
ADAS511: F-GTN - graph envelope feature photon emissivity function

The program interrogates envelope feature photon emissivity functions (\mathcal{F}_{GTN}) files of type ADF44. The coefficient is extracted for a selected wavelength range of an ion. The coefficient may be displayed in a three dimensional plot.

Background theory:

An envelope feature photon emissivity function, denoted by \mathcal{F}_{GTN} , is defined on a wavelength interval and is a composite feature arising from very many lines from a set of ionisation stages of an element. The \mathcal{F}_{GTN} is suitable as a descriptor in wavelength intervals and at spectral resolutions where the individual component lines are unresolved or only partly resolved. This situation occurs with very complex heavy elements for which it becomes helpful and economical to handle the envelope superfeature rather than the individual line emissivity functions (\mathcal{G}_{LN} s). Following Chap 3.8, the emissivity of an individual line is specified as

$$\varepsilon_{j \rightarrow k} = A_{j \rightarrow k} \left(\sum_{\sigma=1}^M \mathcal{F}_{j\sigma}^{(exc)} N_e N_{\sigma} + \sum_{\nu'=1}^{M+1} \mathcal{F}_{j\nu'}^{(rec)} N_e N_{\nu'}^+ \right). \quad 6.11.1$$

where the *excitation* photon emissivity coefficient is

$$\mathcal{P}\mathcal{E}\mathcal{C}_{\sigma, j \rightarrow k}^{(exc)} = A_{j \rightarrow k} \mathcal{F}_{j\sigma}^{(exc)} \quad 6.11.2$$

and the *recombination* photon emissivity coefficient is

$$\mathcal{P}\mathcal{E}\mathcal{C}_{\nu', j \rightarrow k}^{(rec)} = A_{j \rightarrow k} \mathcal{F}_{j\nu'}^{(rec)}. \quad 6.11.3$$

Each of these coefficients is associated with a particular metastable σ or ν' of the X^{+z} , or X^{+z+1} ions of the element X respectively.

Introduce the equilibrium ionisation balance fractional abundances $N_{\sigma}^{(z)} / N_{tot}$ so that

$$N_{\sigma} \equiv N_{\sigma}^{(z)} = \frac{N_{\sigma}^{(z)}}{N_{tot}} \frac{N_{tot}}{N_e} N_e \quad 6.11.4$$

where the ratio $N_{\sigma}^{(z)} / N_{tot}$ is evaluated in equilibrium at the local temperature and density. Then gathering terms

$$A_{j \rightarrow k} N_j = \frac{N_{tot}}{N_e} N_e^2 G(T_e, N_e) \quad 6.11.5$$

where

$$G_{j \rightarrow k}(T_e, N_e) = A_{j \rightarrow k} \left(\sum_{\sigma=1}^{M_z} \mathcal{F}_{j\sigma}^{(exc)} \frac{N_{\sigma}^{(z)}}{N_{tot}} + \sum_{\sigma=1}^{M_z} \mathcal{F}_{j\nu}^{(rec)} \frac{N_{\nu}^{(z+1)}}{N_{tot}} \right) \quad 6.11.6$$

Consider a spectral interval, $[\lambda_0, \lambda_1]$, subdivided into N_{pix} intervals as $\{\Delta\lambda_i^{(0,1)} \equiv [\lambda_0 + i(\lambda_1 - \lambda_0) / N_{pix}, \lambda_0 + (i+1)(\lambda_1 - \lambda_0) / N_{pix}] : i = 0, \dots, N_{pix} - 1\}$

Also suppose that the $j \rightarrow k$ spectrum line has a normalised emission profile $\varphi_{j \rightarrow k}(\lambda)$.

In general, such a profile is a convolution of Doppler and instrumental functions. Then the envelope feature photon emissivity coefficient vector is defined as

$$\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}_i^{[0,1]} = \sum_{\substack{j,k \\ \lambda_{j \rightarrow k} \in [0,1]}} G_{j \rightarrow k} \int_{\lambda_i}^{\lambda_{i+1}} \phi_{j \rightarrow k}(\lambda) d\lambda \quad 6.11.7$$

$\lambda_{j \rightarrow k}$ is the natural wavelength of the $j \rightarrow k$ spectrum line. The default broadening assumed is Doppler with a Maxwellian distribution for the emitting ion at temperature, T_{ion} , equal to the electron temperature, T_e , used in the collisional–radiative modelling of the $\mathcal{G}\mathcal{I}\mathcal{N}$ s. This constitutes a minimum broadening. The integral in equation 6.11.7 is then expressible in terms of error functions as

$$\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}_{\sigma,i}^{[0,1]} = \sum_{\substack{j,k \\ \lambda_{j \rightarrow k} \in \Delta\lambda_i^{[0,1]}}} G_{j \rightarrow k} \left\{ \frac{1}{2} \operatorname{erfc}((\lambda_i - \lambda_{j \rightarrow k})/\sigma) - \operatorname{erfc}((\lambda_{i+1} - \lambda_{j \rightarrow k})/\sigma) \right\} \quad 6.11.8$$

where $\sigma = \lambda_{j \rightarrow k} \alpha \left(\frac{kT_{ion}}{I_H} \cdot \frac{m_p}{m_X} \cdot \frac{m_e}{m_p} \right)^{1/2}$ and m_X is the emitting ion mass.

In principle, the minimal Doppler broadened $\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}$ s can be convolved with effective instrument functions and/or representations of wavelength dependent filters. These are called ‘filtered’ $\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}$ s and they are structurally the same as the unfiltered $\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}$ s.

$$\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}_i^{[0,1]F} = F_i \mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}_i^{[0,1]} \quad 6.11.9$$

where $\{F_i : i = 1, \dots, npix\}$ denotes a filter. The archiving is unchanged except for the need for a filter code to be assigned as part of the archive.

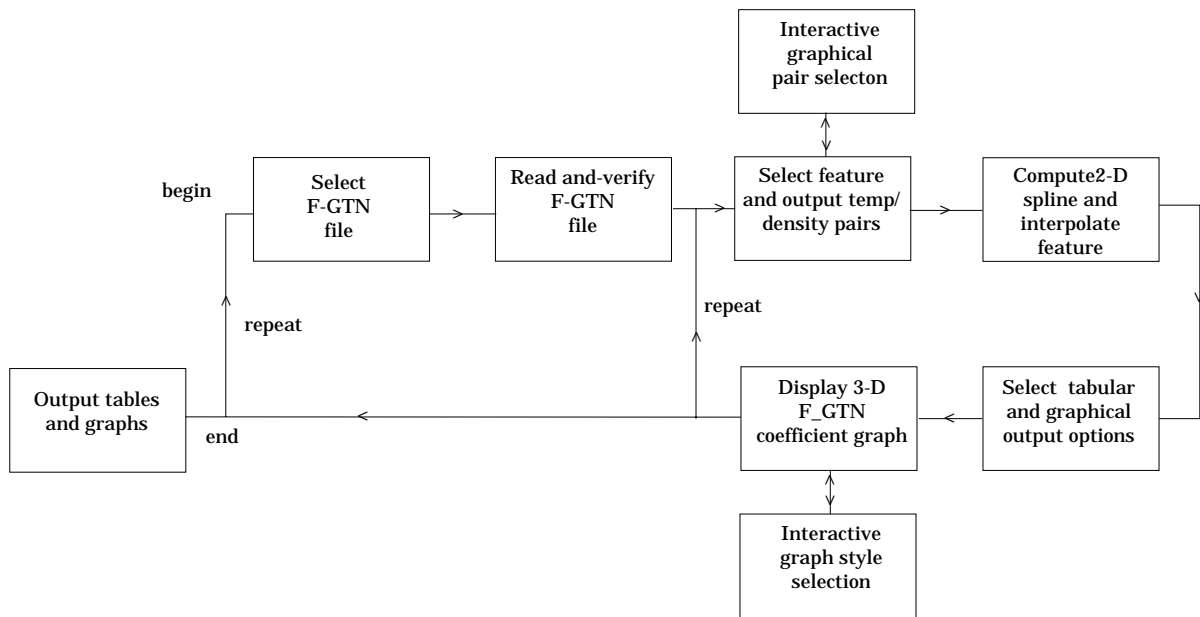
$\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}$ data are extracted from archived files of type ADF43. They are interpolated by cubic splines in electron temperature and density to provide results at an arbitrary set of temperature/density pairs. The code can select the temperature/density pairs graphically. For this purpose the $\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}$ must be contracted over wavelength. The functional used for interactive graphical pair selection is the total photon count over the wavelength interval, namely

$$\overline{\mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}}^{[0,1]} = \sum_i \mathcal{F}_{\sigma} \mathcal{G}\mathcal{I}\mathcal{N}_i^{[0,1]} \quad 6.11.10$$

Program steps:

These are summarised in figure 6.11.

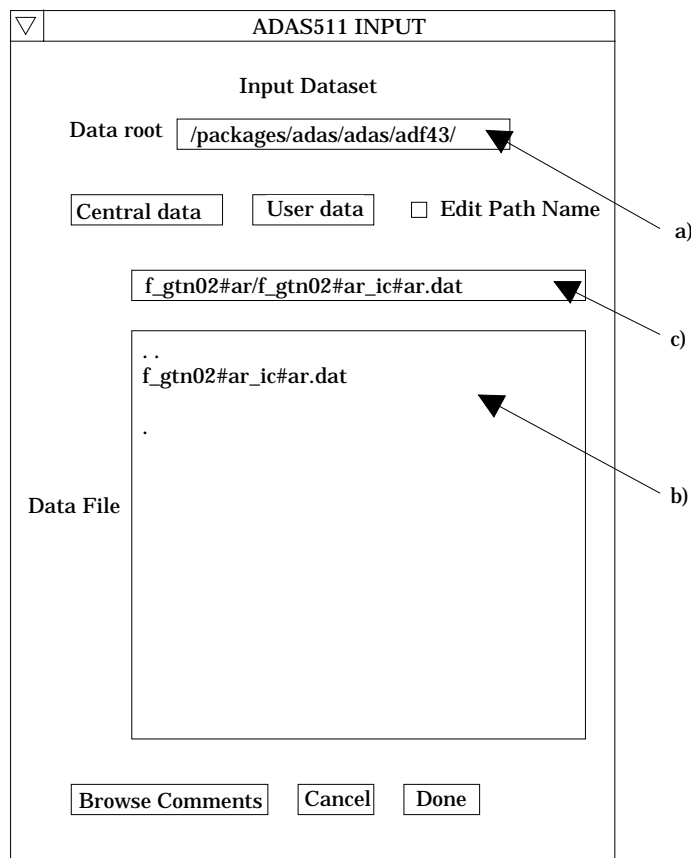
Figure 6.11



Interactive parameter comments:

Programs of series ADAS5 which make use of data from archived ADAS datasets initiate an interactive dialogue with the user in three parts, namely, input file selection, entry of user data and disposition of output.

The **file selection window** has the appearance shown below



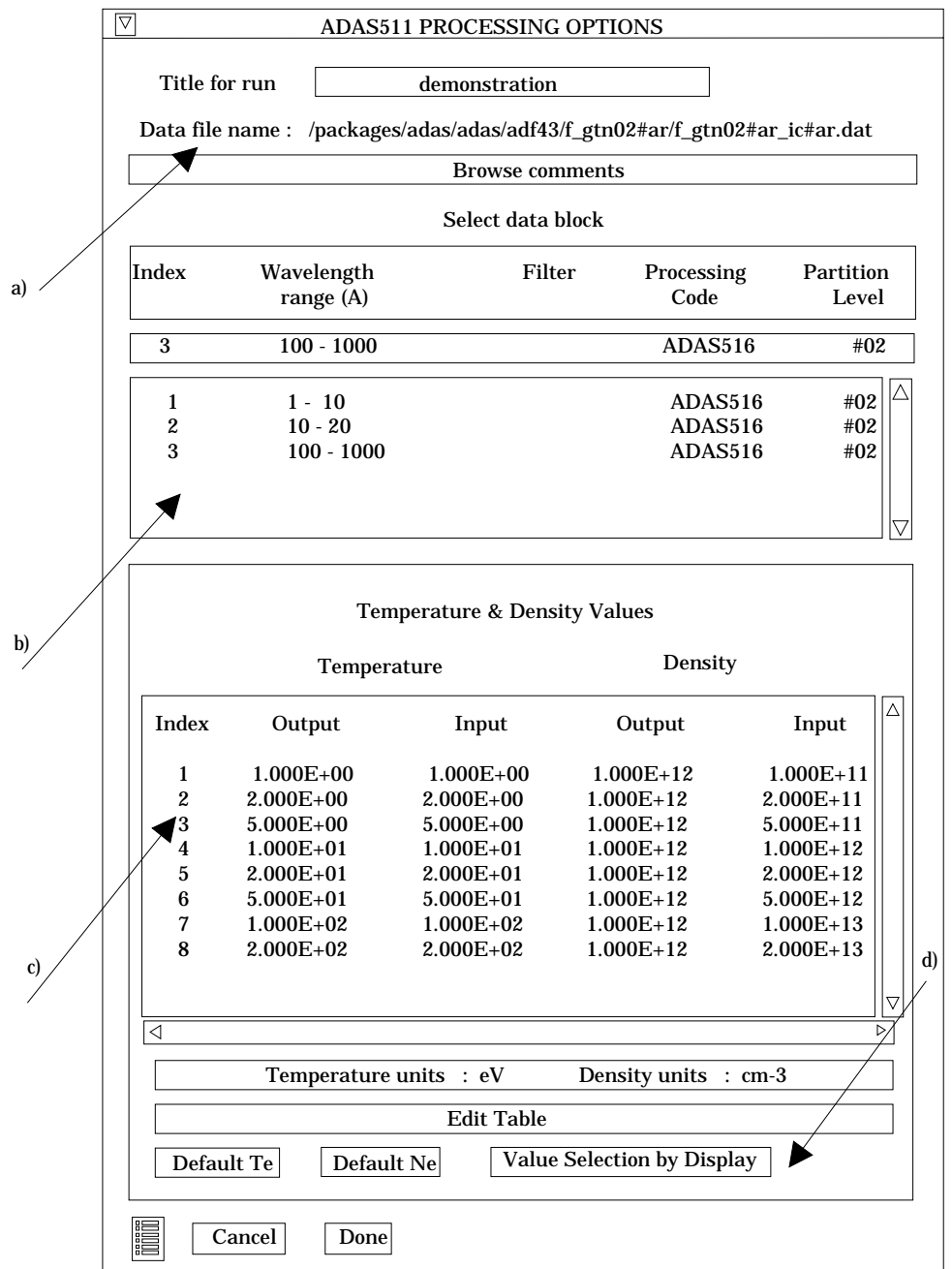
1. Data root a) shows the full pathway to the appropriate data subdirectories. Click the *Central Data* button to insert the default central ADAS pathway to the

correct data type. Note that each type of data is stored according to its ADAS data format (*adf* number). Click the *User Data* button to insert the pathway to your own data. Note that your data must be held in a similar file structure to central ADAS, but with your identifier replacing the first *adas*, to use this facility.

2. The Data root can be edited directly. Click the *Edit Path Name* button first to permit editing.
3. Available sub-directories are shown in the large file display window b). Scroll bars appear if the number of entries exceed the file display window size.
4. Click on a name to select it. The selected name appears in the smaller selection window c) above the file display window. Then its sub-directories in turn are displayed in the file display window. Ultimately the individual datafiles are presented for selection. Datafiles all have the termination *.dat*.
5. Once a data file is selected, the set of buttons at the bottom of the main window become active.
6. Clicking on the *Browse Comments* button displays any information stored with the selected datafile. It is important to use this facility to find out what is broadly available in the dataset. The possibility of browsing the comments appears in the subsequent main window also.
7. Clicking the *Done* button moves you forward to the next window. Clicking the *Cancel* button takes you back to the previous window

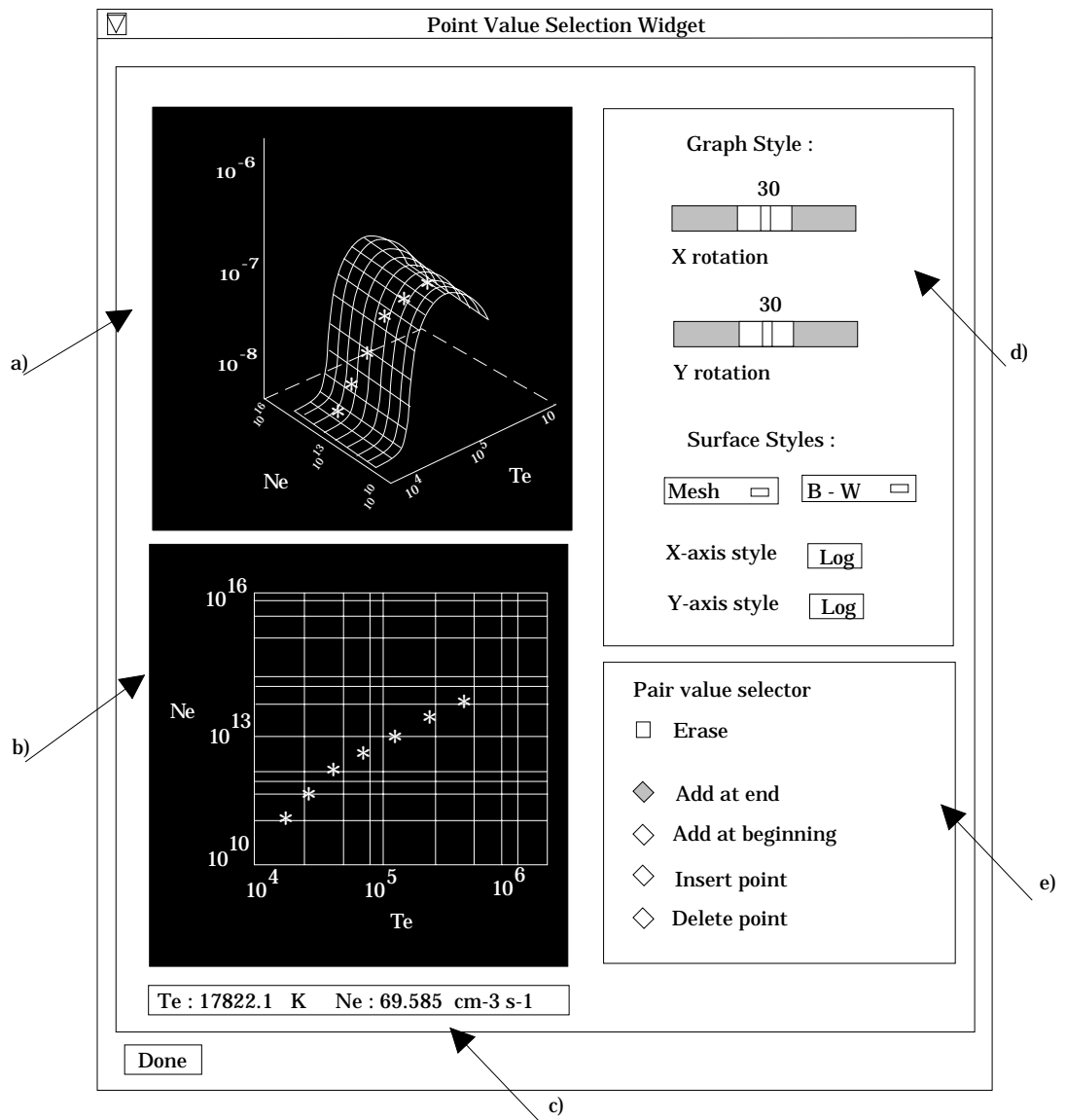
The **processing options window** has the appearance shown below

1. An arbitrary title may be given for the case being processed at a). For information the full pathway to the dataset being analysed is also shown. The button *Browse comments* again allows display of the information field section at the foot of the selected dataset, if it exists.
2. Spectral intervals for which envelope feature emissivity coefficients are available in the data set are displayed in the list display window at b). This is a scrollable window using the scroll bar to the right of the window. Note there is a *Filter* field present for information. Click anywhere on the row for a feature to select it. The selected feature appears in the selection window c) just above the feature list display window.
3. Your settings of electron temperature/electron density pairs (outputs) are shown in the temperature/density display window d). The temperature and density values at which the envelope feature emissivity coefficient is stored in the datafile (inputs) is also shown for information. **Note that you must give temperature/density pairs, ie. the same number of each as for a model.** The underlying datafile has a three-dimensional storage as a function of temperature, density and wavelength.



- The program initially recovers the output temperature/density pairs you used when last executing the program.
- The Temperature & Density Values are editable. Click on the *Edit Table* button if you wish to change the values. The usual 'drop-down' window, the ADAS Table Editor window, appears. At e), *Default Te* and *Default Ne* are available. These buttons insert the electron temperature data or electron density data respectively from the input data set as the output values and offers a choice of a fixed electron density or electron temperature respectively to be associated with these.
- The third button at e) is for *Value Selection by display*. Click to pop-up the *point value selection widget*, which is designed both to provide a display of the actual three-dimensional surface of the density and temperature dependent wavelength interval summed envelope feature collisional-radiative emissivity coefficient (see equation 6.11.6) and to allow selection of temperature/density pairs for the output graphs visually.

The **point value selection widget** has the appearance shown below



7. The summed envelope feature emissivity coefficient surface is shown at a). Controls are provided at b) to orientate and alter the appearance of the display. Sliders allow rotation about the X-axis and about the Y-axis so that the whole surface can be examined. The surface styles can be altered by selecting from drop-down menus. The styles include continuous or mesh surfaces and the colour of the surface. Finally the form of the axes, that is logarithmic or linear can be chosen from drop-down menus.
8. At b), the two dimensional projection on the Te/Ne plane is displayed. Note that the grid lines are those of the actual data in the source file. The code provides a sophisticated method for selecting Te/Ne pairs by mouse click which allows the user to track over interesting parts of the surface.
9. Move the mouse cursor over the lower Te/Ne grid. A tracking pointer moves over the surface in the upper display. Click the left mouse button to select a Te/Ne pair. A symbol marks the selection on the Te/Ne grid in the lower display and a marker also appears on the surface in the upper display. Continue to select point pairs as required. Note that the position of the cursor in Te/Ne space is shown numerically at c) for precise positioning
10. Control buttons at e) allow adjustments to your selection set. Pairs can be added at the beginning or end of the set or inserted between pairs. Also a pair can be deleted. Finally the whole set of pairs can be erased.

- Click *Done* on completion to return to the processing options window. The pairs selected will be present in the editable table. Note that conventional entry or modification of user data with Table Editor remains an option as before.

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

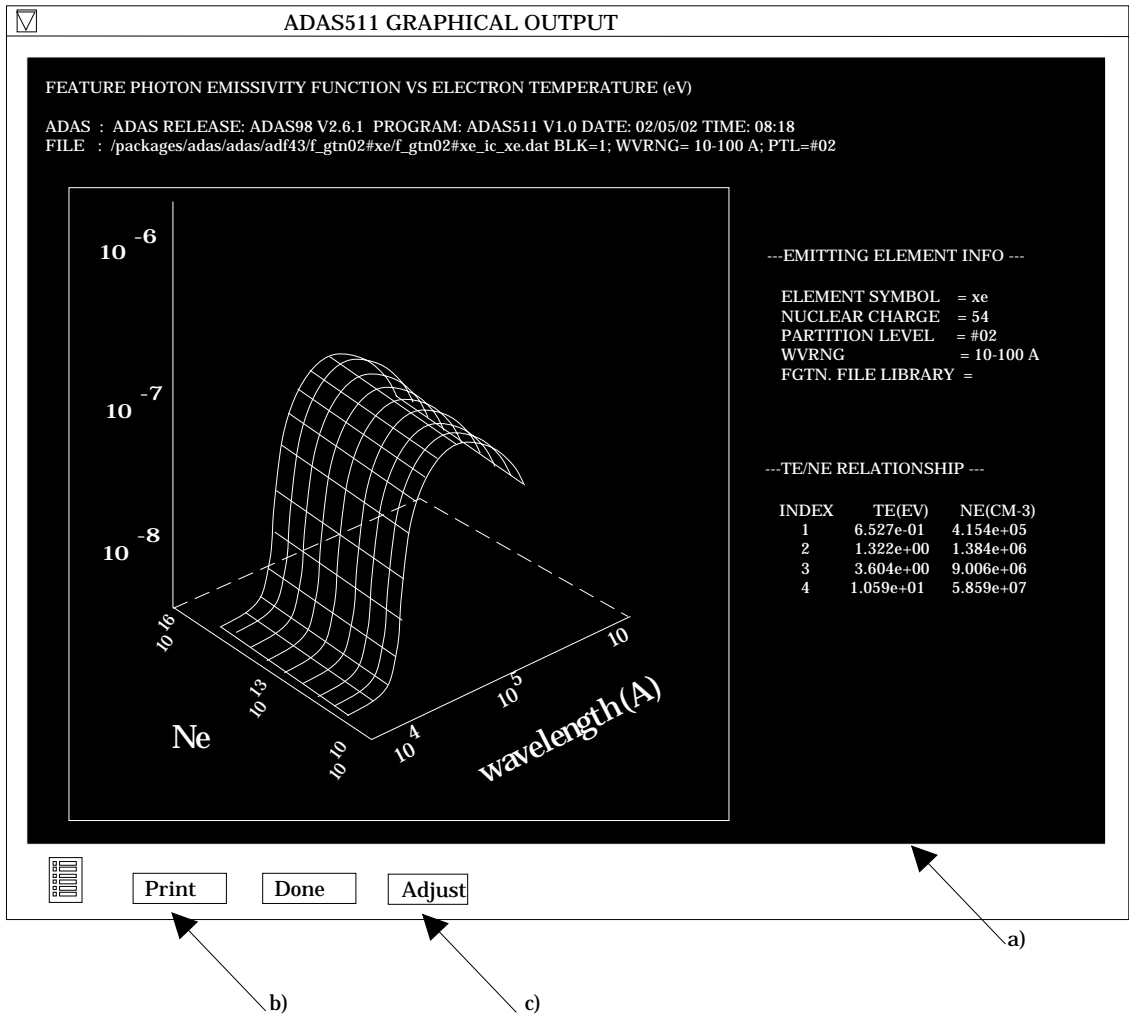
- As in the previous window, the full pathway to the file being analysed is shown for information. Also the *Browse comments* button is available.
- Graphical display is activated by the *Graphical Output* button a). This will cause a graph to be displayed following completion of this window. When graphical display is active, an arbitrary title may be entered which appears on the top line of the displayed graph. By default, graph scaling is adjusted to match the required outputs. Press the *Explicit Scaling* button b) to allow explicit minima and maxima for the graph axes to be inserted. Activating this button makes the minimum and maximum boxes editable.

- Hard copy is activated by the *Enable Hard Copy* button c). The File name box then becomes editable. If the output graphic file already exists and the *Replace* button has not been activated, a 'pop-up' window issues a warning.
- A choice of output graph plotting devices is given in the Device list window d). Clicking on the required device selects it. It appears in the selection window above the Device list window.
- The *Text Output* button activates writing to a text output file. The file name may be entered in the editable File name box when *Text Output* is on. The default file name 'paper.txt' may be set by pressing the button *Default file name*. A 'pop-up' window issues a warning if the file already exists and the *Replace* button has not been activated.

The **graphical output** window has the appearance shown below

- The 3-D plot is displayed at a) together with identifying textual annotation.

18. The *Print* button at b) sends the displayed graph to the graphic file. The *Adjust* button at c) pops up the *3-D graph adjustment* widget which allows modification of the graph.



The **3-D graph adjustment** widget has the appearance shown below

19. Control is provided to alter the axes . At a) a choice for the Y-axis (temperature or density) is provided. Note that the Y-axis is representing the variation with both temperature and density, since model pairs are being used. The X-axis is assigned to wavelength.
20. At b), the style (logarithmic or linear) for each of the axes may be varied.
21. At c), explicit scaling may be activated and then the usual manual entry of minima and maxima for each of the three axis scales is supported.
22. At d), control of the orientation of the 3-D display is provided. Also, the appearance of the surface (mesh or surface) and colour of the surface may be chosen at e).
23. Note that the widget remains present and active for convenience so that a sequence of adjustments may be made. Click *Done* to close the widget..

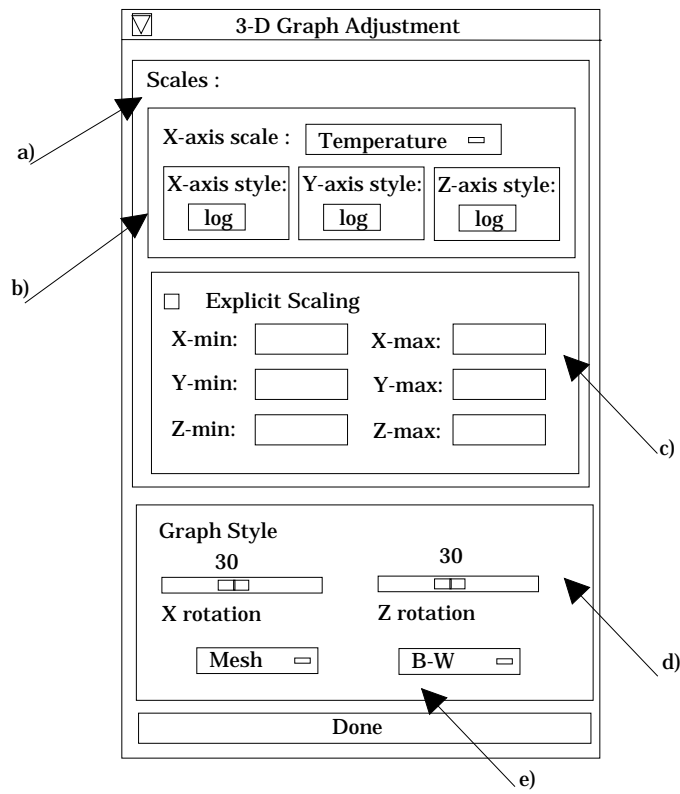


Illustration:

Figure 6.11a To be added.

Table 6.11a To be added

Notes:

