Atomic Data and Analysis Structure

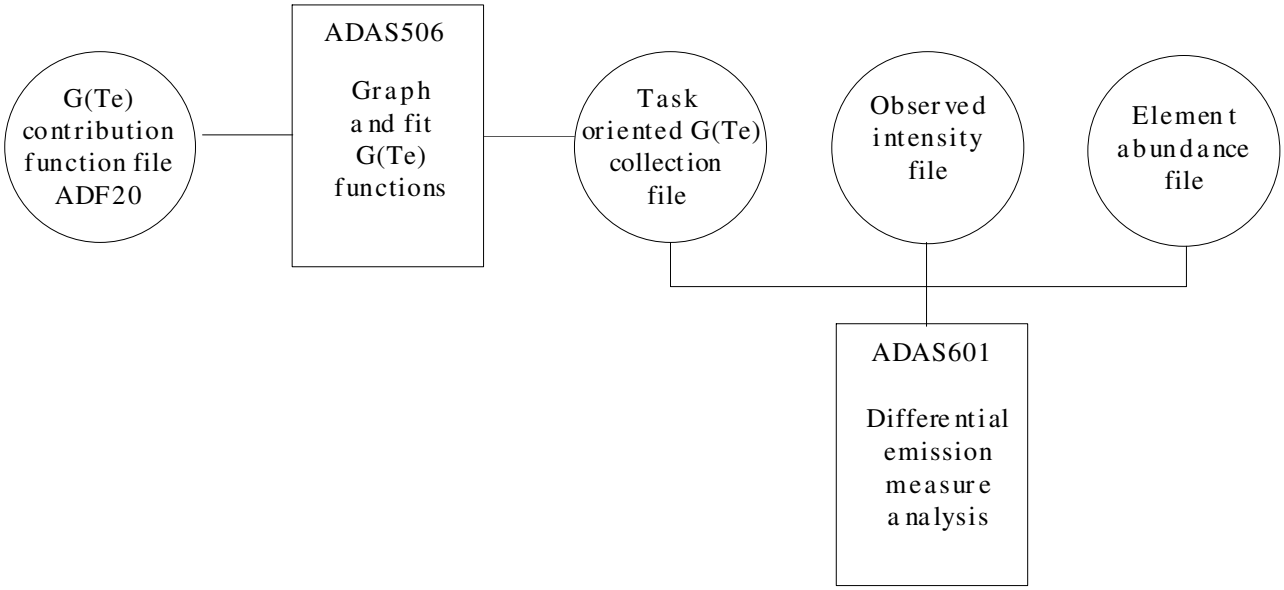
Differential emission measure and emission functions

The programs of series ADAS5 are all interactive interrogation codes on elements of the fundamental and derived databases. This supplementary series has been found of use in analysis and interpretation. The particular type of data of relevance here are the G(Te) functions which merge the photon emissivity coefficients of lines of an ion with an equilibrium ionisation balance of the ion with respect to the total abundance of the species. These data (type ADF20) are of the form and definition usual in astrophysics. They are interrogated by program ADAS506.

The programs of series ADAS6 are data analysis codes fully integrated within the ADAS structure. ADAS601 evaluates an estimate of the *emission measure differential in temperature* from observed spectral intensities, assumed elemental abundances and a collection of G(Te) functions. This latter is directly produced by the interrogation program ADAS506 for the spectral lines of interest. The structure of ADAS601, unlike other ADAS programs, is not sequential. This is to give some agility in the analysis, allowing one to change any of the input data sets (elemental abundances, observed spectral intensities, collection of G(Te) functions), examine the G(Te) functions, change options, evaluate the differential emission measure, and display or print the output at any time during the analysis.

A schematic of the programs and dataset types interrogated is shown in figure 4.0.

Figure 4.0


G(Te) contribution function file ADF20
ADAS506
Graph and fit G(Te) functions
Task oriented G(Te) collection file
Observed intensity file
Element abundance file
ADAS601
Differential emission measure analysis

ADAS506: GFT - graph and fit G(Te) functions

The program interrogates *GFT* files of type ADF20. The $G(T_e)$ function is extracted for a selected radiative transition of an ion. The data may be interpolated using cubic splines at selected electron temperatures. A minimax polynomial approximation is made to the interpolated data. The interpolated data are displayed and a tabulation prepared. The tabular and graphical output may be printed and includes the polynomial approximation.

Background theory:

One of the most widely used methods available for the interpretation of astronomical spectral intensities is the emission measure technique. This method is less familar in spectroscopic studies of fusion plasma. However it and variants designed to determine impurity concentration, impurity variation in time and impurity influx are applicable in fusion.

The intensity of a spectral line from a column of optically thin plasma of cross-sectional area **A** and due to a transition from upper level j to lower level k may be written as

$$I_{j\to k} = \frac{1}{4\pi \mathbf{A}} \iiint A_{j\to k} N_j \, dz dy dx \qquad 4.6.1$$

where N_j denotes the population density of ions in the upper state j, $A_{j\to k}$ is the radiative transition probability for the transition and the integral is taken over the volume of the plasma viewed.

The excited population may be expressed in terms of the ground and metastable populations of the ionisation stage to which it belongs and to those of the adjacent higher ionisation stage by a quasi-equilibrium collisional radiative calculation as

$$N_j = \sum_{\sigma=1}^{M_z} \mathcal{T}_{j\sigma}^{(exc)} N_e N_\sigma + \sum_{\upsilon'=1}^{M_{z+1}} \mathcal{T}_{j\upsilon'}^{(rec)} N_e N_{\upsilon'}^{+} \qquad 4.6.2$$

Usually contributions to the population of the excited state by excitation from the metastables of its own ionisation stage only need to be considered so that

$$N_j = \sum_{\sigma=1}^{M_z} \mathcal{T}_{j\sigma}^{(exc)} N_e N_\sigma \qquad 4.6.3$$

In differential emission measure analysis, the assumption of ionisation balance is normally made. Although a time dependent ionisation could be used, the method would be specific to a particular model for the dynamic behaviour of the plasma and the universality of the emission measure technique would be lost. Thus it is convenient to write.

$$N_\sigma \equiv N_\sigma^{(z)} = \frac{N_\sigma^{(z)}}{N_{tot}} \frac{N_{tot}}{N_H} \frac{N_H}{N_e} N_e \qquad 4.6.4$$

where the ratio $N_\sigma^{(z)} / N_{tot}$ is evaluated in equilibrium at the local temperature and density. For the solar plasma, the generally accepted assumption is that the abundance of the element N_{tot} / N_H does not vary through the depth of the atmosphere. Then gathering terms

$$A_{j\to k} N_j = \frac{N_{tot}}{N_H} N_e^2 G(T_e, N_e) \qquad 4.6.5$$

where

$$G_{j\to k}(T_e, N_e) = A_{j\to k} \frac{N_H}{N_e} \sum_{\sigma=1}^{M_z} \mathcal{T}_{j\sigma}^{(exc)} \frac{N_\sigma^{(z)}}{N_{tot}} \qquad 4.6.6$$

Then the spectral intensity may be written as

$$I_{j\to k} = \frac{1}{4\pi \mathbf{A}} \frac{N_{tot}}{N_H} \iiint G_{j\to k}(T_e, N_e) N_e^2 dz dy dx \qquad 4.6.7$$

It is convenient to change the variable of the integral to electron temperature. However the atomic coefficient depends on both electron temperature and electron density so it is necessary to make some assumption about the relation between them. A common assumption is that the plasma pressure is constant over the relatively small range of temperature where the $G(T_e, N_e)$ function has significant values. In any event a model assumption is made even though the $G(T_e)$ function is usually written as function of temperature alone. Also introduce the concept of surfaces of constant temperature of which there may be more than one in the viewed volume. The intensity then may be rewritten as

$$I_{j\to k} = \frac{1}{4\pi \mathbf{A}} \frac{N_{tot}}{N_H} \int_{T_1}^{T_2} G_{j\to k}(T_e, N_e) \sum_l \int_{S_l(T_e)} \left|\nabla T_e\right|_l^{-1} N_e^2 dS_l \, dT_e \qquad 4.6.8$$

The limits of the integral T_1 and T_1 are the minimum and maximum electron temperatures in the part of the atmosphere contrinbuting to the spectrum. Introduce the differential emission measure, $\phi(T_e)$, defined by

$$\phi(T_e) = \frac{1}{\mathbf{A}} \sum_l \int_{S_l(T_e)} \left|\nabla T_e\right|_l^{-1} N_e^2 dS_l \qquad 4.6.9$$

where the sum is taken over all l of the isothermal surfaces $S_l(T_e)$ and $\left|\nabla T_e\right|_l$ is the modulus of the temperature gradient perpendicular to the surface. By this definition $\phi(T_e)$ is the average value for the differential emisison measure over the area viewed by the spectrometer. It is noted that $\phi(T_e)$ is the part of the integral it is sought to extract since it is the part which gives infromation about the structure of the atmosphere. The above analysis leads to the following expression for the spectral intensity

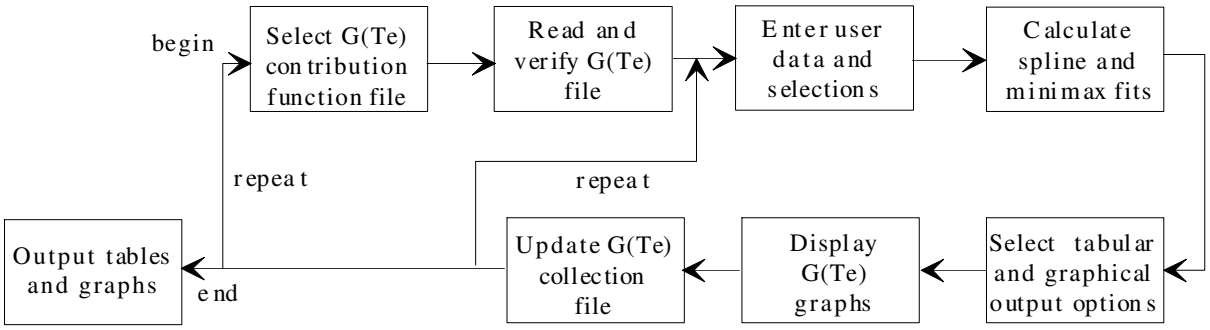
$$I_{j\to k} = \frac{1}{4\pi} \frac{N_{tot}}{N_H} \int_{T_1}^{T_2} G_{j\to k}(T_e, N_e) \phi(T_e) \, dT_e \qquad 4.6.10$$

The program interrogates $G(T_e)$ data sets prepared according to the prescription of equation 6.6.6. Details of the model relating temperature, density, pressure and hydrogen to electron number densities are stored in the $G(T_e)$ datasets and this information is accessed simultaneoulsy with the $G(T_e)$ in the interrogation. Interpolation of the $G(T_e)$ to arbitrary temperatures is done by cubic splines. This implies an implicit interpolation in the other model parameters. For completeness these model parameters are also explicitly interpolated as a function of temperature.

Program steps:

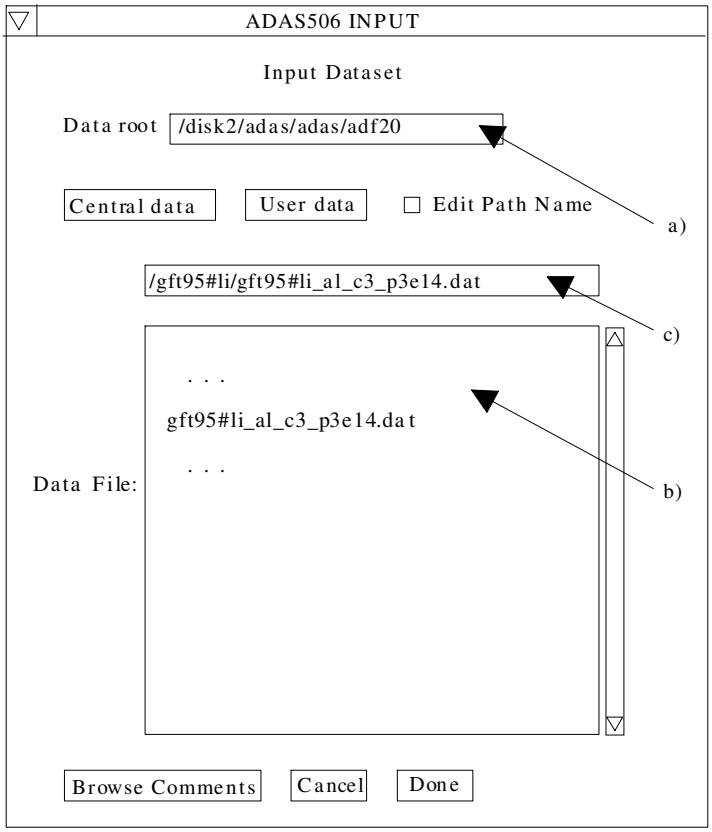
These are summarised in figure 4.6.

Figure 4.6



Interactive parameter comments:

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. The appropriate ADAS data format for input to this program is ADF20 ('G(Te) files'). 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. They are named by iso-electronic sequence (eg. *gft95#li*). specific file names include a source identifier (eg. *al*) the specific ion symbol (eg. *c3*) and the pressure (eg. *p3e14*).

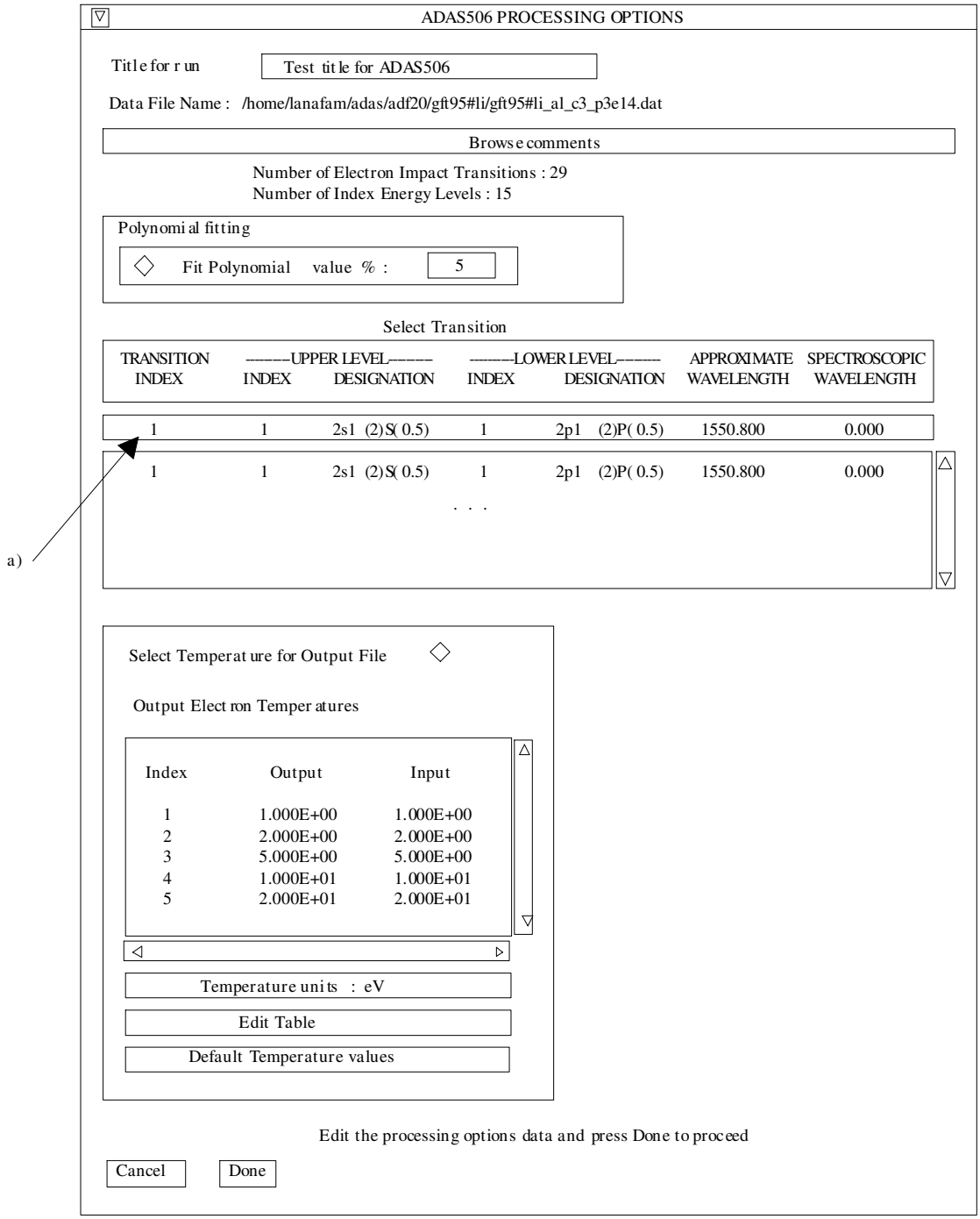
4. Click on a name to select it. The selected name appears in the smaller selection window c) above the file display window. Then the individual datafiles are presented for selection. Datafiles all have the termination *.dat* (eg. *gft95#li_al#c3_p3e14.dat*).

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 has gone into the dataset and the attribution of 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. Transitions for which G(Te) data are available in the data set are displayed in the line list display window. This is a scrollable window using the scroll bar to the right of the window. Click anywhere on the row for a line to select it. The selected transition appears in the selection window a) just above the line list display window.

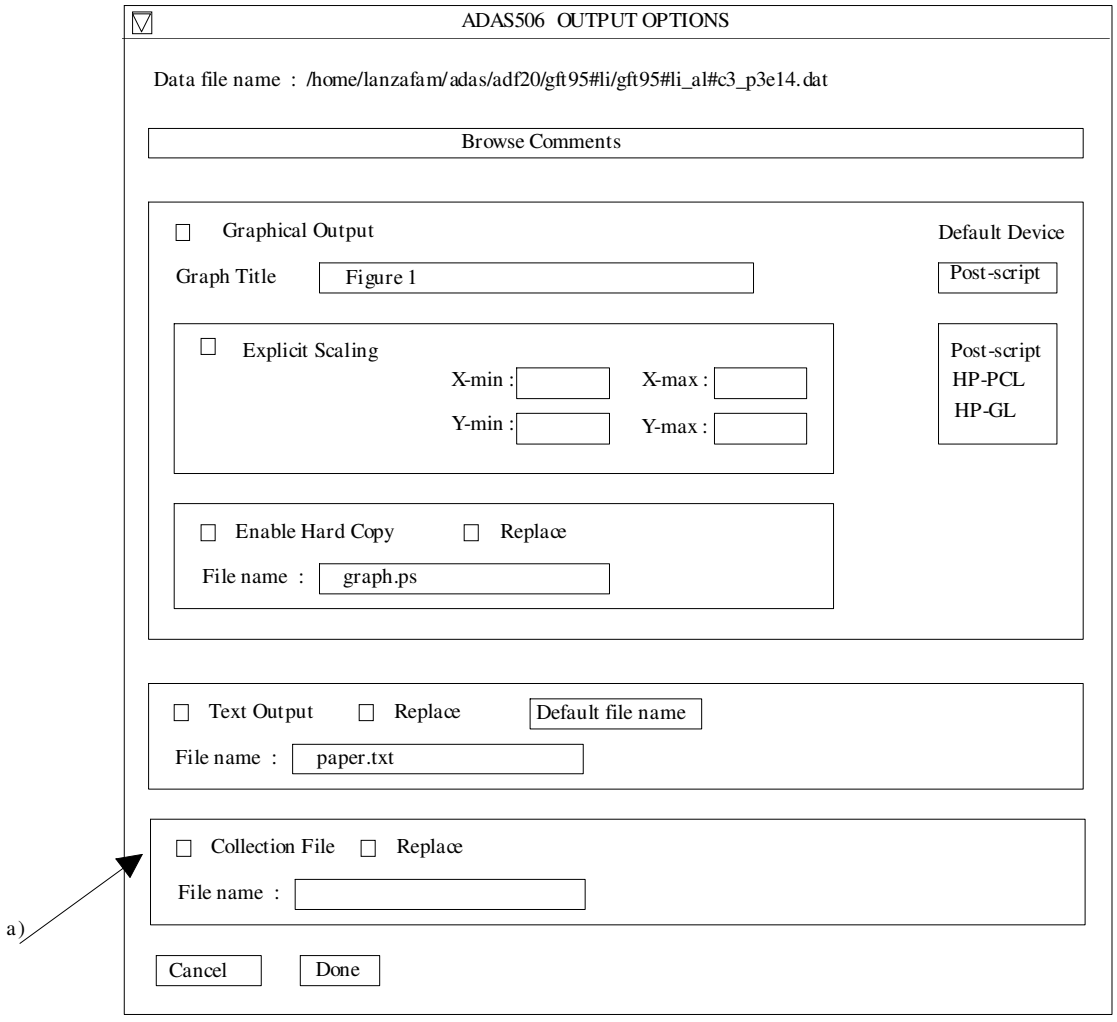
2. Your settings of electron temperatures (output) are shown in the temperature display window d). The temperature values at which the G(Te) coefficients are stored in the datafile (input) are also shown for information.

3. The program recovers the output temperatures you used when last executing the program. Pressing the *Default Temperature values* button inserts a default set of temperatures equal to the input temperatures

4. The Temperature Values are editable. Click on the *Edit Table* button if you wish to change the values. A 'drop-down' window, the ADAS Table Editor window: It follows the same pattern of operation as described in bulletin.

5. Clicking the *Done* button causes the next output options window to be displayed. Remember that *Cancel* takes you back to the previous window.

The **output options window** has the appearance shown below.



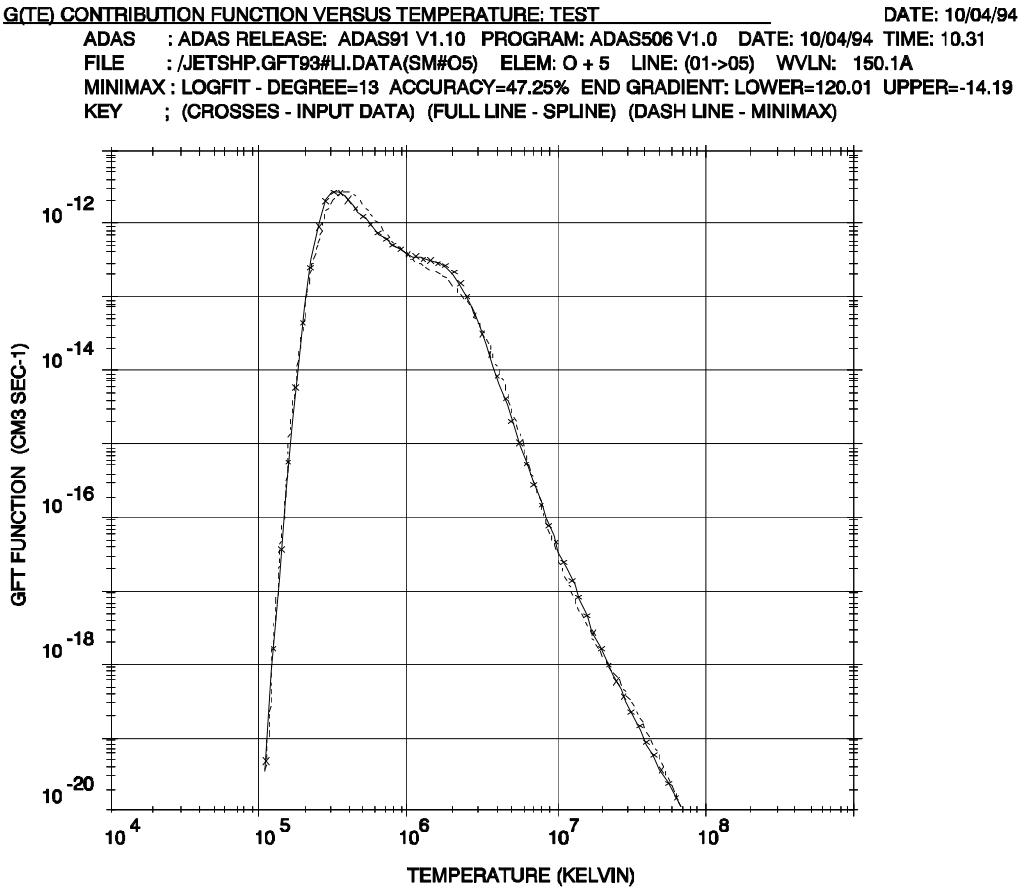
6. The graph is displayed in a following **graphical output** window.

7. Writing to the collection file is activated by clicking the *Collection File* button at a). The operation is slightly different from the usual text output. The collection file is composed of blocks of data for each spectrum line. Each block includes a header line which enables the code to construct an indexed list of lines present in the collection file. A line which is already present in the collection is replaced if the *Replace* button is activated, otherwise it is disallowed. Thus the G(Te) collection file contains any one line only once.

Illustration:

Figure 4.6a shows the G(Te) function for 150.1 A line of OVI. The GFT data set was prepared for a constant pressure model at $3x10^{+14}$ K cm-3. The model includes the variation of the ratio N_H / N_e in the solar atmosphere with temperature in the G(Te) functions.

Figure 4.6a



The tabulation is given in table 4.6a. For completeness, interpolation with temperature of the model electron density, electron pressure and N_H / N_e is given in the table.

Table 4.6a

```
ADAS RELEASE: ADAS91 V1.10  PROGRAM: ADAS506 V1.0   DATE: 10/04/94  TIME: 10:32
******** TABULAR OUTPUT FROM  G(TE) FUNCTION FILES INTERROGATION        PROGRAM: ADAS506 - DATE: 10/04/94 *******

------------------- TEST                                        --------------------

          G(TE) CONTRIBUTION FUNCTIONS AS A FUNCTION OF TEMPERATURE
          ---------------------------------------------------------
                    DATA GENERATED USING PROGRAM: ADAS506
                    ------------------------------------

FILE: /JETSHP.GFT93#LI.DATA(SM#O5)   ELEM: O + 5  LINE: (01->05) WVLN:   150.1A

NUCLEAR CHARGE         (Z0) =   8
RECOMBINING ION CHARGE (Z1) =   6
RECOMBINED ION CHARGE  (Z)  =   5


   LEVEL      CONFIGURATION      QUANTUM NUMBERS
                                2S+1  L  (WI-1)/2
-------------------------------------------------
 5 - UPPER     3p*  3P(J=0        2    1    0.5
 1 - LOWER     2s   2S(J=0        2    0    0.5


TRANSITION WAVELENGTH (APPROX.) =     150.1 A
TRANSITION WAVELENGTH (EXACT)   =     150.1 A


------------- TEMPERATURE -------------    GFT          DENS         PRESS        NH/NE
    KELVIN         EV       KELVIN/Z1**2  CM3 S-1        CM-3         KCM-3
-----------------------------------------------------------------------------------------
  1.00D+05     8.62D+00     2.78D+03     8.46D-22     3.00D+09     3.00D+14     8.49D-01
  2.00D+05     1.72D+01     5.56D+03     4.52D-14     1.50D+09     3.00D+14     8.33D-01
  3.00D+05     2.59D+01     8.33D+03     2.56D-12     9.98D+08     3.00D+14     8.32D-01
  5.00D+05     4.31D+01     1.39D+04     1.27D-12     6.00D+08     3.00D+14     8.31D-01
  7.00D+05     6.03D+01     1.94D+04     6.31D-13     4.29D+08     3.00D+14     8.31D-01
  1.00D+06     8.62D+01     2.78D+04     3.87D-13     3.00D+08     3.00D+14     8.30D-01
  2.00D+06     1.72D+02     5.56D+04     2.14D-13     1.50D+08     3.00D+14     8.30D-01
  3.00D+06     2.59D+02     8.33D+04     4.24D-14     9.98D+07     3.00D+14     8.29D-01
  5.00D+06     4.31D+02     1.39D+05     2.04D-15     6.00D+07     3.00D+14     8.29D-01
  7.00D+06     6.03D+02     1.94D+05     2.97D-16     4.29D+07     3.00D+14     8.29D-01
  1.00D+07     8.62D+02     2.78D+05     4.38D-17     3.00D+07     3.00D+14     8.28D-01
```

```
 ------------------------------------------------------------------------------------

0MINIMAX POLYNOMIAL - TAYLOR COEFFICIENTS: LOG10(GFT) vs. LOG10(TEMP<kelvin>)
 ------------------------------------------------------------------------------
           A( 1) =   7.392163053D+08            A( 2) =  -1.525818821D+09
           A( 3) =   1.445324362D+09            A( 4) =  -8.319180529D+08
           A( 5) =   3.246457026D+08            A( 6) =  -9.070529808D+07
           A( 7) =   1.866822456D+07            A( 8) =  -2.865755607D+06
           A( 9) =   3.281465908D+05            A(10) =  -2.768370818D+04
           A(11) =   1.672659108D+03            A(12) =  -6.854708225D+01
           A(13) =   1.707882983D+00            A(14) =  -1.954078669D-02

 LOGFIT - DEGREE=13  ACCURACY= 47.45%  END GRADIENT: LOWER= 120.01 UPPER= -14.19
 ------------------------------------------------------------------------------
```

Notes:

ADAS601: Differential emission measure analysis

Given a set of observed spectral intensities, $G(T_e)$ functions and elemental abundances, the program evaluates an estimate for the emission measure differential in temperature, using the integral inversion algorithm of A. M. Thompson. Selection of the input data files for elemental abundances, $G(T_e)$ functions, and observed spectral intensities can be made at any time during the analysis. The output consists of displays of the differential emission measure vs. electron temperature and the reconstructed observed spectral intensity ratios. A tabulation of these quantities is also produced. The input set of $G(T_e)$ functions can be displayed and examined at any time.

Background theory:

In order to derive the emission measure differential in temperature, we require to solve the integral equation

$$I_{u\to l} = \frac{1}{4\pi} \text{Ⱥ}(Z) \int_0^\infty G_{u\to l}(T_e)\phi(T_e)\, dT_e \qquad 4.1.1$$

for a set of, say , m spectral lines. In 4.1.1, $I_{u\to l}$ is the intensity of a spectral line from a column of optically thin plasma due to a transition from upper level u to lower level l, $\text{Ⱥ}(Z) \equiv N_{tot}/N_H$ is the fractional elemental abundance assumed to be known, Z the element's nuclear charge, $\phi(T_e)$ the emission measure differential in temperature, as defined in the ADAS506 section.

Note that in equation 4.1.1 the dependence on the electron density has been dropped, which would have lead to the formulation of the bi-variate integral inversion problem. G and ϕ would then have been functions of electron temperature and electron density, and the integral over both variables. The simplified formulation expressed by equation 4.1.1 is achieved by selecting only those spectral lines whose G-functions have a slow dependence on electron density, at least in the physical range of interest. Resonance lines have such properties in most cases. However, in order to achieve the best approximation for the G-functions, the slow dependence on the electron density is taken into account by assuming an approximate constant pressure or constant density for the plasma. This is equivalent to selecting an approximate dependence $N_e = N_e(T_e)$, so that the G-functions can be considered effectively dependent on T_e only. G-functions stored as ADF20 are computed for a grid of constant electron pressure for this purpose.

Equation 4.1.1 is solved by the *data adaptive smoothing approach* of A. M. Thompson. The integral is discretised (product integration method) as

$$\begin{aligned} I_{u\to l} &= \frac{1}{4\pi} \text{Ⱥ}(Z) \int_0^\infty G_{u\to l}(T_e)\phi(T_e)\, dT_e \\ &= \frac{1}{4\pi} \text{Ⱥ}(Z) \sum_{i=1}^{N} \int_{T_{j-1}}^{T_j} G_{u\to l}(T_e)\phi(T_e)\, dT_e \qquad 4.1.2 \\ &= \frac{1}{4\pi} \text{Ⱥ}(Z) \sum_{j=1}^{N} \phi_j^* \int_{T_{j-1}}^{T_j} G_{u\to l}(T_e)\phi_0(T_e)\, dT_e \end{aligned}$$

where

$$\phi_j^* \equiv \frac{\int_{T_{j-1}}^{T_j} G_{u\to l}(T_e)\phi(T_e)\,dT_e}{\int_{T_{j-1}}^{T_j} G_{u\to l}(T_e)\phi_0(T_e)\,dT_e} \qquad 4.1.3$$

represents a weighted average of $\phi(T_e)/\phi_0(T_e)$ between T_{j-1} and T_j . $\phi_0(T_e)$ is an initial estimate of $\phi(T_e)$ towards which we shall smooth the solution. This process can be viewed as scaling the solution using an expected gross behaviour of $\phi(T_e)$ as represented by $\phi_0(T_e)$. The advantage is to reduce the dynamic range of the problem before the actual regularised solution (see below) is obtained. This has been proven to prevent uneven smoothing, with the solution being over-smoothed at large values of ϕ and under-smoothed at low values, when the source function (the differential emission measure) span a large dynamic range.

The prior function $\phi_0(T_e)$ is evaluated as follows. $G_{u\to l}(T_e)$ is approximated by $\overline{G}_{u\to l}\delta(T_e - T_{u\to l}^{\max})$, where

$$\overline{G}_{u\to l} \equiv \int_0^\infty G_{u\to l}(T_e)\,dT_e \qquad 4.1.4$$

$T_{u\to l}^{\max}$ being the temperature corresponding to the maximum of $G_{u\to l}(T_e)$ and δ the Dirac's delta function. A crude estimate of ϕ is then

$$\overline{\phi}(T_{u\to l}^{\max}) = \frac{4\pi}{\not{\alpha}(Z)}\frac{I_{u\to l}}{\overline{G}_{u\to l}} \qquad 4.1.5$$

A cubic B-spline is now fitted to the values $\log(\overline{\phi}(T_{u\to l}^{\max}))$ to obtain a smooth representation for $\phi_0(T_e)$. This representation can only yields features comparable to the typical kernel in width (estimated, to this purpose, to be $\approx 1/2$ decade). The knot points of the B-spline representation are therefore selected approximately $\approx 1/2$ decade apart. In other words, we obtain

$$\log(\phi_0(T_e)) \equiv S(\log(T_e)) \qquad 4.1.6$$

where $S(\log(T_e))$ denotes the B-spline representation with interior knots about $\approx 1/2$ decade apart.

The B-spline fit described above provides a satisfactory estimate of $\phi_0(T_e)$ between the maximum and minimum values of $T_{u\to l}^{\max}$. It is necessary, however, to extrapolate $\phi_0(T_e)$ beyond these boundaries. This is done as follows.

For

$$T > \max[T_{u\to l}^{\max}] \qquad \text{and} \qquad [d\phi_0/dT_e]_{\max[T_{u\to l}^{\max}]} < 0$$

or

$$T < \min[T_{u\to l}^{\max}] \qquad \text{and} \qquad [d\phi_0/dT_e]_{\min[T_{u\to l}^{\max}]} > 0 \quad ,$$

$\log(\phi_0(T_e))$ is extrapolated linearly. This allows the value of $\phi_0(T_e)$ to decrease smoothly while ensuring that it is always positive.

For

$$T > \max[T_{u\to l}^{\max}] \qquad \text{and} \qquad [d\phi_0/dT_e]_{\max[T_{u\to l}^{\max}]} < 0$$

or

$$T < \min[T_{u\to l}^{\max}] \qquad \text{and} \qquad [d\phi_0/dT_e]_{\min[T_{u\to l}^{\max}]} < 0 \ ,$$

$\phi_0(T_e)$ is extrapolated linearly. This is done because any rapid power law variation in $\phi_0(T_e)$ beyond the maximum and minimum of $T_{u\to l}^{\max}$ is likely to lead a gross inconsistency between the values of $\overline{\phi}(T_{u\to l}^{\max})$ and the corresponding averaged value of $\phi_0(T_e)$.

Equation 4.1.1 is then written as

$$g_i = \sum_{j=1}^{N} H_{ij} f_j + \varepsilon_i \qquad (i = 1,2,\ldots,m) \qquad 4.1.7$$

which is the canonical form for inverse problems. In 4.1.7, $f_j \equiv \phi_j^*$ is the quantity to be estimated at the *recovery points* $T_j\ (j = 1,2,\ldots,N)$, $g_i \equiv I_{u\to l}/s_i$ is the data, $\varepsilon_i * s_i$ is the data noise so that ε_i can be regarded as a Gaussian error of constant variance and s_i a weighting parameter or an estimate of the noise variance on the i -th spectral line, and

$$H_{ij} \equiv \frac{A(Z)}{4\pi}\frac{1}{s_i}\int_{T_{j-1}}^{T_j} G_i(T_e)\phi_0(T_e)\,dT_e \qquad . \qquad 4.1.8$$

Equation 4.1.7 is solved by a regularisation approach. In the method of regularisation the extra information required to stabilise the inversion is introduced by a smoothness condition on the source function. A solution is obtained by solving the optimisation problem

$$\min_{\lambda}\left\{\sum_{i=1}^{m}\left(g_i - \sum_{j=1}^{N} H_{ij}\hat{f}\right)^2 + \lambda\Phi\left(\hat{f}\right)\right\} \qquad 4.1.9$$

where λ is a smoothing parameter representing the weight attached to the smoothing constraint $\Phi(\hat{f})$ (a linear functional of *f*), and $\hat{f}$ is the estimate of f. The functional $\Phi(\hat{f})$ represents a prior information about the function f. A choice for this functional derives from the minimisation of the norm of the second derivative of the solution. In other words, of all the solutions that can fit the data the one is chosen that minimises

$$\left\|\Phi\hat{f}\right\|_2^2 = \left\|\hat{f}''\right\|_2^2 = \int\left|\hat{f}''(y)\right|^2 dy \qquad 4.1.10$$

This choice of the linear functional defines the second order regularisation problem and is the one adopted for the solution of equation 4.1.7.

Representing the second derivative by second - order differences, 4.1.9 can be written as

$$\min_{\lambda}\left\{\sum_{i=1}^{m}\left(g_i - \sum_{j=1}^{N} H_{ij}\hat{f}\right)^2 + \lambda\left(\sum_{j=1}^{N}\hat{f}_{j+1} - 2\hat{f}_j + \hat{f}_{j-2}\right)^2\right\}$$

4.1.11

with an appropriate re-scaling of the regularisation parameter. In order to avoid explicit end conditioning, $\hat{f}_0 = \hat{f}_{N+1} = 0$.

Equation 4.1.9 or 4.1.11 can be expressed in matrix form as

$$(\mathbf{H}^T\mathbf{H} + \lambda\Phi)\hat{\mathbf{f}} = \mathbf{H}^T\mathbf{g} \qquad 4.1.12$$

The smoothing parameter λ is selected according to

$$\min_{\lambda} \frac{\left\|\mathbf{H}\hat{\mathbf{f}} - \mathbf{g}\right\|^2}{\left(\text{trace}\left[\mathbf{H}^T\mathbf{H} + \lambda\mathbf{C}\right]\right)^2} \qquad 4.1.13$$

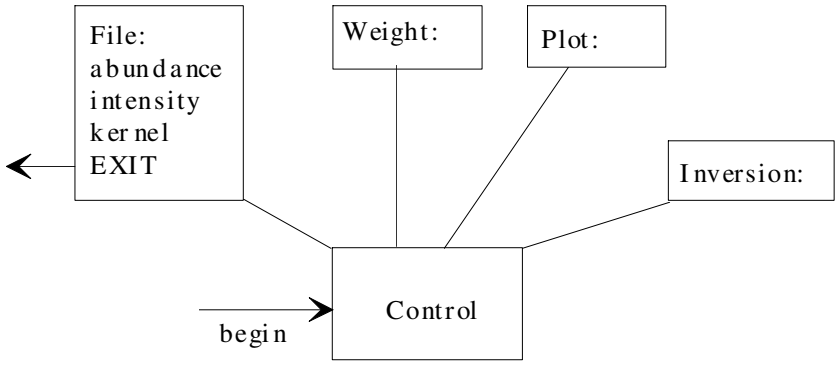
where $\mathbf{C}$ is the hessian matrix of $\Phi(\hat{f})$. This method has the attractive property that we do not need to know explicitly the value of the noise variance of the data point but only their ratio. That is if the true standard deviation of the noise on the i -th element is $\sigma_i = \sigma_0 s_i$ then the scaling factor σ_0 can be calculated *a posteriori* using

$$\sigma_0^2 \frac{\left\|\mathbf{H}\hat{\mathbf{f}} - \mathbf{g}\right\|^2}{(\text{trace}\left[\mathbf{H}^T\mathbf{H} + \lambda\mathbf{C}\right])} \qquad 4.1.14$$

Program steps:

These are summarised in figure 4.1.

Figure 4.1

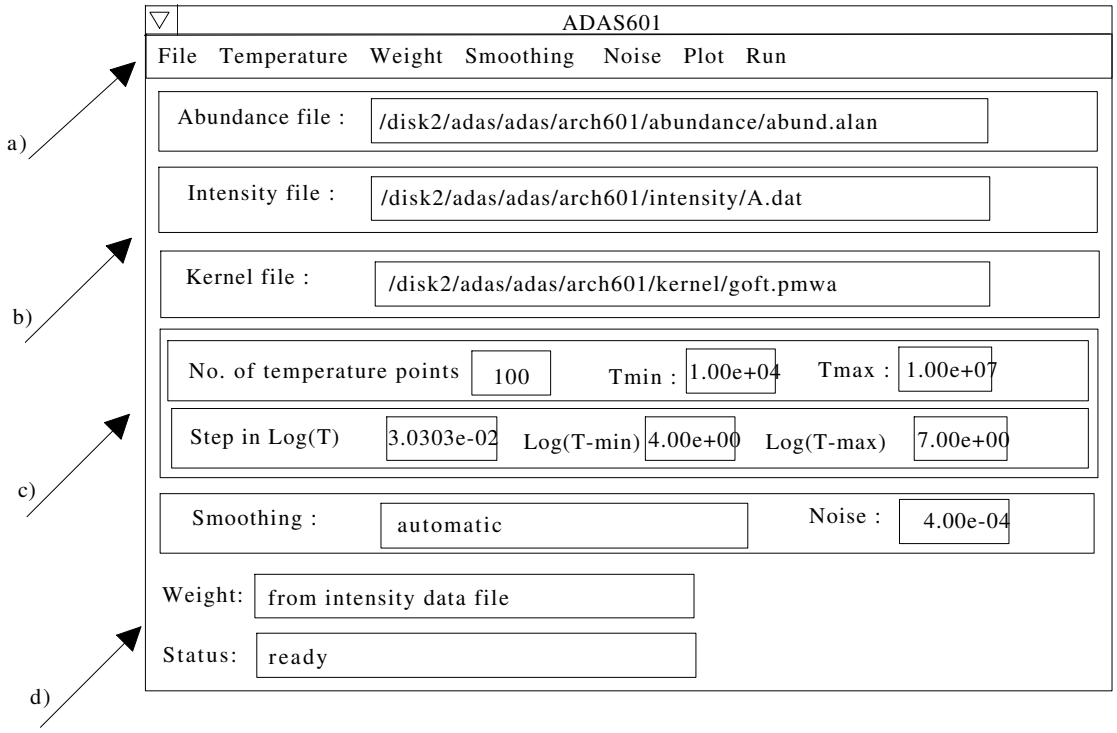


Interactive parameter comments:

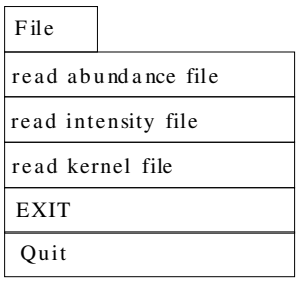
The organisation of the interactive windows differs in ADAS601 from the ADAS norm. Initiate ADAS601 from the ADAS6 series menu. The 'control window' is displayed first.

The **Control window** has the appearance shown below:

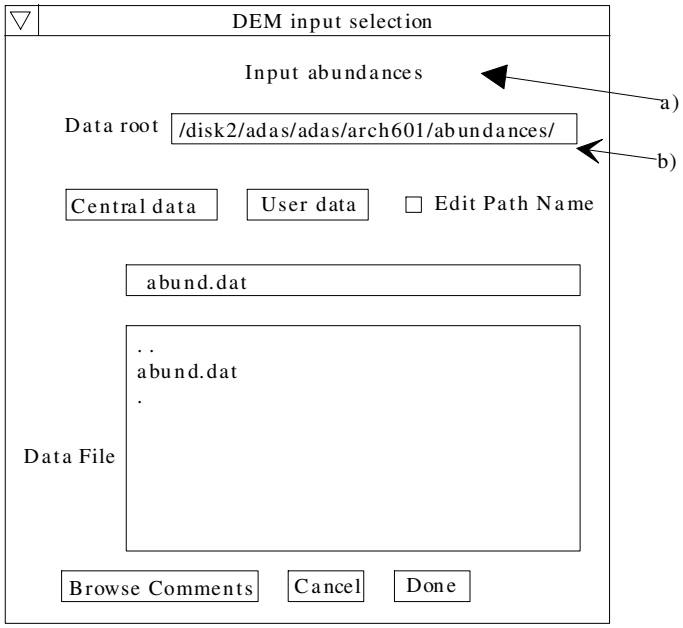
The actions 'File' etc. are activated by clicking on the appropriate name. There are three input data file name information windows and then at the bottom of the control window, shorter information windows for the weighting stategy and the current activity. One can jump freely between actions, but on the first use of this program, the 'File' action must be taken first and files loaded sequentially (see below).



The **File** action drops down the menu shown below:



Clicking on the data type opens the usual form of ADAS file selection window shown below.



1. The data type sought is shown at a)
2. The central ADAS database has no formal data collections of the three types required here, but only sample data. It is suggested that you use the same organisation and main sub-directory naming as the ADAS example. Clicking

the *Central data* or *User data* buttons sets up a Data root b) of the ADAS pattern automatically. Personal data for the program ADAS601 should be held in the subdirectory

/.../<user>/adas/arch601

corresponding to the ADAS central subdirectory

/.../adas/adas/arch601.

Further subdirectories of /arch601 should be assigned, namely, */abundance* , */intensity* and */kernel*. Thus you abundance files should be held in the subdirectory

/.../<user>/adas/arch601/abundance/...

3. It is convenient to set up an additional subdirectory */run* to hold output data from the progarm. Move to this subdirectory before initiating ADAS if you wish to ensure output files are placed directly into this subdirectory.

4. All three files must be identified before excuting the integral inversion.

5. The intensity file has the standard format shown below:

	Spectr. wavelength	configuration	configuration	blnd	G-in
C + 3	312.429	2s1(2)0(0.5) -	3p1(2)1(0.5)	1	5
C + 3	312.4	2s1(2)0(0.5) -	3p1(2)1(1.5)	1	6
C + 3	384.032	2p1(2)1(0.5) -	3d1(2)2(1.5)	2	7
C + 3	384.2	2p1(2)1(1.5) -	3d1(2)2(1.5)	2	8
C + 3	384.165	2p1(2)1(1.5) -	3d1(2)2(1.5)	0	9
C IV	419.718	2p1(2)1(1.5) -	3s1(2)0(0.5)	0	-4

(contd.)

observed wavelength	observed intensity	uncert.	
312.429	14.2	7.2	
312.429			
384.032	8.6	3.3	
384.65	9.5	2.5	
419.718	12.4	2.5	

6. The observed intensity can be given either in *egs cm-2 s-1*, as in the example above, or in *photons cm-2 s-1*. The program will recognise the units from the magnitude. Units can be mixed in the same input data file.

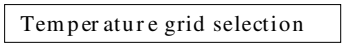
7. The abundance file is of the simple structure shown below:

O	2.470E-04
NE	3.530E-05
SI	3.920E-05
MG	4.470E-05
S	8.630E-06
FE	3.920E-05
CA	2.940E-06

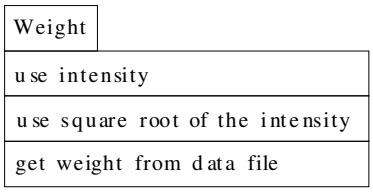
Abundances can be given either as a fraction $N(Z)/N_H$, as in the example above, or in log scale with $\log(N_H)=12.0$. In this latter case, '*H 12.0*' must appear in the data (see the abuandance file example */.../abund.anders_grevesse*.

8. The kernel file is of the form produced directly as the collection file from ADAS506 above. Note that you must keep to precisely the same formatting conventions for you personal files of these types.

The **Temperature** action drops down the menu below. When you click on this, the temperature sub-window at c) in the control window is reproduced with the boxes editable. Note that entry of any one of the fields causes consistent modification of the others.

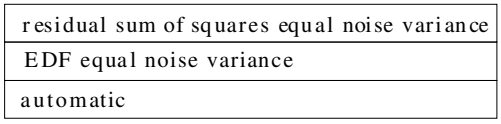


The **Weight** action drops down the menu shown below:

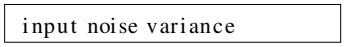


1. Click your choice for weighting of the observed intensities.
2. The last choice from the data file uses the variance estimate of the intensity measurement usually provided as part of the observed intensity data (see the structure of an intensity file). This is the default if no selection is made.

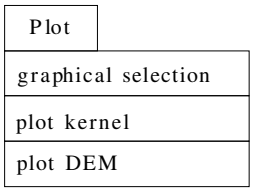
The **Smoothing** action drops down the menu shown below.



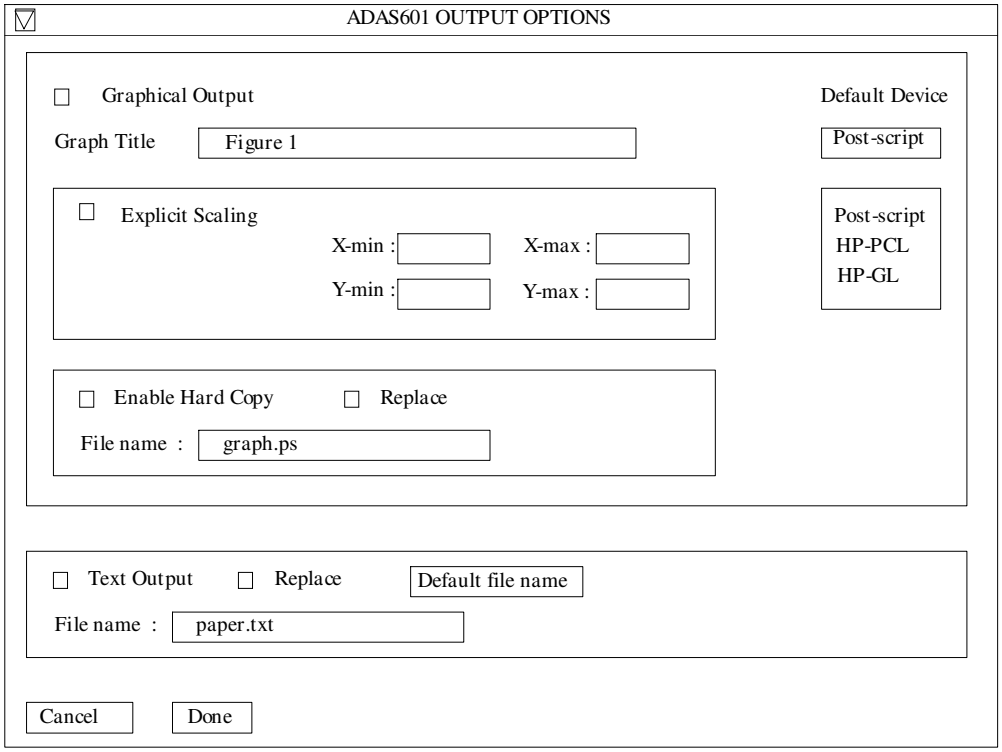
The **Noise** action drops down the menu shown below.



The **Plot** action drops down the menu shown below:

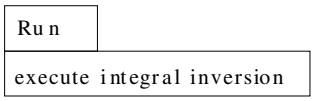


1. Clicking the graphical selection button pops up the standard ADAS output options window below:



2. Click the plot kernel button to show a simple graph of the G(Te) functions available in the kernel file.
3. The DEM plot is only available once the integral inversion has been performed once (see below).

The **Run** action drops down the menu shown below:



1. Click on the execute button to initiate the integral inversion calculation.
2. After completion of at least one calculation the differential emission measure becomes available for plotting as above.

Illustration:

Figure 4.1a shows a plot of kernel data, that is the set of G(Te) functions contained in the selected kernel file. Figure 4.1.b show the resulting differential emission measure for the demonstration case in ADAS. Table 4.1.a shows the standard text output from the code.

Figure 4.1a Graph of the differential emission measure

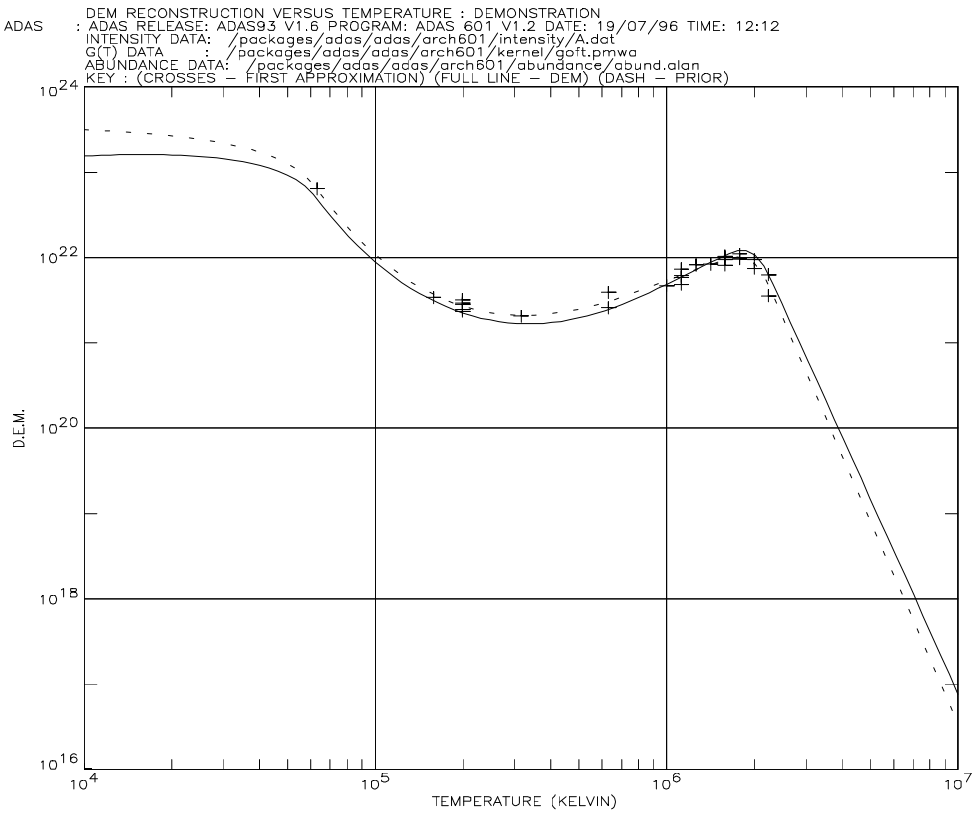
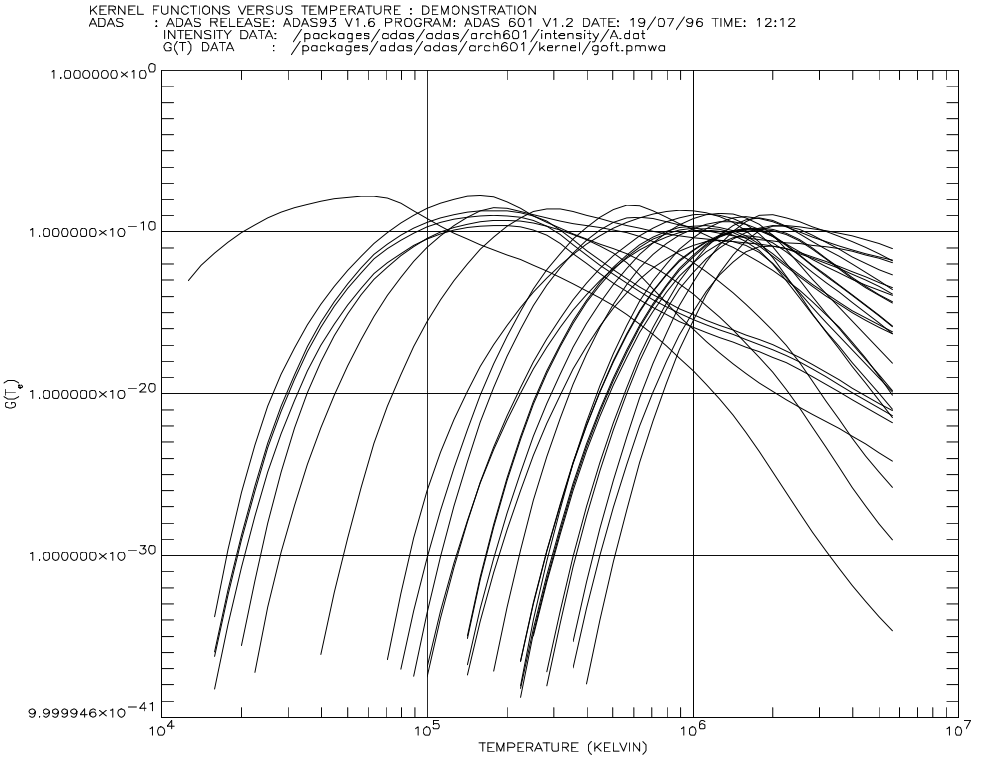


Figure 4.1b Graph of the kernel file (G(Te)) data



Notes: