BESTFIT 1.11 MANUAL

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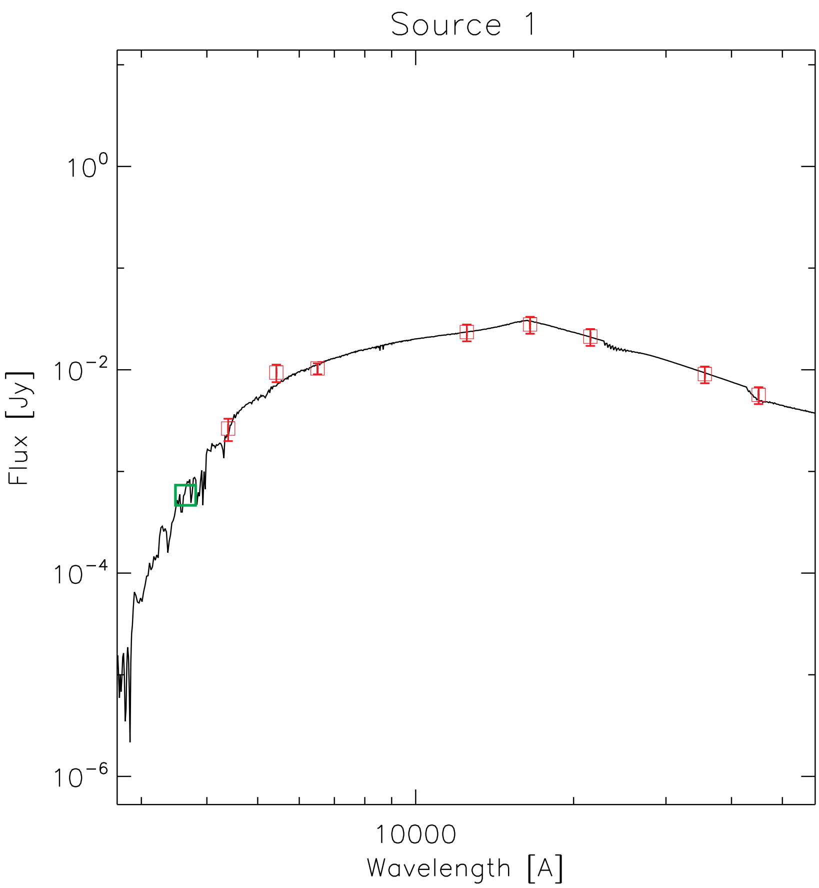

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0.1 BESTFIT overview

BESTFIT is an IDL based function developed to fit photometric data using a collection of template models of star spectra. The method used is based on the χ^2 minimization procedure. Chosing among a collection of models (internal or supplied by the users), BESTFIT computes the spectral model that better fits the input photometric data. BESTFIT also predicts the expected flux in a users-selected photometric filter (or at a given wavelength). This can be useful in all those cases in which a rough photometrical calibration of the fluxes in a given band is needed or when the user wants to check the photometric calibration in a given band. The observed Spectral Energy Distribution (SED) of the a star is compared to a set of spectra using the χ^2 value:

$$\chi^2 = \sum_{i=1}^{N_{\rm filters}} \left[\frac{F_{{\rm obs},i} - a \times F_{{\rm temp},i}(z)}{\sigma_i} \right]^2 \tag{1}$$

where $F_{{\rm obs},i}$ and $F_{{\rm temp},i}$ are the observed and template fluxes in the i-th filter, σ_i is the uncertainty associated to that filter and a is a normalization constant. Using the χ^2 value as a threshold, the users are able to identify the stars in the explored field. Basically, those sources for which the computed χ^2 is very low are well described by a stellar model and can be then classified as stars.

If the users decide to use the internal library of stellar models (Kurucz 1993), BESTFIT gives in output the model name, the stellar temperature, its metallicity and gravity. If instead they decide to use its own library of models, only the ordinary number correspondent to the model used is indicated in the output file.

0.2 Installation

BESTFIT is an IDL (v7.0) function. To use it, the best_fit.pro function needs to be copied either in the working directory or in the IDL library folder (example: /usr/local/itt/idl70/lib/). This is the only file that has not to be modified by the users in order to run BESTFIT. In order to be run, BESTFIT needs some input files that contains all the necessary information and that the users can modify according to their necessity. The first one is the configuration file, described in section 0.3. This file contains the name (and path) of the other files needed. If the best_fit.pro file is located inside the working directory, the following commands can be used:

```
IDL> .compile best_fit.pro

IDL> best_fit, “configuration_file_name.txt”
```

If best_fit.pro was copied in the IDL default library folder, only the second command is required.

0.3 Configuration file

The configuration file contains a list of parameters that BESTFIT uses to perform the fit. Depending on the configuration chosen, the best fitting procedure will be slower (but more precise) or faster (but less precise).

The structures of the input files described are similar to those used by the *hyperz*-code (Bolzonella et al. 2000).

The first parameter listed in the configuration file, FILTERS_FILE, contains the path and name of the filter list. This file contains the list of the filters that the users want to use during the fit. This file can have two different structure. In the first case, setting the FILTER_CONVOL parameter of the configuration file to "no", the fit will be performed without considering the filter's responses. The flux in each band is considered as if it was measured at a specific wavelength (like in a very narrow band). This solution can be a good approximation in those cases in which narrow bands are considered, but it is less precise in all the other cases. However, this procedure is faster and doesn't require the actual filter response of the filters considered (only the characteristic wavelength λ_{eff} is required). A second column in the filters file will contain the names of the filters that the users can set. In table 1, we report an example of the filters file content when the FILTER_CONVOL parameter is set to "no":

4360.0	B_Harris_6002_CTIO	
5370.0	V_Harris_c6026_CTIO	
6517.25	R_WFI_MPG	
12350.0	J_2MASS	
16620.0	H_2MASS	
21590.0	Ks_2MASS	
32000.0	N3_AKARI	
35500.0	I1_IRAC_Spitzer	# FROM handbook IRAC (lamnbda_eff)
41000.0	N4_AKARI	# FROM handbook IRC AKARI (lambda_ref)
44930.0	I2_IRAC_Spitzer	# FROM handbook IRAC (lamnbda_eff)

Table 1: *Content of the filters file in the case FILTER_ CONVOL is set to "no".*

If the FILTER_CONVOL parameters is set to "yes", each model will be convolved with the specific response of each filter used. The filters file structure, in this case has to be different. The first column of the file in this case will be a numerical code representing the filter needed and correspondent to the filter position in the filter.RES file (specified in the FILTERS_RESPONSES_FILE parameter). An example of the content of the filters file for this second case is reported in table 2.

278 # NOAO_CTIO_4m_MOSAIC2 B
279 # NOAO_CTIO_4m_MOSAIC2 V
159 # RWFI_Rc/162_Rc#844+CCD57+wfi_2p2_optics
219 # 2MASS_J
220 # 2MASS_H
221 # 2MASS_K
371 # AKARI_N3
198 # channel_1_IRAC/Spitzer
372 # AKARI_N4
199 # channel_2_IRAC/Spitzer

Table 2: *Content of the filters file in the case FILTER_ CONVOL is set to "yes". The name of the files is optional.*

The parameter FILTERS_RESPONSES_FILE specifies the path and name of the file containing the filters responses (file.RES). If FILTER_CONVOL is set to "yes", the codes specified in the filters file (first column) must correspond to the position of the filter in the file.RES. In this file, the responses of the filters are reported consequentially, with the first column representing an ordinal number (staring from 1), the second column representing the wavelength (in Å) and the third one representing the normalized response. When the response of the successive filter begins, the ordinal number restarts from 1. Each Filter response begins with a line containing the number of lines corresponding to the filter response and the (optional) name. An example of this file is represented in Table 4. One can keep a record of the filters listed in his file.RES in another file, for example using the structure described in Table 3.

ID - description - number of lines		
0001	Koo-Kron U+ filter (Koo's thesis)	13
0002	Koo-Kron J+ filter (Koo's thesis)	23
:		
:		
0275	NOAO KPNO 4m MOSAIC1 B	1201
0276	NOAO KPNO 4m MOSAIC1 V	1301
0277	NOAO KPNO 4m MOSAIC1 I	351

Table 3: *Example of the content of the file.log used to keep a record of the order and the structure of the filters listed in the file.RES.*

13	Koo-Kron U+ filter (Koo's thesis) - 0001	
1	3000.00	0.00000
2	3100.00	0.04300
3	3200.00	0.13000
:	:	:
11	4000.00	0.27400
12	4100.00	0.09900
13	4200.00	0.00000
23	Koo-Kron J+ filter Koo's thesis - 0002	
1	3500.00	0.00000
2	3600.00	0.02500
3	3700.00	0.18200
:	:	:
888	NOAO CTIO 4m MOSAIC2 B - 0278	
1	2698.000	0.000000
2	2702.000	0.000000
:	:	:
886	6238.000	0.000000
887	6242.000	0.000000
888	6246.000	0.000000

Table 4: *Content of the filters file in the case FILTER_CONVOL is set to "yes". The name of the files is optional.*

The parameter METAL_MODELS_FILE specifies the path and the name of the file containing the models that the users want to use. If the KUR93 parameter is set to "yes", the Kurucz (1993) stellar models will be used. In this case, in the file containing the models there will be a list with the path and the folder names of these models. An example is reported in table 5. The users can decide which metallicity models do not want to use simply eliminating them from the list with a # symbol at the beginnning of the line. To select the minimum and maximum temperature and gravity, the parameters T_MIN, T_MAX, GRAVITY_MIN and GRAVITY_MAX of the models can be set in the parameters file.

/home/user1/example/star_spectra/k93models/km50	# metallicity (log_Z relative to solar) = -5.0
# /home/user1/example/star_spectra/k93models/km45	# metallicity (log_Z relative to solar) = -4.5
/home/user1/example/star_spectra/k93models/km40	# metallicity (log_Z relative to solar) = -4.0
:	:
/home/user1/example/star_spectra/k93models/kp10	# metallicity (log_Z relative to solar) = +1.0

Table 5: *Structure of the file containing the Kurucz (1993) models list.*

If the KUR93 parameter is set to "no", the models listed in the METAL_MODELS_FILE will be interpreted as ascii files containing two colums: one with the wavelengths (in Å) and the third with the model value (in units of Hz^{-1}). In this case, the GRAVITY_MIN, GRAVITY_MAX, T_MIN and T_MAX parameters have no effects.

The CATALOG_NAME parameter contains the name of the catalog with the photometric informations that the users want to fit. In the catalog file, the fluxes are reported in units of Jy or AB magnitudes (this has to be specified in the INPUT_UNITS) parameter. The first column of the catalog contains the ID or the name of the sources, then the users need to specify the measured flux in each filter, with the same order indicated in the ILTERS_FILE. The same amount of columns is dedicated to the associated uncertainties in each photometric band. When the flux in a particular filter is not available, the catalog has to contain a -99. value in the corresponding position of the flux and associated error. An example of the input catalog is reported here below:

1 15.34480191 13.96798924 -99.00000000 ... 0.20390000 0.20390000 -99.00000000
2 14.85093083 13.47635142 13.62592220 ... 0.26580000 0.21230000 0.13360000

BESTFIT is able to compute the flux in a filter or at a certain wavelength specified by the users. This option is activated by setting to "yes" the GET_FLUX parameter. If WAV_OR_FILTER is set to "filter", the flux will be computed keeping into account the response of the filter through a convolution with the model shape. The filter code (corresponding to the one in the file.RES explained above) is specified in the FILTER_GET_FLUX parameter. If WAV_OR_FILTER is set to "wavelength", the expected flux will be computed at the wavelength specified by the user in the FILTER_GET_FLUX parameter, that this time is a value of λ expressed in units of [Å]. The slowest but most precise option is the "filter" option. If both FILTER_CONVOL is set to "no" and WAV_OR_FILTER to "wavelength", the RES file is not necessary at all and the elaboration will be the fastest possible.

Using the REF_FILTER option, the users can indicate a reference filter to which the fluxes will be normalized before beeing fitted by the models. This option represents a constraint on the fitted model that will have to pass through the flux value in the chosen filter. If REF_FILTER is set to -1 this option is not active. The reference filter can be chosen only among the filters listed in the filters file. For this reason, the number specified here is not the code of the filter in the file.RES; instead, it is the number corresponding to the filter in the filters file (staring from 1). When this option is not active, the normalization of the model and the input fluxes values are computed considering the mean of the model and input in all the available filters ($\neq$ -99.) weigthed for their associated uncertainties.

A set of options are considered to correct for the extinction. In this sense, if the parameter EXTINCT is set to “yes”, the Allen Milky Way extinction law (Allen 1976) is considered. The value of Av can range between the minimum and maximum values set in the configuration file (AV_MIN, AV_MAX, AV_STEP) with the chosen step. The extinction is kept into account as follows:

$$f_{obs}(\lambda) = f_{int}(\lambda) \times 10^{-0.4A_\lambda} \tag{2}$$

where

$$A_\lambda = k(\lambda)E(B-V) = \frac{k(\lambda)A_V}{R_V} \tag{3}$$

with R_V=3.1. A table with the tabulated $k(\lambda)/R_V$ values for the Allen (1976) extinction law are reported in table 6.

λ[Å]	$k(\lambda)/R_V$
1000	4.2
1110	3.7
1250	3.3
1430	3.0
1670	2.7
2000	2.8
2220	2.9
2500	2.3
2850	1.97
3330	1.69
3650	1.58
4000	1.45
4400	1.32
5000	1.13
5530	1.0
6700	0.74
9000	0.46
10000	0.38
20000	0.11
100000	0.0

Table 6: *Values of $k(\lambda)/R_v$ for the reddening law reported in Allen (1976).*

The OUTPUT_PATH parameter set the path of the folder in which the BESTFIT outputs will be written. The output files names written as a default are set in OUTPUT_FILE1 and OUTPUT_FILE2. The first file will contain the information on each input source (ID, χ^2 value, best fit model, predicted flux in the filter selected in FILTER_GET_FLUX, Extinction Av value) while the second contains the general information on the parameters set. In the file specified in OUTPUT_FILE1, the informations will change depending on the use of certain options specified in the configuration file. However, the first and second column are always the identificative number of the source (ID) specified in the input catalog and the χ^2 value of the best fit. The third column represents the code corresponding to the model associated to the lowest χ^2 value. If the Kurucz (1993) models are used (KUR93 set to “yes”), It is expressed as follows (example): “km15_4250_G15” where “k” stays for Kurucz, “m” for minus (and “p” for positive), “15” for the metallicity model used (in this example is -1.5), “4250” for the temperature model (T=4250K) and “G15” for the gravity model used. If the models used are other models selected by the user, the third column will contain the progressive number correponding to the model used in the model file (METAL_MODELS_FILE parameter). The fourth column contain the number of filters with valid flux or magnitude values (≠-99). If the Kurucz (1993) models are used, the fifth, sixth and seventh columns contains the values of temperature (in Kelvin), logarithmic metallicity and logarithmic gravity. These last two parameters are intended relatively to the solar value. The last column (the fifth or the eighth depending on the kind of models used) contains the value of flux predicted in the filter specified in the FILTER_GET_FLUX parameter. The phisical units are the same specified for the output files (SED_TYPE parameter). An example of the output file is reported here below (in case of Kurucz (1993) models used and GET_FLUX set to “yes”).

```
1 2.324976 km15_4250_G15 8 4250 -1.50 1.50 0.00058355 0.100000
2 5.361801 km20_4250_G30 8 4250 -2.00 3.00 0.00110881 0.250000
3 2.015308 kp00_3500_G50 9 3500 0.00 5.00 0.00007305 0.050000
4 3.071473 km15_4500_G25 8 4500 -1.50 2.50 0.00201259 0.050000
5 2.407928 kp01_3500_G50 10 3500 0.10 5.00 0.00004739 0.150000
```

If other kind of models are used, the output looks like the following one:

```
1 3.413870 12 8 0.00020565 0.150000
2 8.517417 12 8 0.00027680 0.250000
3 12.508525 6 9 0.00003470 0.050000
4 4.427276 15 8 0.00065271 0.050000
5 14.128471 1 10 0.00001180 0.100000
```

The second output file (OUTPUT_FILE2) has the following structure:

```
########################################
# This is the output file of BESTFIT - version 1.0
########################################
DATE: Mon Mar 10 11:52:54 2014
Photometric catalogue :
catalog_sources
# Templates SEDs:
1 /home/user1/example/star_spectra/k93models/km50
2 /home/user1/example/star_spectra/k93models/km40
:
:
19 /home/user1/example/star_spectra/k93models/kp10

# Characteristics of filters:
# n wl_eff
278 4391.3643
279 5426.3340
159 6500.5854
:
```

:
199 45049.348
No reference filter present
Filter in which the flux is computed
n wl_eff
235 3642.28
Gravity (log_g relative to solar) min: 0.00000
Gravity (log_g relative to solar) max: 5.00000
Number of gravity models (available, used): 11 11
T min: 3500.00 K
T max: 50000.0 K
Number of temperature models (available, used): 57 57
Number of temperature models (available, used): 57 15
Minimum Av: 0.0000000
Maximum Av: 0.30000000
Av steps : 0.050000000

If the OUT_BEST_FIT_SED_TXT and/or OUT_BEST_FIT_SED_PS parameters are set to “yes”, two additional kind of files are outputed. The first kind of output is the model that better fits the photometric data for each source in the input atalog. These output files are stored in file.sed files reporting the wavelength in [Å] units and the model value, expressed in the same phisical units specified in the SED_TYPE parameter (AB magnitudes, Jy or normalized units). The second kind of file is an image.ps that shows the best fitting SEDs for each source (same phisical units as in SED_TYPE).

The graphical parameters allows us to show information on the undergoing fitting procedure (VERBOSE and VISUALIZE_FIT) or to change the dimensions, centering and zooming the output plots (RIGHT_EXPANSION, LEFT_EXPANSION, UP_EXPANSION, LOW _EXPANSION, PS_THICK, PS_CHSIZE, PS_XSIZE, PS_YSIZE).

Here below we report an example of the parameters in a configuration file. The parameters are divided in sections. For each single parameter, a short description is reported.

```
############### Configuration file for BESTFIT #################
################# Version 1.11 March 2014 ###################

#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLL INPUT AND PARAMETERS FILES: LLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
FILTERS_FILE              filters_list     # Filter list file. The format of
                                           # the colums in this file depends on the
                                           # FILTER_CONVOL parameter: If it is set to
                                           # 'yes', only one column with the filter code
                                           # is needed. If FILTER_CONVOL is set to 'no',
                                           # the first column will represent the
                                           # characteristic wavelength of the filter and
                                           # the second one the filter name)
FILTERS_RESPONSES_FILE    FILTER.RES
METAL_MODELS_FILE         Kur93_models     # Metallicity models list file
CATALOG_NAME              catalog_sources
INPUT_UNITS               AB_MAG           # JY: Flux in Jansky [Jy].
                                           # AB_MAG: AB magnitudes
```

Table 7: *Parameters in the configuration file and brief description. Input and parameters files*

```
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLL KURUCZ 93 MODELS OPTIONS: LLLLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
KUR93          yes      # "yes" if those listed in METAL_MODELS_FILE
                        # are Kurucz93 models; "no" if the models are
                        # ascii files with two columns, like "wavelength"
                        # and "flux". This last one has to be expressed
                        # in units of Energy area-2 time-2 Hz-2
GRAVITY_MIN    0.0      # log_g relative to solar (min=0.0, step=0.5)
GRAVITY_MAX    5.0      # log_g relative to solar (max=5.0, step=0.5)
T_MIN          3500.    # Temperature (min=3500 Kelvin)
T_MAX          50000.   # Temperature (max=50000 Kelvin)
```

Table 8: *Parameters in the configuration file and brief description. Options concerning the Kurucz (1993) stellar models.*

```
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLLLL EXTINCTION LLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
EXTINCT    yes     # With 'yes', the extinction law (Allen 1976
                   # for the Milky Way) will be considered.
AV_MIN     0.0     # Minimum extinction value
AV_MAX     0.3     # Maximum extinction value
AV_STEP    0.05    # Step between different values
```

Table 9: *Parameters in the configuration file and brief description. Options concerning the Extinction parameter.*

#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
#LLLL COMPUTE EXPECTED FLUX IN A SELECTED FILTER (OR WAVELENGTH): LLLLL		
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
GET_FLUX	yes	# If "yes", the output file contains a column
		# with the expected flux at at a certain
		# wavelength or in a certain filter (specified
		# in FILTER_GET_FLUX. The flux will be expressed
		# in the same units of the output seds (SED_TYPE)
WAV_OR_FILTER	filter	# If "wavelength", the flux is computed at the
		# wavelength specified in "FILTER_GET_FLUX". If
		# "filter", the flux is computed in the filter
		# (log number) specified in "FILTER_GET_FLUX".
FILTER_GET_FLUX	235	# 3642.28 # Wavelength [Angstrom] or filter (ordered as
		# in the filters.log specified in
		# FILTERS_RESPONSES_FILE) in which compute the
		# expected flux.

Table 10: *Parameters in the configuration file and brief description. Parameters used to get the flux in a selected filter or at a certain wavelength (from a fitted model).*

#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
#LLLLLLLLLLLLLLLLLLLLLLLLLL FIT PARAMETERS LLLLLLLLLLLLLLLLLLLLLLLLLLLL		
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
FILTER_CONVOL	yes	# if "yes" (slowest option), fluxes will be
		# convolved with the filter response. If "no"
		# (fastest option), the flux is computed at the
		# precise position of the wavelength that in this
		# case has to be written in the filters file.
REF_FILTER	-1	# Filter to which normalize the fluxes during the
		# fit (ordered as in the FILTERS_FILE). This
		# option can be used in the case the photometry
		# in one particular filter is especially better
		# then in the other. If "-1" is set, all the
		# filters are considered with the same weight

Table 11: *Parameters in the configuration file and brief description. Parameters concerning the fit options.*

#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL OUTPUTS: LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL		
OUTPUT_PATH	outputs/	# folder name in which to put SEDs and output files
		# Default is the directory in which BESTFIT is run
OUT_BEST_FIT_SED_TXT	yes	# Best fit SED outputs (id.sed)
OUT_BEST_FIT_SED_PS	yes	# Best fit SED outputs (id.ps)
OUTPUT_FILE1	out_sources	# Output with informations on single sources
OUTPUT_FILE2	out_info	# Output with informations on the fit procedure
SED_TYPE	Jy	# NORM: Flux [ergs cm^{-2} s^{-1} Hz^{-1}] or Jy,
		# normalized to the Flux in the referement filter
		# AB_MAG: Best fit SED in AB magnitudes (only if
		# the input catalog is in AB_MAG or Jy units)
		# JY: Flux in Jansky [Jy]

Table 12: *Parameters in the configuration file and brief description. Output options.*

```
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLLL GRAPHICAL PARAMETERS: LLLLLLLLLLLLLLLLLLLLLLLLL
#LLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLLL
VERBOSE            yes   # If "yes", the name of the model is printed at
                         # screen, together with the corresponding chi2
                         # and the best fit chi2
VISUALIZE_FIT      yes   # If "yes", the best fit is visualized at screen,
                         # together with the available data points and
                         # associated uncertainties
RIGHT_EXPANSION    1.    # enlarge plots on the right side
LEFT_EXPANSION     1.    # enlarge plots on the left side
UP_EXPANSION       1.    # enlarge plots on the upper part
LOW_EXPANSION      10.   # enlarge plots on the lower part
PS_THICK           2.    # Thickness of the output plots (only files.ps)
PS_CHSIZE          1.2   # Characters Dimension on the output plots
                         # (only files.ps)
PS_XSIZE           1.5   # x size of the ps plot (only files.ps)
PS_YSIZE           1.5   # y size of the ps plot (only files.ps)
```

Table 13: *Parameters in the configuration file and brief description. Graphical parameters.*

Bibliography

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