# STARLIGHT: New version

We are going to see the developments of this new version. We begin with the *grid* file.

```
60
./BasesDir/                                                 [base_dir]
./Test2/                                                    [obs_dir]
./                                                          [mask_dir]
./                                                          [etc_dir]
./Test2/Output/                                             [out_dir]
0                                                           [random phone number]
5350.0                                                      [llow_SN]   lower-lambda of S/N window <-- Not relevant when error-spectrum is provided
5850.0                                                      [lupp_SN]   upper-lambda of S/N window <-- Not relevant when error-spectrum is provided
1650.0                                                      [Olsyn_ini] lower-lambda for fit
6800.0                                                      [Olsyn_fin] upper-lambda for fit
1.0                                                         [Odlsyn]    delta-lambda for fit
1.0                                                         [fscale_chi2] fudge-factor for chi2
FIT                                                         [FIT/FXK] Fit or Fix kinematics
1                                                           [IsErrSpecAvailable]  1/0 = Yes/No
1                                                          [IsFlagSpecAvailable] 1/0 = Yes/No
1                                                           [IsPHOcOn] 1/0 = Yes/No  <=== !PHO! ATT: still needs coding + testing!
0                                                           [IsQHRcOn] 1/0 = Yes/No  <=== !QHR!
0                                                           [IsFIRcOn] 1/0 = Yes/No  <=== !FIR!
1e-16                                         [flux_unit] multiply spectrum in arq_obs by this value to obtain ergs/s/cm2/Angs
sp_m62_030CCC_0E.txt    Test030CCC0.ETCinfo    100.0    PMSv03.k1.config   BASE.bca01   Mask.GeneralEmLines   CCC   0.0   150.0   sp_m62_030CCC_0_CCC_uv_pr
sp_m62_030CCC_0.5E.txt  Test030CCC0.5.ETCinfo  100.0    PMSv03.k1.config   BASE.bca01   Mask.GeneralEmLines   CCC   0.0   150.0   sp_m62_030CCC_0.5_CCC_uv_
sp_m62_030CCC_1E.txt    Test030CCC1.ETCinfo    100.0    PMSv03.k1.config   BASE.bca01   Mask.GeneralEmLines   CCC   0.0   150.0   sp_m62_030CCC_1_CCC_uv_pr
```

We have to choose if we use photometric data (there are other options like QHR or FIR data). We write 1/0 = Yes/No in the [IsPHOcOn] option. In the third column we have to indicate the luminosity distance in Mpc. There is a new file that we have to create in this new version. This new file is indicated in the second column. We refer it as ETCinfo.

```
#
# FIR-data #
FIR
  11.450          > FIR_logLFIR_TOT    = TOTal log FIR luminosity [Lsun]
   1.000          > FIR_LFIRFrac2Model = frac of LFIR_TOT to consider in fit
   0.010          > FIR_ErrlogLFIR     = error in log L_FIR [dex]
 100.000          > FIR_RangelogLFIR   = Range in log L_FIR [dex]
   1.000          > FIRChi2ScaleFactor = in units of chi2_OPTical...
#
# Based on data in Gn001.a3.FIRinfo.u0
#
#
#
# QH-Related data #
QHR
 3                                                          > NQHR_Ys = Number of line-luminosities (Y) used in QHRc-fits
 1   4861.00  4340.00        0.0664       0.0000       1.0000     > IsELROn lambda_A lambda_B Err_logR RangelogR Chi2ScaleFactor
   1.000                                                    > Global weight of chi2_QHR wrt optical fit
 4340.00     20.54400      5.58500      1.00000      0.06208     -1.00000      1.00000
 4861.00      8.54800      6.02100      1.00000      0.02352     -1.00000      1.00000
 6563.00      2.20600   -999.00000      1.00000   -999.00000      0.00000      0.00000
# lambda[Angs] frecomb logY_TOT[Lsun]  YFrac2Model    ErrlogY     RangelogY  Chi2ScaleFactor
#
# Based on lines measured by Rosa in Gn001.a3.txt.u0.FMS2_k0.m3.CCC.m52_b_20G.v05
# Distance used to compute Ys =  126.430 Mpc
#
# Output of MakeETCinfoFiles.for
# This file = Gn001.a3.ETCinfo.CC
# Cid@Granada - 01/Feb/2011
#
#
#
#
#
# Fake-PHO input 4 RAFA...
PHO
0.02  > PHO_redshift
```

```
2 > NPHO_Ys
1.0 > PHO_GlobalChi2ScaleFactor
NUV          GALEX.NUV.dat.txt          45.10           1.00               0.021             1000.0            0.666
FUV          GALEX.FUV.dat.txt          47.50           1.00               0.021             1000.0            0.333
#PHO_name(iY)  PHO_Filter_file(iY)   PHO_logY_TOT(iY)  PHO_YFrac2Model(iY)  PHO_ErrlogY(iY)  PHO_RangelogY(iY)  PHO_Chi2ScaleFactor(iY)
```

The first two blocks are other input that are supported by this version. We are going to center in the third block that is the PHO information:

- PHO_redshift: redshift of galaxy.
- NPHO_Ys: number of filters we want to include.
- PHO_GlobalChi2ScaleFactor: Weight that photometric data will have in the fit.
- PHO_name(iY): name we use, only for output purpose.
- PHO_Filter_file(iY): name of the filter file.
- PHO_logY_TOT(iY): observed magnitude.
- PHO_YFrac2Model(iY): fraction of luminosity to consider in the fit.
- PHO_ErrlogY(iY): the observed error.
- PHO_RangelogY(iY): if we use this option we have to select a range in wich could stay the value of the luminosity in filter i. In this case you dont have to select an error, because the code do the fit considering that all the values in your range are possible to be chosen.
- PHO_Chi2ScaleFactor(iY): The weight that each filter will have in the total $\chi 2_{PHO}$. For example, if you want all filters have the same weight just set PHO_Chi2ScaleFactor(iY) = 1/NPHO_Ys.

Now we are going to see an output file fitting photometry.

```
## Synthesis Results - Best model ##

 1.11869E-01      3.02716E+02                                         [chi2/Nl_eff & chi2]
    0.22849                                                           [adev (%)]
 3.02716E+02  2.98939E+02  0.00000E+00  0.00000E+00  3.77764E+00      [chi2_TOT chi2_Opt chi2_FIR chi2_QHR chi2_PHO - ALL chi2s!]
   99.48756                                                           [sum-of-x (%)]
 4.68373E-03                                                          [Lum_tot (Lsun/A if distance & flux_unit are Ok...)]
 1.08635E+00                                                          [Mini_tot (Msun  if distance & flux_unit are Ok...)]
 9.30492E-01                                                          [Mcor_tot (Msun  if distance & flux_unit are Ok...)]

  -0.35                                                               [v0_min  (km/s)]
   3.60                                                               [vd_min  (km/s)]
 0.4533                                                               [AV_min  (mag)]
  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000  0.000          [exAV_min (mag)] 1...10 of N_exAV =   0
```

In the *Synthesis Results - Best model* block we can see the values of Chi2_TOT, Chi2_Opt and Chi2_PHO (also chi2_FIR and chi2_QHR, but it's 0 in our case). At the end of the file we can see the PHO information, it is *PHOc-FIT RELATED OUTPUT* block. Foremost, we have the input information in *PHO: Input info* block. After it, we have the synthesis information in *PHO: Results for best model*.

```
##################################
##    PHOc-FIT RELATED OUTPUT   ##
##################################

## PHO: Input info
Testbb_400_10000.0CCC0.5ETCinfo          [arq_ETCinfo]
 100.0000                                [LumDist (Mpc)]
 0.000000                                [PHO_redshift]
   1.0000                                [PHO_GlobalChi2ScaleFactor]
  2                                      [NPHO_Ys = number of PHO-bands included in fit]

#name/code  filter_file     logY_TOT  YFrac2Model  ErrlogY  RangelogY Chi2ScaleFactor logY_obs    logY_low     logY_upp
NUV         GALEX.NUV.dat.t  -1.5514     1.0000     0.0600     0.0000     0.6667      -1.5514      -1.5514      -1.5514
FUV         GALEX.FUV.dat.t  -1.2011     1.0000     0.0600     0.0000     0.3333      -1.2011      -1.2011      -1.2011

## PHO: Results for best model
   1.2479     98.7521                    [%-chi2: PHO/TOT & Opt/TOT]
3.77764E+00  2.98939E+02  3.02716E+02    [chi2_PHO chi2_Opt chi2_TOT]

#  name/code  MeanLamb StdDevLamb  q_MeanLamb   logY_obs      ModlogY       chi2_Y   chi2_Y/chi2_Opt  chi2_Y/chi2_TOT
 1 NUV         2315.66     260.18     2.0202      -1.5514      -1.5450     2.2758E+00    7.6129E-03       7.5179E-03
 2 FUV         1538.62     105.29     2.5094      -1.2011      -1.1937     1.5019E+00    5.0240E-03       4.9613E-03

# j  age_j(yr)     Z_j      exAV?   x_j(%)    AV_tot  | %-Y:    1     2
  1  1.000000E+06  0.02000    0     26.6621   0.4533         42.4  46.9
  2  2.880000E+06  0.02000    0     12.0620   0.4533         16.8  17.2
  3  3.160000E+06  0.02000    0      8.1560   0.4533          9.9   9.4
  4  3.980000E+06  0.02000    0     12.1780   0.4533          9.5   8.5
  5  5.010000E+06  0.02000    0      6.3039   0.4533          4.2   3.7
  6  5.750000E+06  0.02000    0      4.1129   0.4533          2.4   2.1
```

The logY_low and logY_up values only have sense if we use the PHO_RangelogY option. In other case, these values are the same that logY_TOT.

# 1 Input data

Suppose we have an observed AB magnitude in a filter $F$ that we want to fit with STARLIGHT. The first step is to correct this magnitude from Galactic extinction and for it we take the same E(B-V) used to correct the observed spectrum. Set $m_l$ the observed magnitude in a filter $F$ corrected from Galactic extinction. If $d$ is the luminosity distance to the galaxy (in Mpc), we do

$$PHO\_norm = 3.826e33/(4 * \pi * (d * 3.086)^2)$$
$$\tilde{m}_l = m_l + 2.5 * \log_{10}(PHO\_norm)\,.$$

and $\tilde{m}_l$ is the input for STARLIGHT. It's the same as compute the magnitude in $F$-filter from a spectrum in units of $L_\odot/\text{Å}$ instead of erg/seg/cm$^2$/Å.

## 2 Computing $\chi 2_{PHO}$

As usual, we define $\chi 2_{PHO}$ as

$$\chi^2_{\text{PHO}} = \sum_{l=1}^{N_l} \left( \frac{m_l^{\text{obs}} - m_l}{\sigma_l} \right)^2$$

The PHO_GlobalChi2ScaleFactor ($= K_{PHO}$) is a constant which relates $\chi 2_{PHO}$ and $\chi 2_{OPT}$ as follow.:

$$\chi 2_{TOT} = \chi 2_{OPT} [1 + K_{PHO} \chi 2_{PHO}]$$

In our simulations, with similar spectroscopic and photometric errors, using the original formulation

$$\chi 2_{TOT} = \chi 2_{OPT} + \chi 2_{PHO}$$

we obtain good quality results. In our typical analysis we fit spectra with $Nl_{eff} \sim 1000$, so we obtain the original formulation of $\chi 2_{TOT}$ setting $K_{PHO} = \frac{2}{Nl_{eff}} = 0.002$. The user is free to modify the value of this constant to give an extra weight to the photometric data.

## 3 The PHO_RangelogY option

To deal with possible apperture mistmach we use the PHO_RangelogY option. This introduce a modified version of $\chi^2_{\text{PHO}} = \sum_l \chi^2_l$ where the $e^{-\chi^2_l/2}$ gaussian likelihood of each $m_l$ is replaced by a flat top gaussian likelihood, where $\chi^2_l$ is given by

$$\chi^2_l = \begin{cases} \left( \frac{m_l - m_l^{\text{low}}}{\sigma_l} \right)^2 & m_l \leq m_l^{\text{low}} \\ 0 & m_l^{\text{low}} < m_l < m_l^{\text{upp}} \\ \left( \frac{m_l - m_l^{\text{upp}}}{\sigma_l} \right)^2 & m_l \geq m_l^{\text{upp}} \end{cases} \tag{1}$$

The PHO_RangelogY option set the values $m_l^{\text{low}}$ and $m_l^{\text{upp}}$ as follow (use $r_l$ for the range value):

$$\begin{aligned} &\text{if } r_l \leq 0: \\ &\qquad m_l^{low} = m_l^{obs} \\ &\qquad m_l^{upp} = m_l^{obs} + \text{abs}(r_l) \\ &\text{else}: \\ &\qquad m_l^{upp} = m_l^{obs} \\ &\qquad m_l^{low} = m_l^{obs} - r_l \end{aligned}$$