

# TELCAL

A GILDAS software

July 5th, 2004

Version 1

Questions? Comments? Bug reports? Mail to: `gildas@iram.fr`

The GILDAS team welcomes an acknowledgement in publications  
using GILDAS software to reduce and/or analyze data.  
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<http://www.iram.fr/IRAMFR/GILDAS>

## Documentation

In charge: J. Pety<sup>1,2</sup>.  
Active developers: S.Bardeau<sup>1</sup>, S. Guilloteau<sup>3</sup>.  
Main past contributors: H. Wiesemeyer.

## Software

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Main past contributors: H. Wiesemeyer.

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## 0.1 TELCAL design explanations

- Several comments on the design of the fitting part:
  - *Derived typed are defined to stay general, in particular no array dimension is explicitly specified.* This implied the use of POINTERS.
  - *Everything can not be passed in the subroutine calling sequences.* Indeed, ALL minimization (and thus fitting) algorithms ask for a function to be minimized which have a pre-defined calling sequence. This calling sequence varies with the used minimization methods and libraries. However, those calling sequence inevitably miss some important parameters (as an example, they never pass function parameters that the user want to stay fixed). Properties of the fitted function (and also sometimes grid of measured points) must be passed by another mechanism. In some F77 parts of GILDAS (*e.g.* UV\_FIT), this problem is solved by INCLUDE files and COMMON. Here, the F90 “use association” mechanism is used (*i.e.* the variable to be shared is define in a module that is called in all the needed subroutines).
  - *There are some duplication between the fitted function calling sequence and the “association module”.* This avoids particular cases for every different minimization methods and libraries.
- The plotting part is done through SIC procedures. This is very flexible but this implies the definition of SIC structures associated to the high levels TELCAL derived types (*e.g.* POINT\_CROSS).
- The TELCAL demonstration could be the basis of a TELCAL test suit.

## 0.2 TELCAL library interfaces

The user may interact with the TELCAL library at different levels:

- Direct call of very general fitting routines (*e.g.* see fit\_1d).
- Direct call of high level functionalites (*e.g.* solve of a cross pointing scan).
- Use of the TELCAL language to access the same high level functionalities (as the GILDAS GTVL library is mainly accessed through the GTVL language).

### 0.2.1 Interfaces

The interfaces of the TELCAL F90 subroutines available to the user are located in the `telcal-interfaces.f90` file. Its contents are reproduced here:

```
module telcal_interfaces
!
! General TELCAL
!
interface ! Load TELCAL environment (Language, global variables, etc...)
  subroutine load_telcal
end subroutine load_telcal
end interface
```

```

!
interface ! Interpret and execute TELCAL commands
  subroutine run_telcal(line,comm,error)
    character*(*) line,comm
    logical error
  end subroutine run_telcal
end interface
!
! FIT related
!
interface ! General unidimensional fitting routine
  subroutine fit_1d(dat,fun)
    use fit_definitions
    type (simple_1d) :: dat
    type (fit_fun)  :: fun
  end subroutine fit_1d
end interface
!
interface ! Initialize the "dat" instance of the simple_1d derived type
  subroutine null_simple_1d(dat)
    use fit_definitions
    type (simple_1d) :: dat
  end subroutine null_simple_1d
end interface
!
interface ! Initialize the "par" instance of the fit_par derived type
  subroutine null_parameter(par)
    use fit_definitions
    type (fit_par) :: par
  end subroutine null_parameter
end interface
!
interface ! Initialize the "fun" instance of the fit_fun derived type
  subroutine null_function(fun)
    use fit_definitions
    type (fit_fun) :: fun
  end subroutine null_function
end interface
!
interface ! Copy the "in" simple_1d derived type into "out"
  subroutine copy_simple_1d(in,out)
    use fit_definitions
    type (simple_1d) :: in,out
  end subroutine copy_simple_1d
end interface
!
interface ! Copy the "in" fit_fun derived type into "out"

```

```

    subroutine copy_function(in,out)
        use fit_definitions
        type (fit_fun) :: in,out
    end subroutine copy_function
end interface
!
! POINTING related
!
interface ! Initialize the point cross structure
    subroutine init_point_cross(ndat)
        use point_definitions
        integer :: ndat ! Size of the data arrays
    end subroutine init_point_cross
end interface
!
interface ! Solve the telescope pointing parameters through a cross
    ! Then plot results
    subroutine solve_point_cross
        use fit_definitions
        use point_definitions
    end subroutine solve_point_cross
end interface
!
end module telcal_interfaces

```

### 0.2.2 Derived types

The TELCAL derived types are defined in the `telcal-types.f90` files:

```

!
! FIT derived type definitions
!
module fit_definitions
!
    type :: simple_1d ! Data vector (simple precision, 1d)
        sequence
        integer :: n ! Number of data
        real(8), pointer :: x(:) ! Abcissae (in)
        real(8), pointer :: y(:) ! Values (in)
        real(8), pointer :: w(:) ! Weights (in)
        real(8), pointer :: d(:) ! derivative of x with time, Not always allocated
    end type simple_1d
!
    type :: fit_par ! Description of a fitted parameter
        sequence
        character(len=16) :: name ! Parameter name (in)
        real(8) :: guess ! Guess (in)
        real(8) :: value ! Fit value (out)
    end type fit_par

```

```

    real(8) :: error          ! Fit uncertainty          (out)
    real(8) :: mini           ! Minimum possible value  (in)
    real(8) :: maxi           ! Maximum possible value  (in)
    logical :: fixed          ! Is the parameter fixed? (in)
    logical :: padding        ! Padding for structure alignment
end type fit_par
!
type :: fit_fun ! Description of a fitted function
    sequence
    character(len=16) :: name          ! Fitted function name (eg GAUSSIAN)
    character(len=16) :: method        ! Fitting library (eg SLATEC)
    real      :: rms                   ! Residual RMS
    integer :: flag                    ! Error/Quality code
    integer :: ncall                   ! Number of iterations
    integer :: npar                    ! Number of fitted parameters
    type (fit_par), pointer :: par(:) ! Array of parameter descriptions
end type fit_fun
!
type :: fit_var ! Variable fitted parameters only
    sequence
    integer :: n                      ! Number
    real(8), pointer :: x(:)          ! Values
    real(8), pointer :: d(:)          ! Errors
    integer, pointer :: idx(:) ! Position index inside full parameter vector
end type fit_var
!
end module fit_definitions
!
! POINTING derived type definitions
!
module point_definitions
    use fit_definitions
    !
    type :: point_cross
        sequence
        integer :: sys                ! Scanning coordinate system
        character(16) :: dir(4) ! Scanning directions
        type (simple_1d) :: dat(4) ! Data vectors
        type (simple_1d) :: sol(4) ! Solution vectors
        type (fit_fun) :: fun(4) ! Fit functions
    end type
    !
    type (point_cross), save :: pcross
    !
end module point_definitions
!
```



## 0.3 TELCAL Language Internal Help

### 0.3.1 GAUSS

```
TELCAL\GAUSS Xvar Yvar [Wvar] [/GUESS Area Position Width] [/FIXED
Afix Pfix Wfix]
```

Fit a one dimensional Gaussian through the (Xvar,Yvar) points. An optional weight array (Wvar) may be given. Area, position and width first guess are given through the /GUESS option. Default first guess is 1. User may impose a parameter through the logical variables Afix, Pfix and Wfix. All parameters are considered variable by default.

### 0.3.2 POINT

```
TELCAL\POINT [/CROSS]
```

Solve for telescope pointing parameters. The default (and currently only solution) is to solve through a LAMBDA/BETA cross. Parameters are solved and the fit is plotted as soon as each subscan is finished. User can access to all related information through the global SIC structure named PCROSS.

## .1 Minutes of the TELCAL kickoff meeting (May 2004)

Introduction:

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Goal:

- NCS delegates the telescope calibration to reduction packages
- need a telescope calibration library, perhaps inside GILDAS

"Desirable" Features

- Re-use what is available
- avoid duplication of efforts
- Standardization
- Easy maintenance

Contraints

- many actors
- short timescales
- Portability
- backward compatibility (must be able to process old data)
- new ATM version

Alternative(s)

- per package solution ? leads to maintenance issues, and serious loss of time...
- make a common library
  - requires to define needs and interfaces
  - requires clients to adapt to the library constraints

Beware:

- RED lifetime was 20 years...
- Wide distribution of the library through GILDAS
- IRAM has a record of success, which leads to high expectations
- Failure is not an option (success is easily forgotten)

For a library, we need to define:

- Functionalities
- Interfaces with outside world (ATM / Reduction packages / NCS / other libraries)
- Internal data format
- Internal design (backend handling, fitting, ...)

\*\*\*\*\*

Conclusions:

-----

- A somewhat cryptic table of the current situation is attached.

- List of desirable library functionalities:
  - \* Focus
  - \* Pointing
  - \* Chopper
  - \* Skydips
  - \* Sideband rejection
  - \* Array geometry
  - \* Array gains
  - \* Baseline
  - \* Regridding
  - (\* Fitting maybe for specialized algorithms)
- J.Penalver is now in charge of Pointing Models for the 30m. Pointing models thus are outside the scope of the library at least in its first iteration.
- Language to be used: F90 with derived types, modules for at least derived types and definition of function interfaces.
- Goals:
  - \* 1st version of library should be available by end of year (November 2004 if possible).
  - \* 1st version meaning same functionalities as providing now by red: focus, pointing, chopper (for spectra), skydips (for spectra), sideband rejection
  - \* Priorities in library building:
    - 1 Focus
    - 2 Pointing
    - 3 Chopper
    - 4 Skydips
    - 5 Sideband rejection
- Work distribution:
  - o Related work without timescale:
    - \* A.Sievers to distribute an example of 30M-FITS file with corresponding documentation for each back-end as soon as they become available starting with bolometer and then 4MHz.
    - \* H.Wiesemeyer to provide translation from 30M-FITS to CLASS data format.
    - \* A.Bacmann and S.Guilloteau to make a memo on bandpass calibration at the 30m and PdBI to take into account bandwidth increase and new ATM possibilities.
  - o Library work:
    - \* Small description of sideband rejection measurement at the 30m.  
=> A.Sievers (ASAP)
    - \* Iteration on interfaces and practical derived types:  
=> J.Pety and S.Guilloteau 31.05.2004

- \* Test on minimization routines (eg can we reliably use a 2-D minimization routine to fit a 1-D problem?):  
=> S.Guilloteau 30.06.2004
- \* One fully working example (focus):  
=> J.Pety and H.Wiesemeyer 30.06.2004
- \* A point will then be made enabling new work distribution round.

\*\*\*\*\*

## Pointing Methods

- least square fit
  - \* Input
    - lambda offsets
    - beta offsets
    - lambda derivatives
    - beta derivatives
    - intensities
    - weights
    - fitting shape (e.g. Gaussian,n-Gaussians)
    - Parameters, Guesses, Fixed/Fitted, Boundaries???
  - \* Output
    - parameters
    - errors
    - quality flags
- evaluate fitted function
  - \* Input
    - fitting shape, parameters
    - input coord (lambda,beta)
  - \* Output
    - intensities
- plotting: Fit overplotted over data for two crosses
  - \* Input:
    - System, Units
  - \* Output:
    - Screen plot
- results for NCS
  - \* Input:
    - Output of fit
    - Logging info

\* Output:

- XML file
- sic procedure (OBS)

Comments:

- dealing with spillover on multi-beam receivers ?
- start with "single-pixel" version
- can deal with multi-pixel in two different ways
- changing the  $\lambda(i)$ ,  $\beta(i)$  for each pixel
- or putting the relative positions of the beams into the fitting function
- is there a gain to be obtained by fitting a broadened beam for planets ? need to evaluate that issue separately.

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Focus Methods: Very similar to pointing...

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Sideband Rejection:

- currently being done using the Martin-Pupplet settings, by coupling one of the sidebands with the cold load, the others with the hot load.
- is the method accurate enough ?
- can we rely on the engineer tables ?
- measurement seems to be the most accurate method, but the precision is unknown ?
- should it be frequency dependent ?

First step: transfert what is currently done in RED into the library ..

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Chopper:

\* Input:

- El
- sideband rejection(i)
- RF Frequency  $\nu(i)$  and Bandwidth  $\Delta\nu(i)$
- Signed IF Frequency
- Hot,Cold,Sky,Offset(dark count) temperature  $T(i)$
- Hot and Cold Temperatures  $T(i)$  and coupling coefficients  $f(i)$
- Telescope specific: Pamb, Water scale height, altitude, latitude
- Date

$$P_{in} = f_{hot} B(T_{hot}) + (1-f_{hot}) B(T_{amb}) = B(T_{eff})$$

- \* Output:
  - Trec(i)
  - Water
  - Water and Others Zenith Opacities(i)

Tcal:

- \* Input:
  - El
  - RF Frequency nu(i)
  - Signed IF Frequency
  - Sideband rejection
  - Set of Tamb (cabine, ground) and coupling coefficients f(i)
  - Water
  - (Interpolated) Trec(i) for dual load
- \* Output
  - Tcal(i)
  - Water and Others Zenith Opacities(i) for DSB analysis

-----

Skydip

- \* Input:
  - El(j)
  - sideband rejection(i)
  - RF Frequency nu(i) and Bandwidth dnu(i)
  - Signed IF Frequency
  - Hot,Cold,Offset(dark count) temperature T(i) Tsky(i,j)
  - Hot and Cold Temperatures T(i) and coupling coefficients f(i)
  - Telescope specific: Pamb, Water scale height, altitude, latitude
  - Date
  - Bolometer bandpass(i)
- \* Output:
  - Value and errors of Water vapour(i)
  - Value and errors of Feff(i)
  - Quality flag

-----

Baseline 1-D

- Fitting:
  - \* Input
    - Abcissa(i)

- Ordinate(i)
- Weights(i) (may be 0 to exclude a window)
- Fitting shape (eg polynomial,spline)
- \* Output
  - Fitted parameters
  - RMS
- Baseline computation:
  - \* Input
    - Abscissa(i)
    - Fitting shape
    - Fitted parameters
  - \* Output
    - Baseline(i)
- Baseline application
  - \* Input
    - Baseline(i)
    - Ordinate(i)
  - \* Output
    - Baseline(i)-Ordinate(i)

-----

Baseline 1-D: On-Off => To be discussed later.

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Baseline 2-D: spectral x time

- Fitting:
  - \* Input
    - Frequency nu(i)
    - Space x(j)
    - Ordinate y(i,j)
    - Weights(i,j) (may be 0 to exclude a window)
    - Fitting shape:
      - \* Factorized polynomials
      - \* Box averaging of independant polynomials
      - \* Cubic spline interpolation of independent polynomials
      - \* Cubic spline interpolation of independent cubic spline
      - \* sinusoidal(nu) with coefficients being polynomials(t)
  - \* Output

- Fitted parameters
  - RMS
- Baseline computation:
  - \* Input
    - Abscissa(i)
    - Fitting shape
    - Fitted parameters
  - \* Output
    - Baseline(i)
- Baseline application
  - \* Input
    - Baseline(i)
    - Ordinate(i)
  - \* Output
    - Baseline(i)-Ordinate(i)

On-off: simultaneous fitting of background and baseline

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Baseline 2-D: Spatial data => to be discussed later

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Regridding 1-D

- \* Input
  - Abscissa(i)
  - Ordinate(i)
  - Weights(i)
  - New reference pixel, value, increment, dimension
  - Algorithm
- \* Output
  - New abscissa(i)
  - New ordinate(i)
  - New weights(i)
  - Transformation matrix for signal and weight

Comment: Special case for already regularly sampled data

---



Regridding 2-D

- If it can be factorized (eg space x spectral), then use 1-D regridding
- Else
  - \* Input
    - Abscissa(i)
    - Ordinate(i)
    - Weights(i)
    - New reference pixel, value, increment, dimension
    - Algorithm
  - \* Output
    - New abscissa(i)
    - New ordinate(i)
    - New weights(i)
    - Transformation matrices for signal and weight

---

Array geometry: No consensus yet. In the first iteration of the library, this functionality will be delivered by MOPSIC.



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