarrow z)} N^{(z+1)} + N_H C_{CD}^{(z+1 \rightarrow z)} N^{(z+1)} \end{aligned} \quad 5.6.2$$

This is called an *unresolved* or stage to stage picture. The coefficients are the (ordinary) collisional radiative coefficients. The equations may be rewritten in matrix form as

$$\frac{d}{dt} \begin{bmatrix} N^{(0)} \\ N^{(1)} \\ N^{(2)} \\ \vdots \end{bmatrix} = N_e \begin{bmatrix} -S_{CD}^{(0 \rightarrow 1)} & \alpha_{CD}^{(1 \rightarrow 0)} + (N_H / N_e) C_{CD}^{(1 \rightarrow 0)} & 0 & 0 \\ S_{CD}^{(0 \rightarrow 1)} & -(S_{CD}^{(1 \rightarrow 2)} + \alpha_{CD}^{(1 \rightarrow 0)} + (N_H / N_e) C_{CD}^{(1 \rightarrow 0)}) & \alpha_{CD}^{(1 \rightarrow 0)} & 0 \\ 0 & S_{CD}^{(1 \rightarrow 2)} & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot \end{bmatrix} \begin{bmatrix} N^{(0)} \\ N^{(1)} \\ N^{(2)} \\ \vdots \end{bmatrix} \quad 5.6.3$$

The solution is such that  $N_{tot}$ , the number density of ions of element  $X$  in any ionisation stage is constant independent of time.

$$N_{tot} = \sum_{z=0}^{z_0} N^{(z)} \quad 5.6.4$$

The fractional abundances  $N^{(z)}(t) / N_{tot}$  are sought at time  $t$  after evolving from an initial distribution  $N^{(z)}(t=0) / N_{tot}$  in a plasma of fixed electron temperature and electron density. The code obtains the solution for a range of fixed plasma electron temperature and electron density pairs. For each pair, the matrix of coefficients in equations 5.6.3 is constant., An eigenvalue approach is therefore used to solve the equations. It is convenient to adopt a scaled time  $t' = N_e t$ . The solution may be written as

$$\begin{bmatrix} \cdot \\ N^{(z)}(t') \\ \cdot \end{bmatrix} = \begin{bmatrix} \cdot \\ N^{(z)}(t' = \infty) \\ \cdot \end{bmatrix} + \sum_{i=1}^{z_0} a_i e^{-\lambda_i t'} \begin{bmatrix} \cdot \\ u_i^{(z)} \\ \cdot \end{bmatrix} \quad 5.6.5$$

where the zero eigenvalue and its eigenvector have been subsumed in the  $t' = \infty$  equilibrium state and the non-zero eigenvalues  $\lambda_i : i = 1, \dots, z_0$  have eigenvectors  $u_i$ . The expansion coefficients  $a_i$  are obtained by equating to the initial condition

$$\begin{bmatrix} \cdot \\ N^{(z)}(t' = 0) \\ \cdot \end{bmatrix} \quad 5.6.6$$

The total radiated energy per impurity atom from time 0 to time  $t'$  is

$$\begin{aligned} \mathcal{W}_{tot}(t') &= \left[ \sum_{z=0}^{z_0} P^{(z)} \int_{t'=0}^{t'} N^{(z)}(t') dt' \right] / N_{tot} \\ &= \sum_{z=0}^{z_0} [P_{LT}^{(z)} + P_{RB}^{(z)} + (N_H / N_e) P_{RC}^{(z)}] \\ &\quad [N^{(z)}(t'' = \infty) t' + \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z)} (1 - e^{-\lambda_i t'})] \end{aligned} \quad 5.6.7$$

A quantity of interest is the radiant energy excess or deficit up to time  $t'$  compared with the energy emitted in ionisation equilibrium over the time  $t'$ , and the limit of this as  $t' \rightarrow \infty$ . These are obtained from the second term in the final bracket of equation 5.6.7 namely

$$\begin{aligned} \mathcal{W}_{tot}^{excess}(t') &= \sum_{z=0}^{z_0} [P_{LT}^{(z)} + P_{RB}^{(z)} + (N_H / N_e) P_{RC}^{(z)}] \\ &\quad \left[ \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z)} (1 - e^{-\lambda_i t'}) \right] \end{aligned} \quad 5.6.8$$

and

$$\mathcal{W}_{tot}^{excess}(t' \rightarrow \infty) = \sum_{z=0}^{z_0} [P_{LT}^{(z)} + P_{RB}^{(z)} + (N_H / N_e) P_{RC}^{(z)}] \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z)} \quad 5.6.9$$

These quantities are to be compared with the *total equilibrium radiated power function*

$$\begin{aligned} P_{tot} &= \sum_{z=0}^{z_0} P^{(z)} (N^{(z)}(t' \rightarrow \infty) / N_{tot}) \\ &= \sum_{z=0}^{z_0} [P_{LT}^{(z)} + P_{RB}^{(z)} + (N_H / N_e) P_{RC}^{(z)}] (N^{(z)}(t' \rightarrow \infty) / N_{tot}) \end{aligned} \quad 5.6.10$$

Note the separate *radiated power coefficient* ( $P^{(z)}$ ) contributions arising from low level line power, recombination-bremsstrahlung-cascade power and charge exchange recombination power.

For photon emission in a particular spectrum line, in the time dependent case, a quantity of interest is the excess or deficit of photons emitted in the line up to the time  $t'$  compared with the number emitted in ionisation equilibrium over the time  $t'$ , and the limit of this as  $t' \rightarrow \infty$ .

$$\begin{aligned} \mathcal{G}_{i \rightarrow j}^{excess(z)}(t') &= [\mathcal{E}_{i \rightarrow j}^{exc} \{ \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z)} (1 - e^{-\lambda_i t'}) \}] \\ &+ \{ \mathcal{E}_{i \rightarrow j}^{rec} + (N_H / N_e) \mathcal{E}_{i \rightarrow j}^{CX} \} \{ \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z+1)} (1 - e^{-\lambda_i t'}) \} / N_{tot} \end{aligned} \quad 5.6.11.$$

$$\begin{aligned} \mathcal{G}_{i \rightarrow j}^{excess(z)}(t' \rightarrow \infty) &= [\mathcal{E}_{i \rightarrow j}^{exc} \{ \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z)} \}] \\ &+ \{ \mathcal{E}_{i \rightarrow j}^{rec} + (N_H / N_e) \mathcal{E}_{i \rightarrow j}^{CX} \} \{ \sum_{i=1}^{z_0} (a_i / \lambda_i) u_i^{(z+1)} \} / N_{tot} \end{aligned} \quad 5.6.12$$

These quantities are to be compared with the usual contribution functions to line emission known as  $G(T_e)$  functions

$$G_{i \rightarrow j}^{(z)} = [\mathcal{E}_{i \rightarrow j}^{exc} N^{(z)} + \mathcal{E}_{i \rightarrow j}^{rec} N^{(z+1)} + (N_H / N_e) \mathcal{E}_{i \rightarrow j}^{CX} N^{(z+1)}] / N_{tot} \quad 5.6.13$$

The  $\mathcal{E}_{i \rightarrow j}$  are called *photon emissivity coefficients* (c.f.  $\mathcal{P}\mathcal{E}\mathcal{C}$  coefficients in the metastable resolved case, equations 3.8.17-3.8.19 of ADAS208). They occur in independent parts  $\mathcal{E}_{i \rightarrow j}^{exc}$ ,  $\mathcal{E}_{i \rightarrow j}^{rec}$  and  $\mathcal{E}_{i \rightarrow j}^{CX}$ , distinguished by the driving process.

The code accesses standard isonuclear master file data of type ADF11 to obtain the coefficients of equations 5.6.3. Standard NAG computer algorithms are used for the matrix diagonalisation.

#### The resolved case:

Properly, although the populations of excited states may be neglected compared with those of metastable and ground states of ions, it is not correct to combine the ground and metastable populations into a single stage population in the time dependent equations. This is because ground and metastable populations may have comparable populations and evolve on similar timescales. The ground and metastable populations

$$N_\rho^{(z)} : z = 0, \dots, z_0 ; \rho = 1, \dots, M_z \quad 5.6.14$$

where  $M_z$  is the number of metastable states (including the ground state) of ionisation stage  $z$ , should be treated separately. The time dependence of the metastable populations is then given by the equations

$$\begin{aligned} \frac{d}{dt} N_\rho^{(z)} &= N_e \sum_{\rho'=1}^{M_{z-1}} S_{CD, \rho' \rightarrow \rho}^{(z-1 \rightarrow z)} N_{\rho'}^{(z-1)} \\ &- (N_e \sum_{\rho'=1}^{M_{z+1}} S_{CD, \rho \rightarrow \rho'}^{(z \rightarrow z+1)} + N_e \sum_{\rho'=1}^{M_{z-1}} \alpha_{CD, \rho \rightarrow \rho'}^{(z \rightarrow z-1)} + N_H \sum_{\rho'=1}^{M_{z-1}} C_{CD, \rho \rightarrow \rho'}^{(z \rightarrow z-1)}) \\ &+ N_e \sum_{\sigma=1}^M Q_{CD, \rho \rightarrow \sigma}^{(z \rightarrow z)} + N_e \sum_{\rho'=1}^{M_z} X_{CD, \rho \rightarrow \sigma}^{(z \rightarrow z)} N_\rho^{(z)} \\ &+ N_e \sum_{\rho''=1}^{M_{z+1}} \alpha_{CD, \rho'' \rightarrow \rho}^{(z+1 \rightarrow z)} N_{\rho''}^{(z+1)} + N_H \sum_{\rho''=1}^{M_{z+1}} C_{CD, \rho'' \rightarrow \rho}^{(z+1 \rightarrow z)} N_{\rho''}^{(z+1)} \\ &+ N_e \sum_{\sigma=1}^{M_z} Q_{CD, \sigma \rightarrow \rho}^{(z \rightarrow z)} N_\sigma^{(z)} + N_e \sum_{\sigma=1}^{M_z} X_{CD, \sigma \rightarrow \rho}^{(z \rightarrow z)} N_\sigma^{(z)} \end{aligned}$$

where there is such an equation for each  $Z$  and  $\rho$ . This is called a *resolved* or generalised picture. The coefficients are the generalised collisional radiative coefficients. The equations may be rewritten in matrix form as

$$N_e \frac{d}{dt} \begin{bmatrix} \mathbf{N}^{(0)} \\ \mathbf{N}^{(1)} \\ \mathbf{N}^{(2)} \\ \vdots \end{bmatrix} = \begin{bmatrix} -\mathbf{S}_{CD}^{(0)} & \mathbf{a}_{CD}^{(1 \rightarrow 0)} + (N_H / N_e) \mathbf{C}_{CD}^{(1 \rightarrow 0)} & 0 & 0 \\ \mathbf{S}_{CD}^{(0 \rightarrow 1)} & -(\mathbf{S}_{CD}^{(1)} + \mathbf{Q}_{CD}^{(1 \rightarrow 1)} + \mathbf{X}_{CD}^{(1 \rightarrow 1)} + \mathbf{a}_{CD}^{(1)} + (N_H / N_e) \mathbf{C}_{CD}^{1 \rightarrow 0}) & \mathbf{a}_{CD}^{(2 \rightarrow 1)} + (N_H / N_e) \mathbf{C}_{CD}^{(2 \rightarrow 1)} & 0 \\ 0 & \mathbf{S}_{CD}^{(1 \rightarrow 2)} & \cdot & \cdot \\ 0 & 0 & \cdot & \cdot \end{bmatrix} \begin{bmatrix} \mathbf{N}^{(0)} \\ \mathbf{N}^{(1)} \\ \mathbf{N}^{(2)} \\ \vdots \end{bmatrix} \quad (5.6.16)$$

which must be interpreted for the metastable resolved case. Each element of the matrix in eqns. 5.5.9 is now itself a matrix extending over the metastable sets of the ionisation stage involved. Thus

$$\mathbf{S}_{CD}^{(0 \rightarrow 1)} = \begin{bmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & S_{CD, \rho-1 \rightarrow \sigma-1}^{(0 \rightarrow 1)} & S_{CD, \rho-1 \rightarrow \sigma}^{(0 \rightarrow 1)} & \cdot \\ \cdot & S_{CD, \rho \rightarrow \sigma-1}^{(0 \rightarrow 1)} & S_{CD, \rho \rightarrow \sigma}^{(0 \rightarrow 1)} & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} \quad (5.6.17)$$

and

$$\mathbf{S}_{CD}^{(0)} = \begin{bmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & \sum_{\sigma=1}^{M_1} S_{CD, \rho-1 \rightarrow \sigma}^{(0 \rightarrow 1)} & 0 & \cdot \\ \cdot & 0 & \sum_{\sigma=1}^{M_1} S_{CD, \rho \rightarrow \sigma}^{(0 \rightarrow 1)} & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} \quad (5.6.18)$$

where the index  $\rho: 1, \dots, M_0$  spans the metastables of stage 0 and  $\sigma: 1, \dots, M_1$  spans the metastables of stage 1. Also

$$\mathbf{Q}_{CD}^{(1 \rightarrow 1)} = \begin{bmatrix} \cdot & \cdot & \cdot & \cdot \\ \cdot & - \sum_{\rho'=1; \rho' \neq \rho-1}^{M_1} Q_{CD, \rho' \rightarrow \sigma-1}^{(1 \rightarrow 1)} & Q_{CD, \rho-1 \rightarrow \sigma}^{(1 \rightarrow 1)} & \cdot \\ \cdot & Q_{CD, \rho \rightarrow \sigma-1}^{(1 \rightarrow 1)} & - \sum_{\rho'=1; \rho' \neq \rho}^{M_1} Q_{CD, \rho' \rightarrow \sigma}^{(1 \rightarrow 1)} & \cdot \\ \cdot & \cdot & \cdot & \cdot \end{bmatrix} \quad (5.6.19)$$

Similar definitions apply for the  $\mathbf{a}_{CD}^{(1 \rightarrow 0)}$ ,  $\mathbf{X}_{CD}^{(1 \rightarrow 1)}$  etc. Also the population vector is

$$\mathbf{N}^{(0)} = \begin{bmatrix} N_1^{(0)} \\ \cdot \\ \cdot \\ N_{M_0}^{(0)} \end{bmatrix} \quad (5.6.20)$$

The solution is such that  $N_{tot}$ , the number density of ions of element  $X$  in any ionisation stage is constant independent of time.

$$N_{tot} = \sum_{z=0}^{z_0} \sum_{\rho=1}^{M_z} N_{\rho}^{(z)}$$

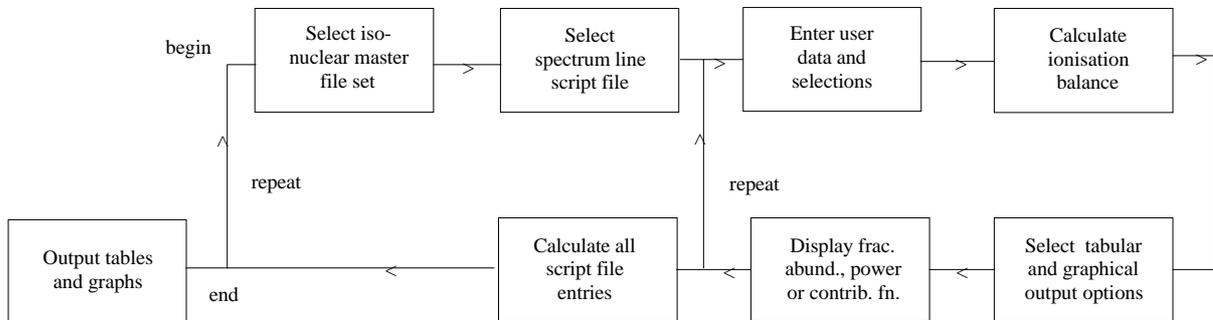
5.6.21

The metastable fractional abundances  $N_{\rho}^{(z)}(t) / N_{tot}$  are sought at time  $t$  after evolving from an initial distribution  $N_{\rho}^{(z)}(t=0) / N_{tot}$  in a plasma of fixed electron temperature and electron density. Solution proceeds in the same manner as for the unresolved case. Total radiant energy excesses  $\mathcal{N}_{tot}^{excess}$ , total radiant power loss functions  $P_{tot}$ , line photon excesses  $\mathcal{G}_{i \rightarrow j}^{excess(z)}(T_e)$  and contribution functions  $G_{i \rightarrow j}^{(z)}(T_e)$  are defined in analogous manner to the unresolved case. However, the sum over the metastables for each ionisation stage must be included.

## Program steps:

These are summarised in figure 5.6.

Figure 5.6



## Interactive parameter comments:

The program which makes use of data from archived ADAS datasets initiates an interactive dialogue with the user in three parts, namely, input data file selection, entry of user data and display/disposition of output.

The **file selection window** appears first as illustrated below

- Two types of data file are identified in the file selection, namely, the iso-nuclear master files required for the ionisation balance and power calculations and the script file. The top part of the file selection window is concerned with identifying the master file data required and the lower part with identifying the script file.
- ADF11 is the appropriate data format for use by the program ADAS406. Your personal data of this type should be held in a similar file structure to central ADAS, but with your identifier replacing the first *adas*. The central ADAS database has extensive data of this form and the collection is steadily being extended. It is also subject to periodic revision as the influences of improved fundamental data are computed.
- Click on the *Select* button at (a) to drop down a selection list of master file data classes. Activate the buttons at the data classes required for your analysis. It is obligatory to select the 'acd' and 'scd' electron impact effective recombination and ionisation data classes since otherwise an ionisation balance cannot proceed. However the other data classes selected are at the user's choice. This enables investigative studies of the importance of different contributions for example to radiated power.
- At JET Joint Undertaking, effective radiated power coefficients ('prb', 'plt' and 'prc') are often made available both as the whole emitted power and as the power which would pass through certain filters (such as Be/Si windows). The filter is specified either simply as an energy cut-off (eg. *ev2000*) or as filter specification (eg. *ft1235*). These codes appear as an extension in the relevant master file names.

Specify the filter choice at (b). **Note the present IDL-ADAS database contains very little filtered power data but it can be added if there is an interest amongst users.**

- The remainder of the file identification (c) follows the general pattern. Note that a default year must be specified. Often the complete set of data classes for a particular year and type are not available and the capability of filling in from a default (perhaps less accurate but more complete) year is allowed.

The screenshot shows the 'ADAS406 INPUT' dialog box. It is divided into two main sections. The top section is titled 'Enter details of the iso-nuclear master files to be analysed :-'. It contains several input fields and buttons:
 

- 'Select iso-nuclear master collisional-dielectronic classes' with a 'Select' button (pointed to by 'a').
- 'Radiated power filter (blank for none)' with an empty text box (pointed to by 'b').
- 'Member prefix (blank for none)' with an empty text box.
- 'Year of data' with a text box containing '93'.
- 'Select directory branch' with a text box containing 'User'.
- 'Default year (if required)' with a text box containing '93' (pointed to by 'c').
- 'Iso-electronic sequence symbol' with a text box containing 'c'.
- 'Type of master files' with a text box containing 'Partial'.
- 'Specify partial type code' with a text box containing 'Resolved'.
- A 'Display data set availability' button (pointed to by 'd').

 The bottom section is titled 'Input Line and Analysis Selection File :-'. It contains:
 

- 'Data root' with a text box containing '/disk2/adas/adas/scripts406/'.
- Buttons for 'Central data', 'User data', and a checkbox for 'Edit Path Name'.
- A text box containing 'test\_c'.
- 'Data File' section with a list containing '.. NULL' and 'test\_c' (pointed to by 'e').
- Buttons for 'Browse Selection FileComments', 'Cancel', and 'Done' (pointed to by 'f').

- In general the two digit year number is used to provide the main groupings of data. Thus '89' is the standard, unresolved, JET base line data of low precision but fairly complete. '93' is metastable resolved data, but available only for light elements of primary importance to fusion. Some flexibility for subdivision within a year is provided by allowing a two character 'member prefix' (eg. 'pj') which may be present in the final part of a file name (eg. './.../acd93r/acd93r\_pj#c.dat').
- The distinctions between *standard* and *partial* master file types and *resolved* and *unresolved* types must be clarified. *Standard* data is stage to stage and has a specific layout. *Partial* data distinguishes metastables and has a different layout. Within the partial data layout it is possible simply to have each stage represented only by its ground state and therefore to be similar to standard data. However the layout is the partial one. We call such data *partial* but *unresolved*. The usual *partial* data with metastables present is called *resolved*. This distinction and added flexibility are helpful in iso-nuclear master file preparation and archiving.

8. Clicking the *Display data set availability* button at (d) causes display of a file availability summary window as illustrated below. It is important to use this facility since it shows which master files classes sought by the user were not available, where default data files were substituted etc.

Class selection and file availability :-									
Class	Year	Element	Member Power		Type	USER DATA		DEFAULT DATA (93)	
			Prefix	Filter		Selected	Availability	Used	Available
acd	93	c			Rpartial	YES	YES	no	YES
scd	93	c			Rpartial	YES	YES	no	YES
ccd	93	c			Rpartial	no	no	no	no
prb	93	c			Rpartial	YES	YES	no	YES
prc	93	c			Rpartial	no	no	no	no
qcd	93	c			Rpartial	YES	YES	no	YES
xcd	93	c			Rpartial	YES	YES	no	YES
plt	93	c			Rpartial	YES	YES	no	YES

All requested files available from user data sets.

OK

9. Script file selection is made at (e). The structure of script file is shown below. We have found it convenient to group script files in a personal ADAS database under a subdirectory classification */scripts405/*. Also, it is possible to bypass contribution function calculation and display by selecting the 'NULL' script. You may find it helpful to copy the 'NULL' script from the central ADAS database to your own space. Note that scripts apply to particular cases. Thus the references to emissivity coefficient data in a script applying to metastable resolved will not in general work for unresolved data, indeed will probably crash. We have not built much protection against faulty references into script files at the moment. More protection may be added if this proves a stumbling point for users. You may find it helpful to fetch the *test\_c* script from central ADAS for first trials.
10. Details of the species, number of (composite) lines and line ratios to be obtained are at the head of the file (SPECIES, NLINE, NRATIO). Note that you must follow the positional layout exactly. Emissivity coefficient data are obtained from 'pec' files of ADAS format ADF15. The number of such files to be searched in the ADAS database are specified at NFILE and the full Unix paths to the files themselves in following lines at PHOTON EMISSIVITY FILE NAMES. The subsequent table identifies the index number of the *pecs* in these files required to build the particular line emission function. The lines are indexed at ILINE, the number of component parts of each line is at NCOMP, the charge of the ion to which the component attaches is at IZION and the components simply indexed at ICOMP. The metastable of the ion to which the component is attached is specified by its ranked index number at IMET (the ground state is 1). INDPH gives the selection index of the component *pec* in the ADF15 file identified at IFILE from the list given earlier. Note the letter qualification on the INDPH index to distinguish electron collision driven *pecs* and charge exchange driven *pecs*. The composite lines may be ratioed as specified by IRATIO, an index number of the ratio; ILINE, the upper composite line of the ratio; JLINE, the lower composite line of the ratio. All other text is for information. Note that a 'c-----' line is used to separate comments which follow it. Each comment line begins with 'c' and we conventionally put in a 'c-----' terminator line for the comments section.



ADAS406 PROCESSING OPTIONS

Title for Run

Script file : /disk2/adas/adas/scripts406/test\_c

Browse Comments c)

Data file information :-

Selected master file element : C

Selected master classes : ACD, SCD, PRB, QCD, XCD, PLT

Enter isotope information :-

Enter element isotope mass number (amu) :

Enter hydrogen isotope mass number (amu) :

Select spectral line for analysis :-

Number of listed lines in script file : 2

LINE INDEX	RADIATING ION CHARGE	NUMBER OF COMPONENTS	TITLE AND WAVELENGTH
1	0	4	CI 1561
1	0	4	CI 1561
2	1	2	CII 904

Integration time (sec) :

Fractional Abundance At Start Time

INDEX	Metastable	Fraction
1	C + 0 (1)	1.000E+00
2	C + 0 (2)	0.000E+00
3	C + 0 (3)	0.000E+00
4	C + 0 (4)	0.000E+00
5	C + 1 (1)	0.000E+00
6	C + 1 (2)	0.000E+00

Edit Table h)

Enter Output Temperature/ Density data

Index	Temperatures		Densities	
	Electron	Hydrogen	Electron	Hydrogen
1	1.000E+00	1.000E+00	1.000E+12	1.000E+11
2	2.000E+00	2.000E+00	1.000E+12	2.000E+11
3	5.000E+00	5.000E+00	1.000E+12	5.000E+11
4	1.000E+01	1.000E+01	1.000E+12	1.000E+12

Temperature Units : eV      Density Units : cm-3

Edit Table

Default Temperature/Density values       Clear Table

Edit the processing options data and press Done to proceed

      f)

The **output options window** is shown below.

1. It follows the usual pattern except that there is a choice of graphs to display. Thus the fractional abundances, power functions and contribution functions are all of potential interest. Click on the appropriate button at (a). Generally, we find that on the first one or two occasions we wish to see the fractional abundances and energy excesses but then have a more sustained interest in the photon excess/deficit contribution function shapes and their location in temperature. All the graphs are provided as a function of electron temperature.
2. The window presented at (b) depends on the graph choice above. The default scaling may be over-riden and explicit values for the graph limits entered.
3. Graphical output is enabled in the window at (c) together with hard copy device and output file name. This follows the pattern of other ADAS programs. Likewise text output selection at (d) is standard.
4. The '*Gcf Passing File*' is the name used for the output data-set of calculated deficit/excess contribution functions. It is organised according to an ADAS data format ADF16. The output file name is specified at (e). Apart from the units, the contribution functions from ADAS405 and ADAS406 have the same organisation. The expected practice is that ADAS405 will be used either recursively or in distinct runs to examine contribution functions. Thus an *Append* button has been provided to allow an existing *Gcf* file to be extended. The *Replace* and *Default file name* buttons have their usual meanings. **NB. The ADF16 structure is somewhat unsatisfactory and is being redefined as this time.**

ADAS406 OUTPUT OPTIONS

Script file : /disk2/adas/adas/scripts406/test\_c

Browse Comments

---

Graphical Output

Graph Title

Fractional abundance plot  
 Energy excess plot  
 Contribution function plot  
 Total energy excess plot

Fractional abundance plot :-

Explicit Scaling

X-min :  X-max :   
Y-min :  Y-max :

---

Enable Hard Copy     Replace   

File name :    

---

Text Output     Replace   

File name :    

---

Goft Passing File     Append     Replace   

File name :    

### Illustration:

The output from the program is illustrated for carbon in the resolved case. Figure 5.6a shows the metastable fractional abundances after  $10^{-5}$  s for the first seven metastables as a function of temperature at a fixed density. The balance is at the electron density  $10^{+13} \text{ cm}^{-3}$ . Figure 5.6b shows the radiated energy excesses (+) or deficits (-) for these metastables up to  $10^{-5}$ s for carbon. Seven curves only are displayed on each graph

Although display of the final two types of graph is possible, they **cannot be printed** successfully at this time.

Figure 5.6a

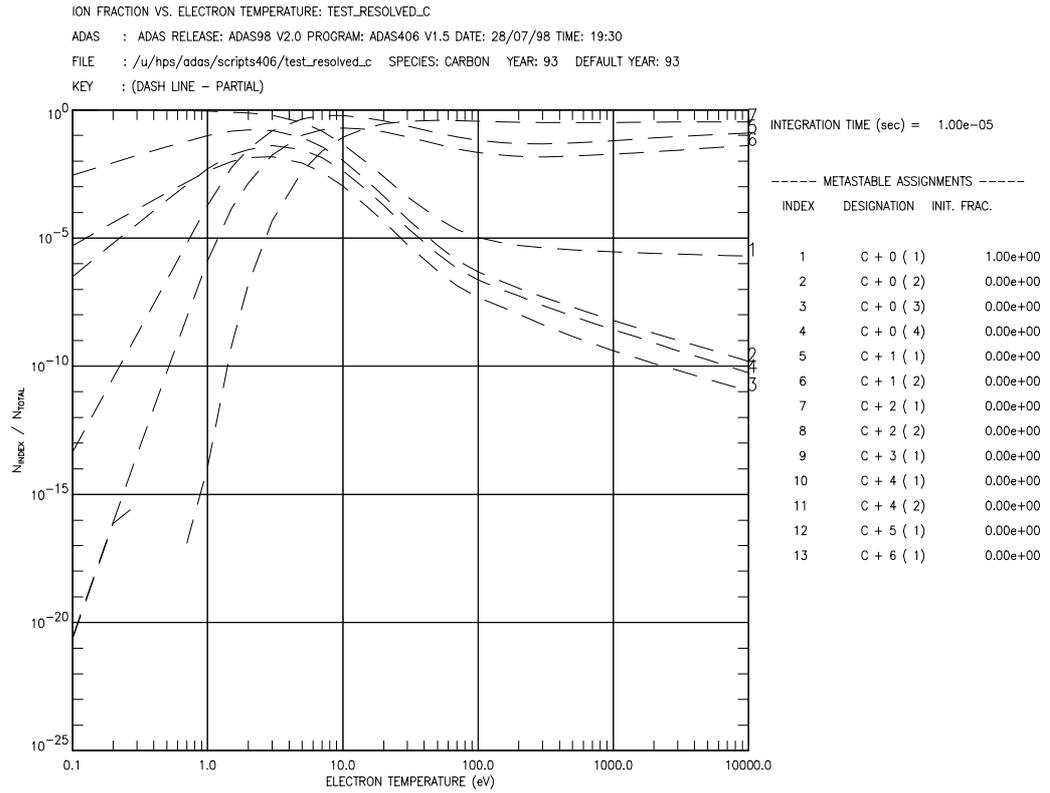


Figure 5.6b

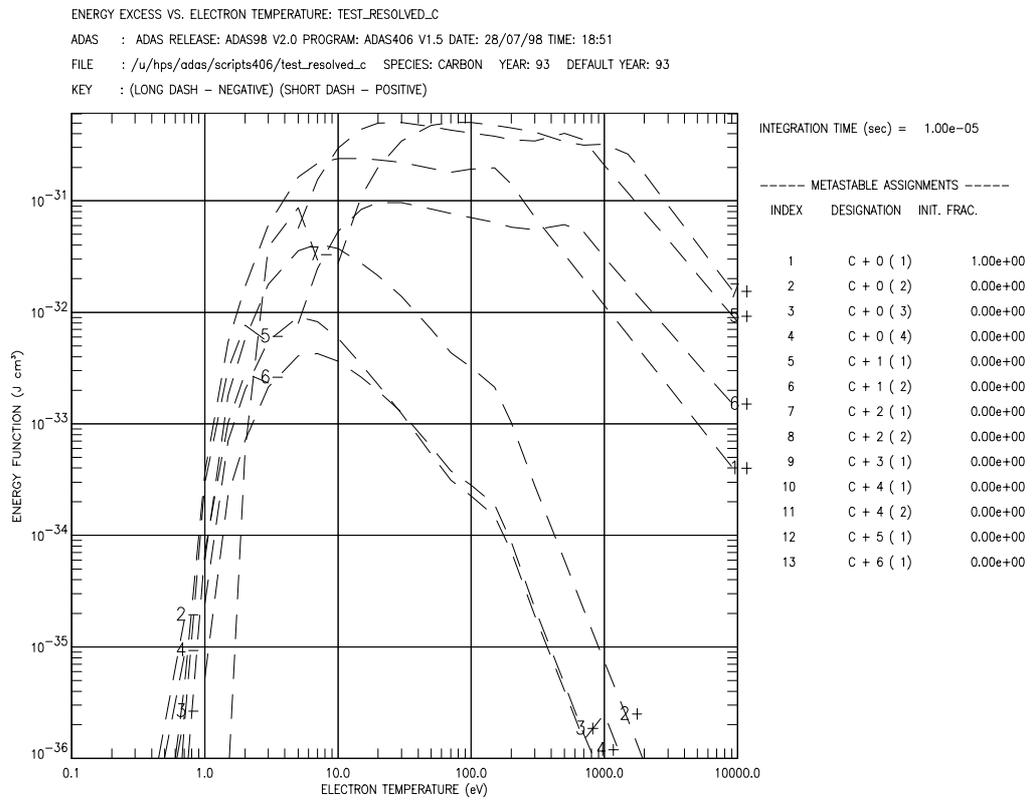


Table 5.6a shows the tabular output from the carbon time dependent ionisation. The option to calculate a ratio of contribution functions for two lines is tabulated but is not available graphically. FILTER applies only to radiated energies. Iso-electronic master files which include the effect of an energy filter are of two qualities, namely, precisely estimated for a window of specified thicknesses of beryllium and quartz (FT) and secondly a simple sharp energy cut-off (EV). FILTER gives the master file name sub-field of the form EV<nnnn> or FT<ll><mm> by which they identified.

Table 5.6a

```

ADAS RELEASE: ADAS98 V2.0 PROGRAM: ADAS406 V1.5 DATE: 28/07/98 TIME: 19:30

***** TABULAR OUTPUT FROM TRANSIENT IONISATION AND EMISSION PROGRAM: ADAS406 - DATE: 28/07/98 *****

-----

ELEMENT NAME : CARBON
RESOLUTION   : PARTIAL

MASTER FILE SELECTION:
-----
SELECTED YEAR : 93
DEFAULT YEAR  : 93

CLASS   TYPE   SELECT  FILTER
-----
ACD     P      S
SCD     P      S
CCD     P
PRB     P      S
PRC     P
QCD     P      S
XCD     P      S
PLT     P      S

KEY:
-----
SELECT: S=SELECTED, D=DEFAULT, blank= not available
TYPE   : P=PARTIAL , S=STANDARD
FILTER: FT=FILTER THICKNESS SPECIFICATION, EV=ENERGY CUT-OFF, blank=no filter

SCRIPT FILE:          u/hps/adas/scripts406/test_resolved_c

PHOTON EMISSIVITY COEFFICIENT FILES:
-----
      IF      FILE
      --      ---
      1      /u/adas/adas/adf15/pec93#c/pec93#c_pjr#c0.dat
      2      /u/adas/adas/adf15/pec93#c/pec93#c_pjr#c1.dat
      3      /u/adas/adas/adf15/ionelec/ionelec_pec#c2.dat
      4      /u/adas/adas/adf15/ionelec/ionelec_pec#c3.dat

IONISATION STAGE/METASTABLE SUMMARY:
-----
NUCLEAR CHARGE          = 6
LOWEST CHARGE STATE     = 0
HIGHEST CHARGE STATE    = 6
NUMBER OF STAGES        = 7
NUMBER OF METASTABLE STATES = 13

OUTPUT PLASMA TEMPERATURE AND DENSITY SETS:
-----
INDEX   ELECTRON TEMPERATURE          ELECTRON          HYDROGEN
        (kelvin)          (eV)          DENSITY (cm-3)    DENSITY (cm-3)
-----
  1     1.16D+03    1.00D-01    1.00D+13    1.00D+09
  2     2.32D+03    2.00D-01    1.00D+13    1.00D+09
  3     3.48D+03    3.00D-01    1.00D+13    1.00D+09
  4     5.80D+03    5.00D-01    1.00D+13    1.00D+09
  5     8.12D+03    7.00D-01    1.00D+13    1.00D+09
  6     1.16D+04    1.00D+00    1.00D+13    1.00D+09
  7     1.74D+04    1.50D+00    1.00D+13    1.00D+09
  8     2.32D+04    2.00D+00    1.00D+13    1.00D+09
  9     3.48D+04    3.00D+00    1.00D+13    1.00D+09
 10     5.80D+04    5.00D+00    1.00D+13    1.00D+09
 11     8.12D+04    7.00D+00    1.00D+13    1.00D+09
 12     1.16D+05    1.00D+01    1.00D+13    1.00D+09
 13     1.74D+05    1.50D+01    1.00D+13    1.00D+09
 14     2.32D+05    2.00D+01    1.00D+13    1.00D+09

```





NH (cm-3)			1.00D+09	1.00D+09	1.00D+09	1.00D+09	1.00D+09	1.00D+09	1.00D+09	1.00D+09	1.00D+09	1.00D+09
IND	ION	WVLEN.(A)										
(IC, IZ, IM, IP, IF)												
1	CI	1561A	1.85D-14	1.74D-14	1.67D-14	1.61D-14	1.54D-14	1.50D-14	1.44D-14	1.37D-14	1.32D-14	1.28D-14
( 1	0	1 1E 1)	1.85D-14	1.74D-14	1.67D-14	1.61D-14	1.54D-14	1.50D-14	1.44D-14	1.37D-14	1.32D-14	1.28D-14
( 2	0	2 54E 1)	1.32D-18	3.61D-19	1.53D-19	6.21D-20	2.29D-20	1.08D-20	3.88D-21	9.81D-22	5.49D-22	1.96D-22
( 3	0	3 107E 1)	8.84D-21	2.20D-21	8.90D-22	3.66D-22	1.03D-22	6.07D-23	1.93D-23	8.96D-24	-1.64D-23	5.65D-25
( 4	0	4 160E 1)	6.45D-19	1.72D-19	7.23D-20	1.46D-19	5.10D-20	2.43D-20	1.84D-21	2.29D-21	9.56D-22	3.78D-22
2	CII	904A	1.11D-13	1.22D-13	1.33D-13	1.45D-13	1.60D-13	1.72D-13	1.90D-13	2.16D-13	2.34D-13	2.55D-13
( 1	1	1 3E 2)	1.11D-13	1.22D-13	1.32D-13	1.45D-13	1.60D-13	1.72D-13	1.90D-13	2.16D-13	2.34D-13	2.54D-13
( 2	1	2 25E 2)	3.00D-16	2.46D-16	2.17D-16	1.91D-16	1.66D-16	1.50D-16	1.31D-16	1.10D-16	9.86D-17	8.73D-17
SPECTRAL LINE RATIOS:												
-----												
IR	JL	KL										
1	1	2	1.66D-01	1.42D-01	1.26D-01	1.11D-01	9.62D-02	8.70D-02	7.56D-02	6.34D-02	5.66D-02	5.02D-02
TABLE KEY:												
-----												
TE	= ELECTRON TEMPERATURE					NE	= ELECTRON DENSITY					
NE	= HYDROGEN DENSITY					IND	= STAGE/METASTABLE COUNT					
ION	= ION SPECIFICATION					MET	= METASTABLE INDEX					
PRB	= RECOMB.+ BREMS. POWER FUNCTION					PRC	= CHARGE EXCHANGE RECOMB. POWER FUNCTION					
PLT	= LINE RADIATED POWER FUNCTION					PRAD	= TOTAL RADIATED POWER FUNCTION					
IL	= SPECTRUM LINE INDEX					IC	= SPECTRUM LINE COMPONENT COUNT					
IZ	= ASSOCIATED ION FOR LINE COMPONENT					IM	= ASSOCIATED METASTABLE FOR LINE COMPONENT					
IP	= PHOTON EMISSIVITY FILE SELECTION INDEX					IF	= EMISSIVITY FILE INDEX					
IR	= SPECTRUM LINE RATIO INDEX					JL	= NUMERATOR SPECTRUM LINE INDEX					
KL	= DENOMINATOR SPECTRUM LINE INDEX											

## Notes: