Online documentation. Part II:
Gyrosynchrotron code input, output, and calling conventions

The gyrosynchrotron codes are implemented as the Windows dynamic link libraries (DLLs) and Linux shared objects (SOs). The IDL users can call these codes by the `CALL_EXTERNAL` function with the following syntax:

```
res=CALL_EXTERNAL(libname, 'GET_MW', ParmIn, s, /F_VALUE)
```

Here `libname` is the name of the appropriate dynamic link library or shared object. This file should be located in one of the directories where the operating system searches for executable modules, otherwise the full path should be specified, e.g.

```
libname='Full_path_to_DLL/DLLname.dll'
res=CALL_EXTERNAL(libname, 'GET_MW', ParmIn, s, /F_VALUE).
```

Then, `ParmIn` is the 29-element single-precision floating-point array that contains the input parameters for the gyrosynchrotron code, and `s` is the two-dimensional single-precision floating-point array that contains the results of the computation.

The input parameters are specified by the array `ParmIn` with the following elements:

- `ParmIn[0]` is the visible source area S [cm^2].
- `ParmIn[1]` is the source depth along the line-of-sight L [cm].
- `ParmIn[2]` is the background plasma temperature T_0 [K]; is used to compute the free-free contribution in all cases and also GS contribution for thermal, thermal/nonthermal, and kappa distributions.
- `ParmIn[3]` is a matching parameter ε in the thermal/nonthermal distributions.
- `ParmIn[4]` is the parameter $\varkappa$ in the kappa-distribution.
- `ParmIn[5]` specifies the integration method and accuracy in the continuous code.

  For the library `libGS_Std_HomSrc_CEH`*:*

  if `ParmIn[5]` > 1 then the trapezoidal method with fixed number of nodes is used, and the number of nodes equals `ParmIn[5]`$+1$ (rounded downwards to the nearest integer);

  if `ParmIn[5]` ≤ 1 then the Romberg method is used (the default accuracy is 10^{-5}).

  For the library `libGS_Std_HomSrc_C`*:*

  absolute value of this parameter defines the number of nodes used in the extended midpoint method with logarithmic node placement.
- `ParmIn[6]` is the low-energy cutoff of the accelerated electrons $E_{\min}$ [MeV] in the power-law distributions.
- `ParmIn[7]` is the high-energy cutoff of the accelerated electrons $E_{\max}$ [MeV] in the power-law, thermal/nonthermal, and kappa distributions.
- `ParmIn[8]` is the break energy $E_{\rm break}$ [MeV] in the double-power-law distribution, $E_{\min} < E_{\rm break} < E_{\max}$.

- `ParmIn[9]` is the power-law index δ in the single-power-law distributions or the low-energy power-law index δ_1 in the double-power-law distribution.
- `ParmIn[10]` is the high-energy power-law index δ_2 in the double-power-law distribution.
- `ParmIn[11]` is the background plasma density n_0 [cm^{-3}].
- `ParmIn[12]` is the number density of fast electrons n_b [cm^{-3}].
- `ParmIn[13]` is the magnetic field B [G].
- `ParmIn[14]` is the viewing angle θ [degrees] relative to the magnetic field.
- `ParmIn[15]` is the starting frequency to calculate the emission spectrum f_0 [Hz].
- `ParmIn[16]` is the logarithmic step in frequency Δ: the emission parameters are calculated at the logarithmically spaced frequency points, i.e. $f_1 = f_0 10^\Delta$, $f_2 = f_1 10^\Delta$, ...
- `ParmIn[17]` specifies the type of the electron distribution over energy (index of the model distribution function, see online documentation, Part I).
- `ParmIn[18]` is the number of frequencies to calculate the emission spectrum N_f (non-integer parameters are rounded downwards to the nearest integer); the highest frequency equals $f_{N_f-1} = f_0 10^{(N_f-1)\Delta}$.
- `ParmIn[19]` specifies the type of the electron distribution over pitch-angle (index of the model distribution function, see online documentation, Part I).
- `ParmIn[20]` is the loss-cone boundary α_c [degrees] in the loss-cone distributions.
- `ParmIn[21]` is the beam direction α_0 [degrees] in the beam-like distributions.
- `ParmIn[22]` is the loss-cone boundary width or the beam angular width $\Delta\mu$ in the loss-cone or beam-like distributions, respectively.
- `ParmIn[23]` is the coefficient a_4 in the supergaussian (SGA, `ParmIn[19]=5`) pitch-angle distribution.
- `ParmIn[24]` *unused (reserved for future needs).*

Parameters `ParmIn[25]`–`ParmIn[27]` are used only in the library `libGS_Std_HomSrc_CEH`.

- `ParmIn[25]` is the parameter $f_\mathrm{cr}^\mathrm{C}/f_\mathrm{Be}$ (boundary frequency expressed in units of gyrofrequency) in the hybrid code.

  If $f_\mathrm{cr}^\mathrm{C} < f_0$ then the code becomes purely continuous (without exact or approximate discrete calculations). In this case, the sign of `ParmIn[25]` controls R-optimization (renormalization by the exact value at $f_\mathrm{cr}^\mathrm{WH}$, defined by `ParmIn[26]`):

  if `ParmIn[25]` ≥ 0 then the code is continuous without R-optimization;

  if `ParmIn[25]` < 0 then R-optimization is applied to the continuous code.
- `ParmIn[26]` is the parameter $f_\mathrm{cr}^\mathrm{WH}/f_\mathrm{Be}$ (boundary or renormalization frequency expressed in units of gyrofrequency) in the optimized hybrid (if `ParmIn[26]` $<$ `ParmIn[25]`) or R-optimized continuous (if `ParmIn[25]` < 0 and $f_\mathrm{cr}^\mathrm{WH} > f_0$) code. It is not used otherwise.

- `ParmIn[27]` controls renormalization in the hybrid code:

  if `ParmIn[27]` $= 0$ then renormalization is not applied;

  if `ParmIn[27]` $\neq 0$ (default value) then the emission spectrum is renormalized to remove matching residuals at the frequencies $f_{\rm cr}^{\rm C}$ and (if necessary) $f_{\rm cr}^{\rm WH}$.

In the library `libGS_Std_HomSrc_C`, containing fast and Q-optimized continuous codes only, three above parameters (`ParmIn[25]`–`ParmIn[27]`) are ignored as the hybrid code and R-optimization are not implemented.

- `ParmIn[28]` controls Q-optimization:

  if `ParmIn[28]` $= 0$ then the terms $(\ln Q)'$ and $(\ln Q)''$ are neglected during calculations;

  if `ParmIn[28]` $\neq 0$ then the terms $(\ln Q)'$ and $(\ln Q)''$ are taken into account.

  In addition, in the library `libGS_Std_HomSrc_C`, the value of `ParmIn[28]` $= 1$ means that the terms $(\ln Q)'$ is only used to specify the correction $\Delta\mu$ by the perturbation formula: $\Delta\mu = -(\ln Q(\mu_{00}))'/h''(\mu_{00})$ and no further root accuracy improvement is performed. Full Q-optimization is performed if `ParmIn[28]` ≥ 2, which gives the most precise results.

The results of calculation are stored in the two-dimensional array `s` with $5 \times N_f$ elements (N_f is given by the parameter `ParmIn[18]`), designed to be applicable for both the uniform source case and as the input for numerical solutions of the radiation transfer equation. This array must be created before calling `CALL_EXTERNAL`. After completion of the calculations, the array `s` contains the following data:

- `s[0, *]` is the N_f-element array of the emission frequencies f [GHz].

- `s[1, *]` is the N_f-element array of the observed (at the Earth) O-mode emission intensities $I_f^{\rm O} = (j_f^{\rm O}/\varkappa^{\rm O})[1 - \exp(-\varkappa^{\rm O} L)]$ [sfu] from the uniform source with the specified input parameters located at the Sun.

- `s[2, *]` is the N_f-element array of the gyrosynchrotron damping factors for O-mode $\exp(-\varkappa^{\rm O} L)$; this output is intended for numerical radiation transfer solution.

- `s[3, *]` is the N_f-element array of the observed (at the Earth) X-mode emission intensities $I_f^{\rm X} = (j_f^{\rm X}/\varkappa^{\rm X})[1 - \exp(-\varkappa^{\rm X} L)]$ [sfu].

- `s[4, *]` is the N_f-element array of the gyrosynchrotron damping factors for X-mode $\exp(-\varkappa^{\rm X} L)$; this output is intended for numerical radiation transfer solution.

The return value of the function `CALL_EXTERNAL` (stored in the variable `res`) is set to zero if no problems were detected. If either the energy distribution index (`ParmIn[17]`) or the pitch-angle distribution index (`ParmIn[19]`) is not in the list of pre-defined values (see online documentation, Part I) then the default distribution (PLW or ISO, respectively) is used, then `res=1`.

Additional options controlling the computation accuracy

In the library `libGS_Std_HomSrc_CEH`, some default computation parameters can be changed using the additional function `SetParams`. For example, to change the default integration and summation accuracies (10^{-5}) to respectively 10^{-3} and 10^{-4}, the IDL users can call it by the `CALL_EXTERNAL` function with the following syntax:

```
eps_int=1e-3
eps_sum=1e-4
libname='Full_path_to_DLL/libGS_Std_HomSrc_CEH.dll'
res=CALL_EXTERNAL(libname, 'SetParams', eps_int, eps_sum)
res=CALL_EXTERNAL(libname, 'GET_MW', ParmIn, s, /F_VALUE)
```

Here `eps_int` and `eps_sum` should be single-precision floating-point values.

The parameter `eps_int` specifies the relative integration accuracy for the Romberg method. It is used when calculating the integral over energy in the continuous code, or the integrals over the resonance curves (for all cyclotron harmonics) in the exact and approximate discrete codes. Default value: 10^{-5}.

The parameter `eps_sum` specifies the relative accuracy for the series summation in the exact and approximate discrete codes. Summation over the cyclotron harmonics is stopped when the ratio of a current term of the series to the accumulated sum becomes less (by absolute value) than `eps_sum`. Default value: 10^{-5}.

The changed accuracy parameters are applied to all subsequent calls to the main gyrosynchrotron code. They remain active till the next call to the function `SetParams` or until the dynamic library (or shared object) is unloaded.