SED3FIT

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I present the code SED3FIT[1] (Berta et al. 2013), performing SED fitting with a combination of three components: stellar emission; dust emission from star formation; and a possible dusty torus/AGN. The stellar and dust emission are linked by energy balance arguments: the amount of energy absorbed by dust at UV-optical wavelength is re-emitted at infrared wavelengths. Torus emission is independently included.

Originally inspired by MAGPHYS (da Cunha et al. 2008), this code was first designed, used and briefly described by Berta et al. (2013). The libraries of reference for the three components are: stellar population emission spectra computed using the Bruzual & Charlot (2003) or Bruzual (2007) models, including the effects of dust attenuation as prescribed by Charlot & Fall (2000); emission from dust, computed as described in da Cunha et al. (2008); torus AGN emission by Fritz et al. (2006) and Feltre et al. (2012).

1 This release and proper credits

The SED3FIT package includes the fortran codes needed to produce filter-convolved libraries, as well as the code performing the three components fit. A couple of reduced torus/AGN libraries, extracted from the full library by Fritz et al. (2006), in the recent implementation by Feltre et al. (2012), are also provided. In order to run the code, one needs also to download the optical and IR-dust libraries by da Cunha et al. (2008), the filter files, and other additional files of MAGPHYS, which can be retrieved from the webpage http://www.iap.fr/magphys. For further details about the original MAGPHYS, please read da Cunha et al. (2008, 2015).

When using SED3FIT, proper referencing is warmly appreciated: please cite and refer to the Berta et al. (2013) and da Cunha et al. (2008) works. For tracking the work carried out with SED3FIT, it is always advisable to contact the author (S. Berta). Such a contact could also be useful if further details are desired, or simply for collaborating.

1.1 Thanks

I would like to thank the collaborators, who already benefited from the output of SED3FIT, morally supported me, and stimulated me to finally produce a sharable version: Vernesa Smolčić, Ivan Delvecchio, Hugo Messias, Carlotta Gruppioni, Anna Feltre, Lucia Marchetti, Jacopo Fritz, David Rosario, Ivano Baronchelli, Giulia Rodighiero, Joana de Medeiros, Barbara Lo Faro.

[1] previously known also as *Balance of Energy in gaLaxies with Infrared Nuclear emission* (BELIN) code.

1.2 Installation

The SED3FIT code and additional components needs a *gfortran* compiler. Fortran source files are included in the release, as well as a `Makefile` to produce executables.

2 Code/procedure components

Running SED3FIT consists in two main steps, aimed at: *1)* convolve the model libraries with filter passbands, for each redshift under exam, and produce model cubes to be then compared with observations; *2)* actually combine the three model components and compare the result to observations, finally converging to a best fit and marginalized probability distribution functions of each physical parameter involved in the modeling, as well as for derived quantities (e.g. stellar mass, AGN accretion luminosity, etc.).

2.1 Step-by-step streamline

This procedure involves also other minor steps, needed to prepare the data and the libraries to be used. Here follows a very brief and schematic outline of all steps:

1. locate the MAGPHYS libraries of optical and IR models;
2. locate the torus library;
3. locate the libraries of filters (in MAGPHYS and EAZY formats);
4. prepare the catalog in MAGPHYS format;
5. prepare the list of filters;
6. prepare the list of torus models to be used, including the torus parameters;
7. prepare the *input_sed3fit* file;
8. prepare the *get_libs* and *fit_sample* scripts (as in the original MAGPHYS);
9. prepare the running directory and copy there catalog, filters, optional ascii filters library files, list of torii, *input_sed3fit* file, *get_libs* and *fit_sample* scripts;
10. produce the redshift grid using the code MAKE_ZGRID_0P01 (using $\Delta z = 0.01$);
11. run *get_libs*, which calls the GET_*_COLORS codes and produces filter-convolved libraries; remember to use the proper libraries setup (BC03/CB07, torii, etc.);
12. move the filter-convolved libraries thus produced to their storage directory, if needed;
13. finally run the *fit_sample* script, which calls SED3FIT for each entry in the catalog.

2.2 Description of steps

The formats of files to be prepared are described in Sect. 3. The MAGPHYS optical and infrared libraries are in binary format and can be directly retrieved from the MAGPHYS web page. The requirements for the torus library are described in Sect. 6. Filters formats are in sect. 7. Finally, the content of the SED3FIT main input file is listed in Table 1.

The filter-convolution and the SED fitting codes work on one object (galaxy) at at time. The scripts *get_libs* and *fit_sample* read a list of redshift values, and launch the codes subsequently on all objects/redshifts in the catalogs.

The MAKE_ZGRID_0P01 short code reads redshift values from the input catalog and offers the possibility to either use all of them "as they are" or build a grid of evenly-spaced redshifts. The output *zlibs.dat* list of redshifts is nothing else than the abovementioned input for the *get_libs* and *fit_sample* shell scripts.

The *get_libs* script calls the codes GET_OPTIC_COLORS, GET_IR_COLORS, and GET_TORUS_COLORS. For each redshift value in the list the model SEDs are shifted and convolved with filter passbands, thus producing cube **.lbr* files including all convolved fluxes.

The *fit_sample* finally calls the SED3FIT code for each object in the catalog.

Name	Example value	description
obs	'./observations.dat'	input (phot) catalog
user_filt	'./filters.dat'	list of filters to be used
filtfile	'....../FILTERBIN.RES'	MAGPHYS filters library
eazy_filt_info	'./eazy_FILTER.RES.info'	info file for EAZY ascii filters
eazy_filt	'./eazy_FILTER.RES'	library of EAZY ascii filters
infile1	'....../OptiLIB_bc03.bin'	first OPT stellar library
infile1b	'....../OptiLIBis_bc03.bin'	second OPT stellar library
infile2	'....../InfraredLIB.bin'	IR dust library
torus_list	'list_torus_models_sed3fit.txt'	list of torii
convlib1	'starformhist_bc03_z'	main name of convolved optical library
convlib2	'infrared_dce08_z'	main name of convolved infrared library
convlib3	'torus_f06_z'	main name of convolved torus library
lib_dir	'../all_libs/'	path of filter-convolved libraries
n_ran_opt	1000	number of random samples of optical stellar library
n_ran_ir	1000	number of random samples of IR SF dust library
n_ran_norm	100	number of random normalizations of torus
n_ran_torus	100	number of random samples of torus library
print_all_out	0	print the full list of attempted combinations?
print_pho_pdf	0	print photometry PDF file?
use_up_lim	0	switch on/off the *erf* function for up. lim.
use_rdn_t	1	switch off/on random sampling of torus library

Table 1: Content of the *input_sed3fit* file needed to run SED3FIT.

3 Input files

The SED3FIT code needs the following input files:

- the input file *input_sed3fit* setting the main input parameters, as summarized in Table 1.
- an input photometric catalog, in the same format as required by MAGPHYS, for example named *observations.dat*.
- a file listing the filter passbands, in the same format as required by MAGPHYS (but see Section 7 for additional filters), for example named *filters.dat*.
- a binary filter library, as the one included in the MAGPHYS package.
- an ascii library of filters in EAZY format (see Section 7).
- a *zlibs.dat* file produced by the MAKE_ZGRID code (see Sect. 2.2).
- filter-convolved libraries, as produced by the codes GET_*_COLORS starting from the optical (Bruzual & Charlot 2003, BC03; or Bruzual 2007, CB07), IR (da Cunha et al. 2008) and torus full libraries (see Sect. 2.2).
- a list of torus/AGN models to be used, inlcuding thier main parameters (see Sect. 6).

See Section 2.1 for a brief step-by-step tutorial of how to run SED3FIT.

4 The *input_sed3fit* file

The names (including path) of the input libraries and files are specified in the first part of *input_sed3fit* file (see Table 1).

The `obs` and `user_filt` parameters give the filename of the photometric catalog and of the list of filters to be used. The catalog consists of an ID column and a redshift column, followed by a flux and fluxerr column for each band to be used (and listed in the filters file). The list of filters consists of four columns: filter name, central wavelength, filter ID in library, and use-flag (0/1).

The filenames and paths of libraries are described by the input parameters `filtfile`, `eazy_filt_info`, `eazy_filt`, `infile1`, `infile1b`, `infile2`, and `torus_list`. Filter libraries are given by `filtfile` (MAGPHYS binary filters) and `eazy_filt_info`, `eazy_filt` (the EAZY ascii filters). The filenames of the MAGPHYS binary optical libraries are `infile1` and `infile1b`, while `infile2` is the IR dust emission library. Finally, the list of torii to be used is named `torus_list`.

The three parameters `convlib1`, `convlib2`, and `convlib3` assign a name to the convolved libraries, produced by the codes GET_*_COLORS. For each redshift in the list, the convolved libraries are saved with filename "`convlib1`_*z*.lbr*", where "*" denotes the redshift value. Finally, `lib_dir` is the path where the convolved libraries should be stored (manually) after running GET_*_COLORS and where they will then be seeked by SED3FIT.

The parameters `n_ran_opt`, `n_ran_ir`, `n_ran_norm`, `n_ran_torus`, `print_all_out`, `print_pho_pdf`, `use_up_lim`, `use_rdn_t` control the performance of SED3FIT and are described in Sects. 5, 8, and 9.

5 Random sampling of libraries

Adding a third component to the SED fitting implies a significantly increase in the number of model combinations to be compared to the data. The optical library embedded in MAGPHYS consists of

50,000 models (split in two files), to be combined to other 50,000 IR-dust models. The total number of combinations is therefore of the order of 10^9 (although several are excluded by the priors conditions regulating energy balance). Adding a torus/AGN library of – for example – a couple thousands models implies reaching 10^{12} possible combinations. Moreover, the normalization of the stars+dust component is free to vary, because the residuals could in principle represent AGN+torus emission in different amounts at different wavelengths. Therefore the number of combinations increases further, and it is clearly not possible to sample all combinations.

Random sampling of the libraries and of the stars+dust model normalization has been chosen. Optical models are randomly picked from the binary star formation library, as many times as given by the *input* parameter `n_ran_opt`. For each choice of the optical model, a number `n_ran_ir` IR-dust models (da Cunha et al. 2008) are picked. For each combination optical+IR, a random normalization is used – limited to a range embedded in the code – for a number of times given by `n_ran_norm`. In this way, the effective number of attempted optical+IR combinations is already very large, although the individual values of `n_ran_opt`, `n_ran_ir`, `n_ran_norm` are relatively small (usually of the order of 1000). The residuals of the observed photometry from the normalized optical+IR model are finally fit with the torus/AGN model. In this way, the torus is effectively fit to the data in a simultaneous 3-component model, because the normalization of the stars+dust component is free (see also Fritz et al. 2006; Berta et al. 2007; Noll et al. 2009; Santini et al. 2012; Lusso et al. 2012; Bongiorno et al. 2012; Ciesla et al. 2015, for alternative implementations).

5.1 Sampling the torus/AGN library

As mentioned before, two options are possible for the torus/AGN library sampling.

First of all, it is possible to randomly pick `n_ran_torus` models from the list of torii/AGNs for each (`n_ran_opt`, `n_ran_ir`, `n_ran_norm`) triplet. A typical choice is to use 100 samplings.

If the list of torus/AGN models is small, e.g. 10 models only are used, it is not convenient to randomly sample the library a large number of times. A better option is instead to use all models in the torii/AGNs list, testing them all one by one, systematically. In other words, in this case the random sampling of the torus/AGN library is switched off and the number of torus/AGN models considered is simply equal to the length of the torii/AGNs list.

The *input* parameter controlling how the torus/AGN library is sampled is called `use_rdn_t` and must have a value of “0” (no random sampling of torus library) or “1” (switch random sampling on).

6 The torus/AGN library

The use of the torus/AGN library is implemented such that any library can be fed to the code, provided it is arranged in the proper format. Two main pieces are needed: *(a)* a file containing the list of all models, including the main parameters for each one of them; *(b)* the files containing the SED of models, one per each model.

The list file includes all properties of torii/AGNs. It was designed on the Fritz et al. (2006) and Feltre et al. (2012) library, therefore the properties listed are those available there: filename (including path, and within single quotes), rm, ct, ta, be, al, plw, phi, where *rm* is the outer/inner torus radii ratio; *ct* is the torus aperture angle (measured from the polar axis); *ta* is the value of the equatorial optical depth; *be* and *al* describe the density distribution along the horizontal and vertical axes; *plw* is the slope of the power law in the NIR-MIR domains (valid for Fritz et al. 2006, but no more for Feltre et al. 2012); *phi* is the viewing angle of the line of sight.

When using a different library, if any of these properties is unknown, one should simply put an arbitrary value (e.g. -99.99) in that field. In this case, the user should keep in mind that the best fit values and the PDF of the given parameter will be of no use. On the other hand, the 7 columns can be filled with alternative parameters – if available – provided that the user keeps track of the correspondence between parameters name and meaning.

Each torus/AGN model SED file should contain at least 2 columns: wavelength in units of [μm] and total luminosity in units of [erg/s/μm]. The code assumes that the models are normalized such that their accretion luminosity of the AGN is 10^{46} [erg/s].

Each torus/AGN model SED file must contain the emission as seen from one single line of sight only. In the case of the Fritz et al. (2006) and Feltre et al. (2012) models – for example – each original file provided by the authors includes 10 different lines of sights, which need to be split into separate files in order to be properly used as inputs of SED3FIT. The small library included in this release already accounts for this split.

6.1 Using the list of torii to impose priors on AGN models

Sometimes additional information on the nature of the AGN hosted in the galaxies, whose SED is under study, is available. A typical example are X-ray data or mid-IR spectroscopy, providing constraints on N_H, or on the presence of Si absorption features.

The SED3FIT code does not have the possibility to set constraints on specific parameters, but it is possible to use the additional knowledge a priori, by working on the input list of torus/AGN models.

For example, if it is known that a given set of galaxies consists of type-2 AGNs, one can simply limit the library to lines of sight intersecting the obscuring torus.

6.2 The Fritz/Feltre torus/AGN library

We adopt the torus/AGN library by Fritz et al. (2006), in its most recent update described by Feltre et al. (2012). The model SED includes the emission of central AGN nucleus as well as of the dusty obscuring torus.

The geometry of the dust distribution around the central AGN nucleus is varied by means of the ratio between outer and inner radii ($R_{\rm out}/R_{\rm in}$ = 10–150), and the aperture angle of the torus (measured starting from the equatorial plane, Θ = 50°–140°). The latter is parametrized as the half-width of the polar "hole" of the torus, called *ct*, with value $ct = 90 - \Theta/2$.

The spectrum emitted by the central engine is modeled with a broken power-law $\lambda\, L(\lambda) \propto \lambda^{\alpha}$, with indexes $\alpha_1 = 1.0$, $\alpha_2 = -0.2$, $\alpha_3 = -1.5$, $\alpha_4 = -4.0$ in the ranges λ_1 = 0.001–0.05, λ_2 = 0.05–0.125, λ_3 = 0.125–10, and λ_4 >10 μm, respectively. When visible along the line of sight, the direct AGN light is included in these SED models.

The density distribution of dust in the torus is modeled, in polar coordinates, as $\rho\,(r, \theta) = A \times r^{\beta} \exp\left(-\gamma \times cos(\theta)\right)$, where θ is the polar angle, β is the slope of the radial dependence of density, assuming values -1.0, -0.75, -0.5, -0.25, 0.0; γ is the slope of the polar dependence and can have values 0.0, 2.0, 4.0, 6.0. The two parameters β and γ are called *be* and *al* in the models list ad filenames.

The optical depth at the equator covers the range $\tau_{9.7}\,(\mathrm{eq}) = 0.1 - 10.0$ at 9.7 μm. The effective optical depth along the line of sight is computed as $\tau_{9.7}\,(\mathrm{l.o.s.}) = \tau_{9.7}\,(\mathrm{eq}) \times \exp\left(-\gamma\, |\cos\phi|\right)$, where ϕ is the viewing angle. This relation holds only if $\phi < 2\Theta$, otherwise $\tau_{9.7}\,(\mathrm{l.o.s.}) = 0.0$ because the line of sight does not intersect the dusty torus.

The full library by Feltre et al. (2012) comprises 2376 models, each one computed at 10 different lines of sight angles ϕ. We usually limit the use of this library to $R_{\rm out}/R_{\rm in} \leq 100$, as extreme values have so far not been confirmed by observations (e.g. Mullaney et al. 2011; Hatziminaoglou et al. 2008; Netzer et al. 2007). Similarly, we avoid extreme optical depths, keeping $\tau_{9.7}\,(\mathrm{eq}) \leq 6.0$. In order to further reduce the number of models to be used, a typical choice is to select only a limited number of β and γ values, e.g. $\beta = -1.0,\ -0.5,\ 0.0$ and $\gamma = 0.0$.

Nevertheless, in this release we provide only a small library of 10 models, spanning the whole range of colors covered by the full library. This is meant to be used with the option `use_rdn_t`=0 and was introduced to speed up the analysis of very large samples (see for example Delvecchio et al. 2014), and limit degeneracies due to limited data coverage.

See Fritz et al. (2006) and Feltre et al. (2012) for more details on this model. The full library can be retrieved by contacting J. Fritz and A. Feltre directly. For a comparison of smooth torus models and clumpy torus models see Feltre et al. (2012) and Stalevski et al. (2012).

7 Filter passbands

As of August 2015, the filters library of MAGPHYS contains 422 passbands, which are likely enough to cover the needs of most users. In case these are not enough, and the user does not want to require an ad hoc update of the filters binary file, the SED3FIT package allows for an alternative filters file.

The GET_*_COLORS codes have been modified to accept also an ascii filter file, in EAZY (Brammer et al. 2008) format. In order to use passbands from this file, the identification number of the extra filters should be $10000 + \mathrm{ID}_{\mathrm{EAZY}}$, where $\mathrm{ID}_{\mathrm{EAZY}}$ is the identification number of the given filter in the EAZY-formatted file.

As usual in EAZY, two files are needed: one containing the whole filters library, and one containing its short description. The two files need to be named as in the *input_sed3fit* file.

8 Upper limits

Photometric upper limits are recognized when the actual flux is negative and the associated uncertainty is positive, i.e. $S_\nu < 0$ and $\sigma_\nu > 0$, for a given band. In this case, the upper limit is set to the value of $\sigma_\nu > 0$, as in the catalog.

The contribution to the χ^2 from a non-detected band having an upper limit estimate is computed as:

$$\chi^2_{\mathrm{not\ det}} = 2 \log \left(0.5 \left(1 + erf \left(\frac{\sigma_\nu - S_{\nu,\mathrm{model}}}{\sqrt{2}\sigma_\nu} \right) \right) \right) \tag{1}$$

The input parameter `use_up_lim` switches on/off the use of the above equation and of upper limits (defined as above) in the process of SED fitting.

9 Additional control parameters

Table 1 lists the input parameters needed by SED3FIT, in the *input_sed3fit* file. Some of them have already been described in the previous Sections.

9.1 lib_dir

The parameter lib_dir is the path of the directory where the library files produced by GET_*_COLORS are stored. When dealing with large samples of galaxies it might be convenient to fit several objects in parallel, using multiple CPUs. In fact SED3FIT is not parallelized and therefore uses one CPU at a time, only. If a multi-core machine is available, then it is possible to take advantage of its full capabilities by running several processes in parallel, each one fitting a different SED, separately, in different directories. For all processes, a common library directory is preferable.

9.2 torus_list

The filename of the list of torus/AGN models to be used is controlled by the parameter torus_list (see Section 6). In addition to the filename of each model, it contains key pieces of information, to be then used to produce PDFs.

9.3 n_ran_*

As described in Sect. 5 the random sampling of libraries is controlled by four parameters, that set the number of samplings of the optical, IR, torus libraries, as well as the number of random normalization values of the stars+dust model.

The random sampling of the torus library is switched off/on by the parameter use_rdn_t. If the library is small (e.g. as the provided 10-torus list), it is more convenient to scan it systematically rather than randomly pick models.

9.4 print_all_out

Since the sampling of the optical and IR libraries is random, one might want to keep track of the actual attempted combinations for further checks/studies.

For example, Delvecchio et al. (2014) compared the results of SED fitting with and without the torus/AGN component by means of a Fisher test, in order to evaluate the statistical significance of the torus presence. To this aim they fed to MAGPHYS the list of optical/IR models actually used in the run with torus/AGN, in order to properly perform the test.

The print_all_out switches off/on the writing of an additional output file for each entry in the input catalog. This file is named **.all* and contains the list of all optical and IR model ID combinations attempted while fitting. It contains 3 columns: the ID of the stellar model, a flag indicating whether the stellar model belongs to the 1st or 2nd optical library (from the MAGPHYS package), the ID of the IR dust model.

Note that printing the **.all* file slows down the code.

9.5 print_pho_pdf

As a result of the SED fitting, the best fit model is recorded in the **.sed* files, and the PDF of the relevant parameters and derived quantities are saved in the **.fit* outputs. Only the best fit SED is recorded, while it might desirable to keep track also of the other attempted SEDs, be it even for visualization puroposes only.

The option print_pho_pdf=0/1 allows one to record the PDF and percentiles of the modeled photometry, for each photometric passband used. These PDFs are stored in the new output files **.pho*.

It is important to note that these PDFs are computed *only* for passbands and *not* at all wevelengths in the model wavelength grid. Figure 1 shows an example SED fitted by SED3FIT. On the left the best fit is shown, on the right the 2.5th-97.5th and 16th-84th percentiles ranges.

Note that recording the photometry PDFs and printing the **.pho* file slows down the code.

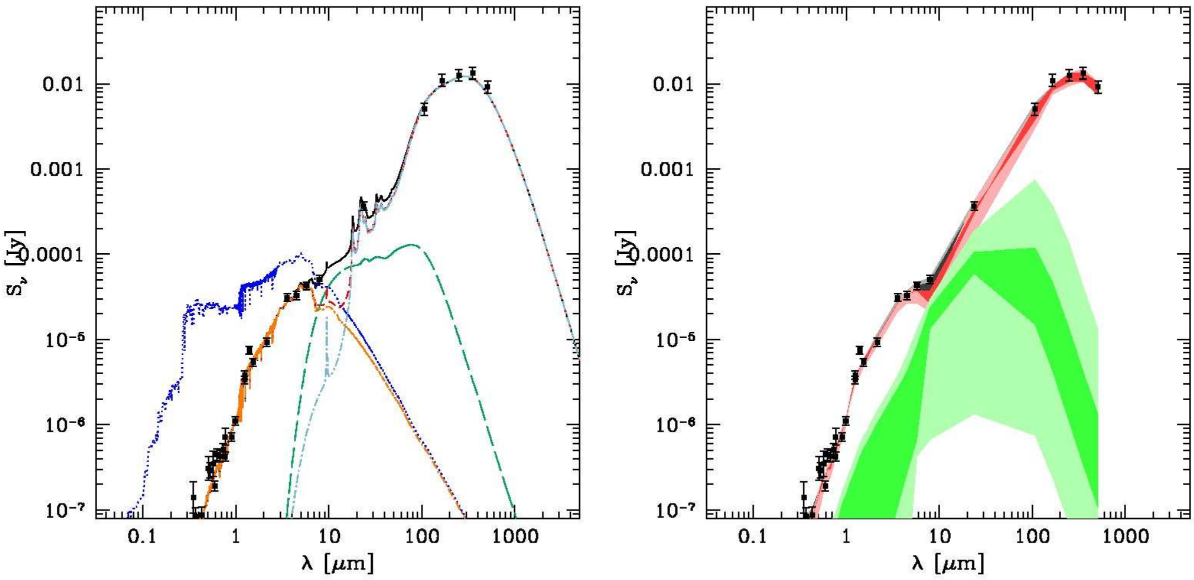

Figure 1: Example fit with SED3FIT. *Left*: best fit solution. The blue dotted line represents the unobscured optical/NIR stellar emission; the orange dashed line is the obscured stellar emission; the light-blue dot-dash line is the emission from dust; the red line combines the obscured stellar emission and the dust emission; finally green long-dashed line depicts the torus/AGN component and the thick solid black line is the total emission. *Right*: 2.5th-97.5th and 16th-84th percentile ranges of the models attempted, for the torus (green), stars+dust (red) and total (gray) components, computed through the used photometric passbands.

10 Output files

Depending on the input setup, SED3FIT can produce up to 4 files for each entry in the input catalog. These are called **.sed*, **.fit*, **.all*, and **.pho*. The label "*" is nothing else than the name of each entry, i.e. the value in the first column of the input photometric catalog.

The **.all* and **.pho* outputs have already been described above. The **.sed* and **.fit* output files are very similar to those produced by MAGPHYS, with some changes related to the larger number of output parameters recorded.

The **.sed* file contains the best fit model. Just like in MAGPHYS, few best fit parameters defining the stars+dust model are listed, then followed by 7 columns describing the SED:

```
log(lambda [Angstrom])
log(Lum, total, [Lsun/Angstrom])
log(Lum, total excluding AGN, [Lsun/Angstrom])
log(Lum, stars, not attenuated, [Lsun/Angstrom])
log(Lum, torus/AGN, [Lsun/Angstrom])
```

```
log(Lum, stars, attenuated, [Lsun/Angstrom])
log(Lum, SF dust, [Lsun/Angstrom])
```

The **.fit* file contains the main best fit parameters and derived quantities for all three spectral components, and the PDFs of the model parameters and derived quantities:

```
observed fluxes and errors in MAGPHYS work-format

ID of optical, IR, torus best fit components, chi2, redshift

best fit parameters:
tform, age_wm, age_wr, fmu(SFH), fmu(IR), mu, tauv, sSFR6, sSFR7, sSFR8,
M*, Ldust, T_W^BC, T_C^ISM, xi_C^tot, xi_PAH^tot, xi_MIR^tot, xi_W^tot,
tvism, Mdust, SFR6, SFR7, SFR8
torus_rm, torus_ct, torus_ta, torus_be, torus_al, torus_plw, torus_phi,
a_torus, agn_frac, L(IR,tot), L(IR,SF), L(IR,AGN), L(acc), tau(9.7, l.o.s.)

Mid-IR results (best fit): AGN fractions in the (1.0-2.5), (2.5-5.0), (5-10),
(10-20), (20-40), (5-40) micron wavelength ranges

best fit model fluxes in MAGPHYS work-format

Marginal pdf histograms
and 2.5th, 16th, 50th, 84th and 97.5th percentiles
for each of the following parameters:

tform
age_wm
age_wr
f_mu (SFH)
f_mu (IR)
mu parameter
tau_V
sSFR_0.001Gyr
sSFR_0.01Gyr
sSFR_0.1Gyr
M(stars)
Ldust
T_C^ISM
T_W^BC
xi_C^tot
xi_PAH^tot
xi_MIR^tot
xi_W^tot
tau_V^ISM
M(dust)
SFR_0.001Gyr
```

```
SFR_0.01Gyr
SFR_0.1Gyr
torus rm
torus ct
torus ta
torus be
torus al
torus plw
torus phi
torus normalization
agn fraction
L(IR,tot)
L(IR,AGN)
L(IR,SF)
L(acc)
agn fraction (1.0-2.5 um)
agn fraction (2.5-5.0 um)
agn fraction (5-10 um)
agn fraction (10-20 um)
agn fraction (20-40 um)
agn fraction (5-40 um)
tau(9.7um, along the line of sight)
```

The computation of $L_{\rm acc}$ assumes that the torus/AGN models are normalized to $L_{\rm acc} = 10^{46}$ [erg/s]. The general "agn fraction" and IR luminosities are computed between 8 and 1000 μm.

Note that the number of output parameters and derived quantities is rather large, but the user should keep in mind that their use should be commensurate to the quality of the input data. Some quantities, such as stellar mass or the AGN fraction in different wavelength ranges are rather stable. On the other hand, in order to constrain the details of the models – e.g. the fine details of the dust distribution in the torus, or the optical depth, just to mention a couple of cases – one needs detailed input data (e.g. mid-IR spectroscopy).

11 Computational time

In terms of computational time, the performance of SED3FIT is comparable to MAGPHYS. On an Intel® Xeon™ 3.2 GHz CPU, 10^{10} model combinations are sampled in roughly 100 minutes, to be compared to 10–15 minutes spent for $\sim 10^9$ evaluations in MAGPHYS. This holds switching off the extra output files (**.all* and **.pho*) and using the random sampling of the torus library.

Switching on the recording of all attempted models (`print_all_out`) increases the execution time by roughly 10%. Switching on the computation and recording of the model photometry PDFs (`print_pho_pdf`) increases the execution time by roughly a factor of 5. Table 2 reports some examples.

References

Berta, S., Lonsdale, C. J., Siana, B., et al. 2007, A&A, 467, 565

Paramater	run 1	run 2	run 3	run 4[a]	run 5[b]	run 6[b]	run 7
n_ran_opt	100	100	100	100	100	1000	1000
n_ran_ir	100	100	100	100	100	1000	1000
n_ran_norm	100	100	100	100	100	100	100
n_ran_torus	100	100	100	100	–	–	100
print_all_out	0	1	0	0	0	0	0
print_pho_pdf	0	0	1	0	0	0	0
use_up_lim	0	0	0	1	0	0	0
use_rdn_t	1	1	1	1	0	0	1
Exec. time[†] [s]	70	77	265	100	32	644	6408

[†]: per source.
[a]: including 3 bands with upper limit.
[b]: using a small library of 10 torus/AGN models.

Table 2: Examples of execution time for SED3FIT with different setups, using 21 photometric pass-bands between the U band and 500 μm, measured on an Intel® Xeon™ 3.2 GHz CPU.

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