BoA User Manual : APEX-MPI-MAN-0018

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BoA – The Bolometer Data Analysis Project

User and Reference Manual

Purpose

The purpose of this document is to provide an overview on the design and usage of the Bolometer Analysis (**BoA**) software package that was designed for the *Large APEX Bolometer Camera* (LABOCA) at APEX.

Contents

Part I

User's Manual

1. INTRODUCTION

The Atacama Pathfinder Experiment (APEX)[1] is a 12-meter radio telescope at the best accessible site for submillimeter observations, Llano de Chajnantor in Chile's Atacama desert.

Figure 1.0.1: The APEX telescope at Chajnantor in November 2003

LABOCA is a 295-channel facility bolometer camera for APEX. It operates in the 870 μm atmospheric window and is to be commissioned in September 2006. It was built at the MPIfR bolometer lab by Dr. Ernst Kreysa and his staff.

BoA is a newly designed software package for the reading, handling, and analysis of bolometer array data. Its design and implementation is a collaborative effort of scientists at the MPIfR, AIfA and AIRUB that was started in 2002 and in part funded through a "'Verbundforschung"' grant to the MPIfR and RAIUB. **BoA** is an APEX facility software as part of the LABOCA instrument. The primary goal of **BoA** is to handle data from LABOCA at APEX, both for online visualization and offline processing. **BoA** could also be used to process data acquired with other instruments such as ASZCa at APEX or MAMBO at the IRAM 30-meter telescope. **BoA** includes most of the relevant functionalities of the current reduction packages (MOPSIC, NIC, SURF). The major difference is that **BoA** is written in a programming environment that is easier to modify, maintain, and re-use. Moreover, **BoA** naturally interfaces with APECS and the MBfits format.

[1] http://www.mpifr-bonn.mpg.de/div/mm/apex/

1.1 Philosophy and basic structure

1.1.1 Philosophy

BoA is designed with two major goals in mind: to provide a comprehensive tool for the reduction and analysis of data from the new generation of bolometer arrays, and to facilitate the extension and modification of the software by any user. **BoA** is intended to combine a simple and intuitive usage with the coverage of all aspects of data reduction, from raw data to final images. The natural choice for the creation of **BoA** is object oriented programming.

1.1.2 Programming language: Python

Most of **BoA** is written in Python, an interpreted, interactive and object-oriented programming language. Python does not adhere to all concepts of object-orientation as strictly as, e.g., C++ does. The resulting shortcomings can be overcome by sticking to some basic programming rules.

Python is a scripting language and as such allows **BoA** to be quickly and easily extended by the user. It also facilitates the wrapping of code written in C/C++ or FORTRAN. To improve execution speed, **BoA** computing-intensive tasks are therefore written in Fortran95.

1.1.3 Basic structure

BoA consists of a set of classes, most of which are defined in dedicated modules (files). In addition, a few functions are defined in separate modules. A detailed description of all classes and methods can be found in Sec. 3. The subdivision was chosen to reach a high modularity and an intuitive grouping of related functionalities within one class.

Two kinds of classes may be distinguished:

- Data classes: The DataEntity class defines the data structure which is used within **BoA** . Objects of this class contain the raw and reduced data and all relevant parameters of a single scan. This class also defines methods to fill the data object from an MBFITS file. Then, the DataAna class inherits from DataEntity: it contains all data related methods, plus some methods for data analysis (e.g. flagging, baseline). Then, the Map class inherits from DataAna: it contains all methods defines in DataEntity and DataAna, plus specific methods for map processing and display. Finally, classes dedicated to various observing modes inherit from the Map class: they contain additional methods specific to a given type of observation. Table 1.1 lists **BoA** data classes, with module names and short descriptions of their responsibilities.
- Peripheral classes: All other classes provide methods which either are used by data objects (e.g. Image is used within Map objects), or provide functionalities on the **BoA** level (e.g. MessHand). These classes are summarized in Table 1.2.

Finally, a few functions are defined in separate modules (listed in Table 1.3), which do not define any class. Thus, these functions can easily be imported and run from any level. In particular, the **BoA** Graphic Library (**BoGLi**) is defined in a collection of modules, which can be imported at the python level and do not require **BoA** . A description of **BoGLi** is given in Sect. 6.

In addition, a number of utility and computing routines are written in Fortran modules. These routines are used within Python methods, and should in principle not be called directly by a **BoA** user.

Table 1.1: **BoA** data classes

class name	module	purpose
DataEntity	BoaDataEntity.py	data and parameters storage
DataAna	BoaDataAnalyser.py	general data analysis methods
Map	BoaMapping.py	map reduction
Focus	BoaFocus.py	focus reduction
Point	BoaPointing.py	pointing reduction
Sky	BoaSkydip.py	skydip reduction

Table 1.2: Other **BoA** classes

class name	module	purpose
Image	BoaMapping.py	image and axis description
Error	BoaError.py	
Help	BoaHelp.py	online help
MessHand	BoaMessageHandler.py	message handling
MamboMBFits	MamboMBFits.py	MAMBO to/from MB-Fits conversion
Timing	Utilities.py	benchmarking utilites

Table 1.3: Other **BoA** modules

module name	purpose
BoGLi (see Sect. 6)	Graphic library
Utilities.py (see Sect. **??**)	collection of utilities
BoaConfig.py (see Sect. **??**)	global parameters definitions
BoaSimulation.py	LABOCA data simulator

2. INSTALLING **BoA**

This section describes how to install **BoA** and all required additional software packages, as well as how to update an existing **BoA** version.

2.1 Prerequisites

So far, **BoA** has been installed and tested on the following LINUX distributions:

- SuSE 10.0
- Scientific Linux 4.2

The following software packages must be installed on a system to be able to install and run **BoA** . (The given version numbers indicate the versions that where used during development and tests with the respective LINUX distribution.)

Table 2.1: Prerequsites

Package	Version SuSE	Version Scientific Linux
gcc / gccc-c++	4.0.2	3.4.4
compat-g77	3.3.5	3.4.4
readline-devel	5.0	4.3
libpng-devel	1.2.8	1.2.7
xorg-x11-devel	6.8.2	6.8.2
findutils-locate	4.2.23	4.1.20
cvs	1.12.12	1.11.17

With SuSE, depending on the original setup of the system, some or all of these packages my be missing. Uso SuSE's package manager *YaST* to check if they are present and to install or update them.

With Scientific Linux, all necessary packages are part of a standard installation. If a package is missing or needs to be updated, use *rpm*.

2.2 Obtaining the installation script and packages

Make sure that the shell variables CVSROOT and CVS_RSH are set to

```
CVSROOT: :ext:[yourUserNameOn_aibn28]@aibn28.astro.uni-bonn.de:/var/lib/cvs
CVS_RSH: /usr/bin/ssh
```

The command

```
cvs co boa-install
```

will download the external packages and the installation script *install.sh* (written by Alexandre Beelen, Thomas Jürges, Frederic Schuller, and Reinhold Schaaf) to the directory boa-install in your current dirctory.

Make the *install.sh* script executable:

```
chmod u+x boa-install/install.sh
```

You are now ready to start the installation. (The **BoA** software itself is not downloaded at this stage. It will be downloaded from the CVS server during the installation.)

2.3 Installation using the *install.sh* script

2.3.1 Running the *install.sh* script

Before running the *install.sh* installation script make sure that you have fulfilled the prerequisites described in Sect. 2.1!

1. Go to the directory where you have downloaded the openboa cvs directory and files. Change into the directory openboa/install/ where the installation script *install.sh* is stored.
2. Run the *install.sh* script by typing:

   ```
   ./install.sh
   ```

   This begins the process of installing **BoA** .

   The script will prompt you for some paths (reasonable defaults are offered). If you don't want to use the default path, then please enter your chosen path, e.g. */home/smueller/BoA*, when prompted. Don't forget to first create your chosen directory if not already present!

   You will also be prompted to enter yes (y) or no (n) for the installation of each software package. For a fresh installation, you should install every package included (even if, say Python, is allready present on your system). Skipping installation of packages is useful if you resume an aborted installation (see below). If you wish to, you can try to see whether **BoA** works with your preinstalled versions of software; however, that is at your own risk!

   The script will create in this installation directory six sub-directories, *bin*, *BoA*, *include*, *lib*, *man* and *tmp* where all necessary files will be installed. The required disk space is about 220 MB.
3. After the installation is complete, type

   `source ~/.boarc.sh` (if you are working in bash)

   or

   `source ~/.boarc.csh` (if you are working in csh).
4. You can now run **BoA** by typing `boa` at the prompt!

2.3.2 Details of the installation process

The installation consists of three stages, all of which are performed by the installation script:

- Installation of the external packages necessary for BoA
- Installation of BoA itself, including documentation and example FITS files
- Installation of BoA's initialization files .boarc.sh and .boarc.csh

After the installtion, you will find a installation log in boa-install/build.stat. If the installation fails, the install script will tell you that something went wrong and give you a place where you can find information related with the failure. In addition, you can consult boa-install/build.stat for information about the earlier steps of the installation.

Installation of external packages

The installation script will install the following external packages:

Table 2.2: External packages

Package	Version
Python	2.3.2
Numeric	23.1
numarray	0.9
swig	1.3.23
Intel FORTRAN	8.1
scipy_distutils	3.3_33.571
f2py	2.44.240_1892
pgplot	5.2
pPGPLOT	1.3
slalib	
pySLALIB	0.4
blas / lapack	
cfitsio	2.49
pCFITSIO	
BoA-FFTW-Numpy	1.0
mpfit	
wcslib	4.1
dchelper	
apexFitsWriter	
apexCalibrator	

The installation script prompts you for the location of the external packages. The default should allways be correct.

Next, you are prompted for the directory where BoA is to be installed. If this directory allready exists, you must confirm that choice. (This case is necessary to resume an aborted installation or to update the BoA software itself. In all other cases, install to a new directory!)

The script then installs all external packages into this directory.

For some packages, (e.g. scipy_obsutils) you are prompted whether you want the package to be updated via CVS. This may not be necessary, so you can safely answer n. If you do update, the installtion script

provides you the necessary information (CVS login and password). Be aware that the CVS server may be slow or even down. If this is the case, you are prompted after a timeout of about 2 min whether you want to proceed without the CVS update. If you are nervous, cancel the installation with `Ctrl-C` and resume the installation (see below).

Installation of BoA

When the installation of the external packages is complete, the BoA software itself is installed. Since it is not included in the boa-install download, it is downloaded from the CVS server now. (Please be aware that you have to use your own CVS login and password here!) As an alternative, you may use a BoA tar-ball.

The script prompts you for a directory, where BoA is to be installed. You can choose any accessible directory.

After the installation of the BoA software, the documentation and example FITS files are downloaded from the CVS server and installed. Again you are prompted whether and where you want these features to be installed.

Installation of BoA's initialization files

As last step, the script installs the initialization files .boarc.sh and .boarc.csh to your home directory. These scripts define a runtime environment for BoA (setting shell variables, paths, and aliases) for bash (.boarc.sh) and csh (.boarc.csh). Before running BoA, type

```
source ~/.boarc.sh
```
(if you are working in bash)

or

```
source ~/.boarc.csh
```
(if you are working in csh)

You may want to add this to your shell's startup script.

2.4 Resuming an incomplete installation

To resume an incomplete installation, run

```
boa-install/install.sh
```

again. When prompted for the directory to which BoA is to be installed, specify the same directory as in the aborted installation. (Do this even if you will not install a single external package; the information is needed for the initialization files!)

You can then safely skip all installation steps, that where performed successfully in the last installation run.

Please be aware that you are prompted for the variable `PGPLOT_DIR` after skipping the installation of pgplot. A reasonable default is offered. However, if you want to use a pre-installed pgplot, you can specify this here.

2.5 Installation FAQ

2.5.1 BoA fails to start

- `ImportError: No module named fUtilities`

the fortran modules have not been compiled. Go to the fortran directory and type `make`

- `ImportError: libifport.so.x`

you dont have the fortran librarie in you `$LD_LIBRARY_PATH`, please source the `boarc.xx` file or check your installation.

2.5.2 I can't open a Graphical Device

- check the pgplot and p_pgplot installation
- if trying to output png files, make sure that libpng was present when compiling pgplot.

2.5.3 Reading a MBFits file fails

- check the cfitisio and pcfitsio installation
- check that the version of `MBFits.xml/$MBFITSXML` you are using match the file you are trying to read

2.6 Updating BoA

Depending on the changes in **BoA** that make an update necessary (or desirable), an update of **BoA** alone or an update of the external packages and of **BoA** may be necessary. Unfortunately, presently there is no systematic way to find out whether a update of the external packages is necessary. The best choice may be first to try an update of **BoA** alone, and if this causes problems, make an update of the external packages and **BoA** .

Updating BoA alone

Examine the shell variable BOA_HOME_BOA that is set in the initialization files `~/.boarc.sh` and `~/.boarc.csh`, to find out, where **BoA** is installed. Move to this dirctory:

```
cd $BOA_HOME_BOA
```

Make sure that the shell variables CVSROOT and CVS_RSH are set to

```
CVSROOT: :ext:[yourUserNameOn_aibn28]@aibn28.astro.uni-bonn.de:/var/lib/cvs
CVS_RSH: /usr/bin/ssh
```

Now update **BoA** from the CVS server by typing

```
cvs update
```

Updating external packages and BoA

Follow the instructions in section 2.2 to obtain a new installation script and the external packages from the CVS server. Then follow section 2.4 to replace the external packages of your current installation that need to be updated. Do not forget to update **BoA** itself in this process!

If this does not result in a working installation, do a fresh installation according to section 2.3, possibly into a new directory.

3. OVERVIEW OF **BoA** STRUCTURE

In this Chapter, we give a basic overview of the structure of **BoA** . Section 3.1 gives a brief introduction to the raw data file format, and Section 3.2 shows an overview of the data structure within **BoA** . More in-depth descriptions are given in Chapter 7.

3.1 Input data

The data acquired at the APEX telescope are stored in a new file format, known as the MB-Fits format (for Multi-Beam FITS format, see the reference document APEX-MPI-IFD-0002 by Hatchell et al. for details). These files contain:

- the raw data as provided by the Frontend-Backend in use at the telescope
- data associated parameters: time of the observations, positions on the sky...
- a description of the complete Scan (eg. for a map: number of lines, steps between lines...)
- parameters of the receiver channels in the array: relative positions, relative gains

A more complete description of the input data format is given in Sect. 7.1.

3.2 Internal data handling

Taking full advantage of the object-oriented nature of Python, **BoA** handles data by means of objects of various classes. The primary class for data storage and manipulation is called DataEntity (see also Section **??**). This class allows to store the raw data and associated parameters, and it provides methods relevant for any kind of observations (e.g. reading data from an MB-FITS file, plotting the signal as time series, plotting the telescope pattern). The most important attributes of this class are:

- BolometerArray: here, the relative positions and gains of the receiver channels are stored, as well as generic informations about the instrument and telescope (name, diameter, coordinates...)
- ScanParam: this contains the data associated parameters: coordinates of each point in several systems, timestamps (in LST and MJD), subscans related informations
- Data: this is a 2D array (time $\times$ bolometer) which contains the current version of the data. At time of reading, the raw data are stored there; the content of this array is then altered by any processing step
- DataFlags, DataWeights: 2D arrays, with same size as Data, where flagging values and relative weights are stored for each individual data point

For processing different types of observations, **BoA** then provides several classes which inherits from DataEntity. Inheritance allows to define a class which contains all attributes and methods of the parent class, plus some specific attributes/methods. The inheritance scheme in **BoA** is as follows:

```
DataEntity < DataAna < Map < Point < Focus
```

When **BoA** is started, one object of class *Focus* is created with name *data*; this is the current data object, on which all reduction procedures can be applied. Additional objects of any data class can be created by the user within one **BoA** session. Then, applying processing methods to a data object with a different name that *data* requires to enter the full syntax (see Chapter ...), including the full name of the method, as opposed to the shortcuts described in Chapters 4 and 5.

Note: Python ensures no real difference between private and public attributes. There are only hidden attributes but this hiding can be overcome easily. Therefore the user might set any attribute directly and call any method. This is not advisable and may easily corrupt the whole **BoA** session. It is more recommendable to just use those methods for which the start script *BoaStart.py* provides abbreviations.

4. QUICK USER GUIDE

This section describes how to start up **BoA** for the first time and lists a small set of **BoA** commands needed when starting **BoA** for the first time. Detailed information on these and many more **BoA** commands can be found in Chapter 5.

4.1 Starting up BoA

You can invoke **BoA** in the following ways:

- call python in interactive mode (*-i*) with the file *BoaStart.py*

  ```
  python -i BoaStart.py
  ```

- as above but using an alias you have set up in your .cshrc (see section **??**)
- from an already running python session it is possible to import the **BoA** functionalities and commands by typing

  ```
  >>> execfile('BoaStart.py')
  ```

  at the python prompt.

BoA then prints a welcome message providing version information and changes the prompt to the boa> prompt. Nevertheless, you are still in the interactive python layer. The start script *BoaStart.py* imports a set of modules, instantiates the most essential objects and makes the respective methods available.

4.2 Some useful BoA commands

In this section we list some useful **BoA** commands, classified in terms of their function. Just enter them at the boa> prompt (note that the parentheses are mandatory).

Note, these commands are abbreviations for the full user method names, as is described in Chapter 4.

4.2.1 Setting up

- `indir()` Change the input directory
- `proj()` Define the APEX project ID and simplify the I/O
- `ils()` List the content of the input directory
- `find()` Reset the above input directory list

4.2.2 Display

- `open()` Open a device
- `close()` Close the current device
- `device()` Select a particular device

4.2.3 Reading in & plotting data

- `read()` Load a given fits file to BoA
- `signal()` Plot the signal against time
- `azeloff()` Plot the telescope pattern on the sky in azimuth/elevation offsets coordinates
- `chan()` Select a subset of channel
- `select()` Select scans depending on the given criteria

4.2.4 Flagging data

- `flagLST()` Flag data against time
- `flagCh()` Flag a given channel

4.2.5 Basic data analysis

- `base()` Remove a baseline
- `stat()` Compute basic statistic on the data
- `plotcor()` Correlation plot

4.2.6 Mapping

- `chanMap()` Produce a channel map
- `fastMap()` Project the data in the sky plane

4.2.7 Getting Help

You can get help on a **BoA** `command()` at any time by typing

```
print command.__doc__
```

at the prompt.

5. DETAILED USER GUIDE

In this chapter you will find detailed descriptions of user methods, their arguments, output and abbreviations and some examples of the different tasks possible to execute in **BoA** . As many user methods have an abbreviated form, these are listed in Section 5.10.

5.1 Overview of how to use BoA

5.1.1 Methods

BoA tasks are accessed by directly calling the appropriate methods from the interactive python layer. This ensures the full availability of all python and ppgplot facilities. As the method names to be called from the python layer may be rather long, the start script *BoaStart.py* provides a set of convenient abbreviations for those methods which are meant to be called directly by the user ("public" methods). We will therefore refer to these as user methods.

Example:

The name of the method to open a new graphic device is *DeviceHandler.openDev* and it can be called by

```
DeviceHandler.openDev()
```

or more conveniently by the abbreviations (user methods)

```
open() or  op()
```

(note that the parentheses are always mandatory).

5.1.2 Arguments

Nearly all user methods require arguments to be passed. Nevertheless, the methods provide default arguments which thus may be omitted. In this case many methods just supply status information.

Example:

The user method `indir()` sets the desired input directory and requires the directory name as its argument:

```
indir('/home/user/data/')
```

The directory name is a string argument and has to be passed embedded in double or single quotes. Note that for consistency, in the examples throughout this manual we always use single quotes, but these can of course be substituted for double quotes.

Omitting the argument does not change the input directory but instead results in the supply of the current directory name:

```
indir()
```

In case an argument has to be typed more often a python variable can be used:

```
a='/home/user/data/'
indir(a)
```

Some methods require a list as argument. In python a list is embedded in square brackets with a comma as separator. Python provides a variety of functionalities to manipulate lists.

Example:

The user method `signal()` plots the time series of the data (flux density or counts versus time). It allows the user to define the list of channels plotted:

```
signal([18,19,20])
```

To create a list you can use the python function `range()`:

```
mylist=range(1,163)
signal(mylist)
```

or:

```
signal(range(1,163))
```

Even if the list contains only one element the square brackets are mandatory:

```
signal([5])
```

User methods can also be called using keyword arguments of the form *keyword* = *value*.

Example:

By default, the user method `signal()` plots the signal versus time connecting the datapoints with lines:

```
signal()
```

However, if you prefer, for example, to see the individual datapoints without lines, you can modify the value of the *style* argument:

```
signal(style='p')
```

A description of plotting related arguments such as *style* is given in Section **??**.

5.1.3 Output

Most user methods supply status information as screen output when being called. The amount of information displayed can be restricted using the message handler associated with the main *data* object:

```
data.MessHand.setMaxWeight(4)
```

where the arguement is an integer value between 1 and 5, with the following meaning:

- 1: errors, queries
- 2: warnings
- 3: short info
- 4: extended info
- 5: debug

5.2 User methods for data reduction and map making

5.2.1 Pointing

Processing a Pointing scan requires an object of the class Point. Since the default *data* object is of class Map, it has to be redefined before reading the file. Then the method to process the data is called *solvePointing*. Optionally, the method *showPointing* can be called to show the results on a map:

```
data = BoaPointing.Point()  # instantiate a Point object
read('APEX-600')       # fill it with data
solvePointing()        # compute pointing offsets
showPointing()         # display map and fitted 2D-Gaussian
```

5.2.2 Focus

The recommended way to conduct Laboca focus observations is to perform a series of n*3 short, symmetric on-offs, e.g. 3 or 6*(4*5sec). For this simply the onoff has to be reduced and then the results can be fitted by a parabola.

```
solveFocus()           # compute the optimal focus position
```

5.2.3 Skydip

5.2.4 OnOff

5.2.5 Mapping

Several methods are provided to construct a map, taking into account the relative positions of the bolometers in the instrument. The `slowMap()` method computes exact positions and loops over the pixels of the resulting map to calculate the contributions to the flux at a given position from all bolometers. This is a *very* slow method.

The `fastMap()` method loops over the signal series in each bolometer, and dumps fluxes at the nearest pixel on the final map. Then the maps produced from each bolometer are coadded. This method makes use of operations on arrays, and is thus very fast.

```
read('lissajou')
open()                # open an XWindow device
fastMap()             # reconstruct a map with the fast method
```

5.2.6 Beam maps

5.3 User methods for file reading

5.3.1 Reading a FITS file

Reading a FITS file into **BoA** is done with the `read()` command. You may want to define the input directory first:

```
indir('../fits/')       # set the input directory
read('APEX-600')        # read file APEX-600.fits
```

The data are then stored in the default *data* object. It is possible to use several data objects, and to store the content of a file to a user defined object requires the following syntax:

```
data2 = BoaMapping.Map()   # define a second data object
                           # of class Map
data2.read('APEX-600')
```

5.4 User methods for controlling graphics display devices

In order to display your data in various ways using the **BoA** plotting methods described in Section 5.5 below, you first need to open a graphics display device (e.g. Xwindows). Graphics display in **BoA** is controlled by a software package called **BoGLi** (the **BoA** Graphic Library), which is described in Chapter 6. A few basic **BoGLi** commands which are needed in order to carry out the **BoA** plotting methods described in section 5.5 are thus described in this section.

5.4.1 Opening a plot window

Opening a graphic device is done with the `open()` command:

```
open()     # open a device, default: XWindow
op()       # alternatively, use the abbreviated command
```

The default is to open an XWindow. You can use

```
op('?')
```

to get a list of all recognized devices. Alternatively, if you know which device you want you can enter it directly, for example

```
op('/ps')
```

You can also open a named PostScript file, here a colour PostScript file named *signal.ps*, with

```
op('signal.ps/CPS')
```

5.4.2 Clearing a plot window

Clearing a plotting window is done with the `clear()` command:

```
clear()              # clear the active device
```

However, any plot command will first clear the active device before plotting a new graph, unless the *overplot=1* keyword is supplied.

5.4.3 Closing a plot window

Closing a graphic device is done with the `close()` command:

```
close()    # open a device, default: XWindow
```

5.5 User methods for displaying data

5.5.1 Displaying channel maps

If you want to display channel maps you can do this with the command `chanmap()`. The default is to plot channel maps for all available channels. You can also specify a list of channels to be plotted.

Example:

```
read('3543')          # read in a file
op()                  # open an XWindow device
chanmap()             # produce channel maps for all channels
chanmap(range(26))    # channel maps for the first 25 channels
chanmap([1,4,20,55]) # channel maps for a selection of channels
```

5.5.2 Plotting azimuth versus LST

DESCRIPTION: Plot the time series of the azimuth, i.e. azimuth versus LST.

USAGE: `azimuth(`*optional arguments*`)`

OPTIONAL ARGUMENTS:

flag	flag to be used (default = 0: all valid data; -1: plot all)
limitsX	range of X values to be plotted (comma separated values, in square brackets)
limitsY	range of Y values to be plotted (comma separated values, in square brackets)
style	linestyle to be used ('p' or 'l', for points and solid line respectively)
ci	colour index to be used (integer values)
overplot	
aspect	

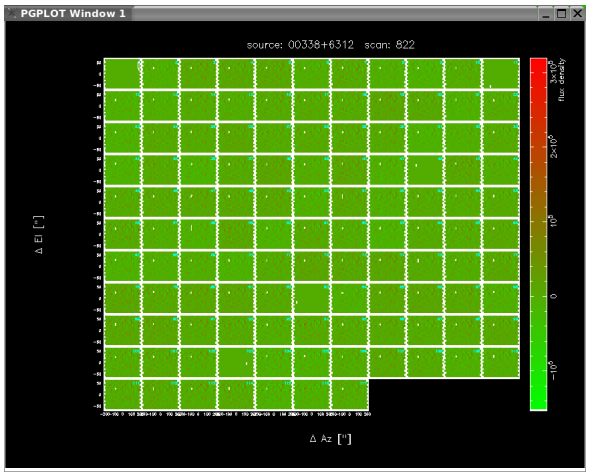


Figure 5.5.1: Default graphical outputs of a channel map of the source 00388+6312, including a wedge.

A more detailed description of plotting related arguments can be found in Section **??**.

Example:

`azimuth(style='p', ci=2, limitsY=[-14,-13])`

Plot azimuth versus LST but show individual plotted points (rather than lines), make plotted points red, and only plot azimuth (y axis) from -14 to -13 degrees.

5.5.3 Plotting elevation versus LST

DESCRIPTION: Plot the time series of the elevation i.e. elevation versus LST.

USAGE: `elevation` (*optional arguments*)

OPTIONAL ARGUMENTS:

flag	flag to be used (default = 0: all valid data; -1: plot all)
limitsX	range of X values to be plotted (comma separated values, in square brackets)
limitsY	range of Y values to be plotted (comma separated values, in square brackets)
style	linestyle to be used ('p' or 'l', for points and solid line respectively)
ci	colour index to be used (integer values)
overplot	

A more detailed description of plotting related arguments can be found in Section **??**.

Example:

as for `azimuth()`, above.

5.5.4 Plotting elevation versus azimuth

DESCRIPTION: Plot elevation versus azimuth.

USAGE: `azel` (*optional arguments*)

OPTIONAL ARGUMENTS:

flag	flag to be used (default = 0: all valid data; -1: plot all)
limitsX	range of X values to be plotted (comma separated values, in square brackets)
limitsY	range of Y values to be plotted (comma separated values, in square brackets)
style	linestyle to be used ('p' or 'l', for points and solid line respectively)
ci	colour index to be used (integer values)
overplot	

A more detailed description of the plotting related arguments can be found in Section **??**.

Example:

as for `azimuth()`, above.

5.5.5 Selecting channels

DESCRIPTION: Select a channel or a list of channels to be plotted. The list is automatically sorted.

USAGE: `channels(`*optional argument*`)`

OPTIONAL ARGUMENTS:

chanList:	list of channel numbers, of the form: [1,2,3]
'all'... 'al'...'a'	
'?'	

Example:

`channels([1,2,3])`	list of channels to be plotted
`channels(chanList=[1,2,3])`	list of channels to be plotted
`channels('all')`	set current list to all possible channels
`channels('?')`	get current list of channels (the default if no argument is specified)

5.5.6 Plotting flux density versus LST

DESCRIPTION: Plot the time series of the flux density i.e. flux density versus LST.

USAGE: `signal(`*optional argument*`)`

OPTIONAL ARGUMENTS:

chanList	list of channels, of the form [1,2,3]
flag	flag to be used
mjd	if set, use mjd instead of lst
limitsX	range of X values to be plotted (comma separated values, in square brackets)
limitsY	range of Y values to be plotted (comma separated values, in square brackets)
style	linestyle to be used ('p' or 'l', for points and solid line respectively)
ci	colour index to be used (integer values)
overplot	

A more detailed description of the plotting related arguments can be found in Section **??**.

Example:

```
signal(chanList=[18,19,20], mjd=1, style='p', ci=2)
signal([18,19,20], mjd=1, style='p', ci=2)
```

5.5.7 Plotting the FFT of the signal

A Fast Fourier Transform (FFT) of the signal can be plotted using the *fft* method:

```
read('spiral1')
op()                  # open an XWindow device
data.fft(range(10))   # plot FFT for the first 9 channels
```

5.6 MB-Fits to FITS file conversion

To convert an MB-Fits file to a FITS file in the MAMBO format you can use the command `mambo()`. The current version does NOT use the data contained in the data object in Boa, but reads the input file (with default name = BoaB.currData.FileName) and converts it to the Mambo format. Therefore, this procedure is somewhat decoupled from Boa.

5.7 Scripts

As BoA provides the full functionality of python this allows the use of scripts. Scripts can be run with the `execfile()` function where the name of the file has to be given as string argument. The suffix of the file is arbitry.

Example:

If you want to have a look at the time series of channels 10 to 30 succesively, create the following script with your preferred editor. Note that in python the contents of the for loop (like if blocks, method definitions, etc.) have to be indented.

```
# testBoa.py
indir('../Fits/')       # set the input directory
read('3543')            # read file 3543.fits
op()                    # open graphic display
for i in range(10,31): # start a for loop, the indentation in
                        # the following lines is mandatory
sig([i])                # plot time series
raw_input()             # wait for <Return>
```

To run the script type:

```
execfile('testBoa.py')
```

5.8 Commands in alphabetical order

arrayParameters	determine the array parameters from the data
basePoly	fit and subtract baseline from individual scans or subscans
basePolySubscan	subtract baseline subscan by subscan
beamMap	build a beam map in (Az,El) coordinates
blankAmplitude	blank the amplitude below and/or after a certain frequency
checkChanList	Return a list of valid channels
checkFits	check for MBFits name structure
clear	clear the active plot window
closeDev	close one device
computeBeamSize	Compute the beam size in arcsec
computeChanSep	Compute separation between pixels (in arcsec)
computeChanSepValid	Compute separation between VALID (i.e. not flagged -1) pixels (in arcsec)
computeCorMatrix	compute correlation matrix
computeOnOff	determine ON-OFF pairs from content of WobblerSta, and fill OnOffPairs attribute with pairs of integration numbers. The result is a 2 x Nb_Integ. array of integers.
computeSN	compute correlated noise, run after computeCorMatrix, computeWeight, correlate
computeWeight	compute weight matrix of the used channels, run after computeCorMatrix
correlate	compute correlation relative to a reference channel
despike	Flag yet unflagged data below 'below'*rms and above 'above'*rms
doFFT	perform the FFT
dumpData	save data object to a file
fastChanMap	plot channel maps (quick method)
fastmap	reconstruct a map in (Az,El) coordinates combining bolometers
findInDir	???
findSubscan	compute subscan indices from steps in az, el
flag	flag data at more than n*rms
flagChannels	flag a list of channels
flagLST	flag data by LST interval
flagLon	flag data by Az offset interval
flagPosition	flag a position in the sky within a given radius
flagRms	Flag channels with rms below or above respective given values
flagSubscan	flag certain subscans
getChanData	get data for one channel
getChanIndex	convert from physical channel number to index in UsedChannel
getChanListData	get data for a list of channels
getChanSep	return the channel separation in both direction from the reference channel

getPixel	allow user to get pixel values using mouse
invFFT	perform the inverse FFT
iterMap	reconstruct a map in (Az,El) coordinates combining bolometers and using varying scale to zoom on signal
listInDir	list the input directory
mambo	convert MB-Fits file to MAMBO format
medianBaseline	baseline: Remove median value per channel and per subscan
medianFilter	median filtering: remove median values computed over sliding window
open	open a graphic device
plotArray	plot the receiver parameters
plotAzEl	plot elevation versus azimuth
plotAzElOffset	plot elevation offset versus azimuth offset
plotAzimuth	plot azimuth versus LST
plotAzimuthOffset	plot azimuth offset versus LST
plotCorMatrix	plot the correlation matrix
plotCorrel	plot signal vs. reference channel
plotElevation	plot elevation versus LST
plotElevationOffset	plot elevation offset versus LST
plotFFT	plot FFT of signal
plotGain	plot the gain of the Array
plotMean	plot mean flux values vs. subscan numbers
plotMeanChan	plot mean value for each subscan vs. chan. number
plotRms	plot rms flux values vs. subscan numbers
plotRmsChan	plot rms value for each subscan vs. chan. number
plotSubscan	generate a plot showing starting and ending times of subscans
plotSubscanOffsets	Use four colours to show subscans on the Az, El pattern
read	read in a file
readAsciiRcp	update receiver channel offsets from a simple ascii file, channelNumber AzOffset(arcsec) ElOffset(arcsec)
readRCPfile	update Receiver Channel Parameters (attributes Offsets, Gain and ChannelSep) from the content of a file
reduce	Process a Pointing scan - this method is called by the apexCalibrator
resiz	resize the plot, after resizing window with mouse
resetCurrentList	reset the CurrentList to the complete list
restoreData	restore a previously stored BoA *.sav file
rotateArray	rotate array offsets according to elevation
saveMambo	convert an MB-Fits file to the MAMBO FITS format, readable by MOPSIC
selectDev	select an open device
selectInDir	make a selection in the current list

setCurrChanList	select list of channels
setInDir	set the input directory
setInFile	set the input file name
setMess	display a message
setOutDir	set the output directory
setOutFile	set the output file name
setProjectID	set the project ID
showMap	show the reconstructed map in (Az,El)
showPointing	???
signal	plot the time series of the data (flux density versus LST)
slowMap	reconstruct a map in (Az,El) coordinates combining bolometers
smoothBy	smooth the image with a 2D gaussian of gived FWHM
smoothWith	smooth the image with the given kernel
snf	compute and subtract skynoise
solveFocus	compute the optimal focus position
solvePointing	compute the pointing offset
solvePointingOnMap	compute the offset on the data.Map object
statistics	prints the statistics
unflag	unflag data
unflagChannels	unflag a list of channels
updateArrayParameters	Update the Parameters Offsets with the computed values
writeMBfits	write the data (and parameters) contained in the current data out to a FITS file in MB-Fits format
writeRCPfile	store current Receiver Channel Parameters (Offsets, Gain) to a file with mopsi like format

5.9 Commands in functional order

5.9.1 Plotting

plotArray	plot the receiver parameters
plotAzEl	plot elevation versus azimuth
plotAzElOffset	plot elevation offset versus azimuth offset
plotAzimuth	plot azimuth versus LST
plotAzimuthOffset	plot azimuth offset versus LST
plotCorMatrix	plot the correlation matrix
plotCorrel	plot signal vs. reference channel
plotElevation	plot elevation versus LST
plotElevationOffset	plot elevation offset versus LST
plotFFT	plot FFT of signal
plotGain	plot the gain of the Array
plotMean	plot mean flux values vs. subscan numbers
plotMeanChan	plot mean value for each subscan vs. chan. number
plotRms	plot rms flux values vs. subscan numbers
plotRmsChan	plot rms value for each subscan vs. chan. number
plotSubscan	generate a plot showing starting and ending times of subscans
plotSubscanOffsets	Use four colours to show subscans on the Az, El pattern
signal	plot the time series of the data (flux density versus LST)
slowMap	reconstruct a map in (Az,El) coordinates combining bolometers

5.9.2 Device handling

clear	clear the active plot window
closeDev	close one device
open	open a graphic device
resiz	resize the plot, after resizing window with mouse
selectDev	select an open device

5.9.3 Pointing and focus

reduce	Process a Pointing scan - this method is called by the apexCalibrator
showMap	show the reconstructed map in (Az,El)
showPointing	???
solveFocus	compute the optimal focus position
solvePointing	compute the pointing offset
solvePointingOnMap	compute the offset on the data.Map object

5.9.4 Flagging and despiking data

blankAmplitude	blank the amplitude below and/or after a certain frequency
despike	Flag yet unflagged data below 'below'*rms and above 'above'*rms
flag	flag data at more than n*rms
flagChannels	flag a list of channels
flagLST	flag data by LST interval
flagLon	flag data by Az offset interval
flagPosition	flag a position in the sky within a given radius
flagRms	Flag channels with rms below or above respective given values
flagSubscan	flag certain subscans
unflag	unflag data
unflagChannels	unflag a list of channels

5.9.5 Map making

beamMap	build a beam map in (Az,El) coordinates
fastChanMap	plot channel maps (quick method)
fastmap	reconstruct a map in (Az,El) coordinates combining bolometers
iterMap	reconstruct a map in (Az,El) coordinates combining bolometers and using varying scale to zoom on signal

5.9.6 Baseline subtraction, sky removal and statistics

basePoly	fit and subtract baseline from individual scans or subscans
basePolySubscan	subtract baseline subscan by subscan
computeCorMatrix	compute correlation matrix
computeSN	compute correlated noise, run after computeCorMatrix, computeWeight, correlate
computeWeight	compute weight matrix of the used channels, run after computeCorMatrix
correlate	compute correlation relative to a reference channel
doFFT	perform the FFT
invFFT	perform the inverse FFT
medianBaseline	baseline: Remove median value per channel and per subscan
medianFilter	median filtering: remove median values computed over sliding window
smoothBy	smooth the image with a 2D gaussian of gived FWHM
smoothWith	smooth the image with the given kernel
snf	compute and subtract skynoise
statistics	prints the statistics

5.9.7 File handling

checkFits	check for MBFits name structure
dumpData	save data object to a file
mambo	convert MB-Fits file to MAMBO format
read	read in a file
restoreData	restore a previously stored BoA *.sav file
saveMambo	convert an MB-Fits file to the MAMBO FITS format, readable by MOPSIC
writeMBfits	write the data (and parameters) contained in the current data out to a FITS file in MB-Fits format

5.9.8 Data handling

arrayParameters	determine the array parameters from the data
checkChanList	Return a list of valid channels
computeOnOff	determine ON-OFF pairs from content of WobblerSta, and fill OnOffPairs attribute with pairs of integration numbers. The result is a 2 x Nb_Integ. array of integers.
findSubscan	compute subscan indices from steps in az, el
getChanData	get data for one channel
getChanIndex	convert from physical channel number to index in UsedChannel
getChanListData	get data for a list of channels
getChanSep	return the channel separation in both direction from the reference channel
getPixel	allow user to get pixel values using mouse

5.9.9 Selecting files and directories

findInDir	???
listInDir	list the input directory
resetCurrentList	reset the CurrentList to the complete list
selectInDir	make a selection in the current list
setCurrChanList	select list of channels
setInDir	set the input directory
setInFile	set the input file name
setOutDir	set the output directory
setOutFile	set the output file name
setProjectID	set the project ID

5.9.10 Misc.

computeBeamSize	Compute the beam size in arcsec
computeChanSep	Compute separation between pixels (in arcsec)
computeChanSepValid	Compute separation between VALID (i.e. not flagged -1) pixels (in arcsec)
readAsciiRcp	update receiver channel offsets from a simple ascii file, channelNumber AzOffset(arcsec) ElOffset(arcsec)
readRCPfile	update Receiver Channel Parameters (attributes Offsets, Gain and ChannelSep) from the content of a file
rotateArray	rotate array offsets according to elevation
setMess	display a message
updateArrayParameters	Update the Parameters Offsets with the computed values
writeRCPfile	store current Receiver Channel Parameters (Offsets, Gain) to a file with mopsi like format

5.10 Abbreviations

As we have noted already, user methods are abbreviations of the full methods. For example, the method `DeviceHandler.openDev()` can be called by the user method `open()`. For further convenience, most user methods can also be called by even shorter abbreviations of the user methods (in this example `op()` is all that is needed). A list of user methods and their abbreviations is given in Table 5.1.

Command	Abbreviations
basePoly	baseline ... base
basePolySubscan	basesub
clear	clea ... cle ... cl
closeDev	close ... clos ... clo
computeCorMatrix	cormatrix ... cmatrix
correlate	cor
dumpData	dumpDat ... dumpD ... dump
fastChanMap2	chanmap ... ChanMap ... chanMap
fastmap2	mapping ... fastMapping ...fastMap
findInDir	find ... fd
flagChannels	flagCh ... flagC ... fCh
listInDir	indirls ... ils
setMess	mess
open	ope ... op
plotAzEl	azel
plotAzElOffset	azeloff ... azelo
plotAzimuth	azimuth ... azim ... az
plotAzimuthOffset	azimuthOffset ... azimoff ... azo
plotCorrel	plotcorrel ... plotcor ... plotCor
plotElevation	elevation ... elev ... el
plotElevationOffset	elevationOffset ... eleoff ... elo
plotMean	plotmean ... plotMean
plotMeanChan	plotmeanchan ... plotMeanChan
plotRms	plotrms ... plotRms
plotRmsChan	plotrmschan ... plotRmsChan
readRCPfile	readRCP ... rcp
resiz	resi
restoreData	restoreD ... restore ... restor
saveMambo	mambo
selectDev	device ... devic ... devi ... dev
selectInDir	select ... slt
setCurrChanList	channels ... channel ... chan
setInDir	indir ... indi ... ind
setInFile	infile ... infil ... infi ... inf
setOutDir	outdir ... outdi ... outd
setOutFile	outfile ... outfil ... outfi ... outf
setProjectID	setproj ...proj
signal	signa ... sign ... sig
statistics	stat
unflagChannels	unflagCh ... unflagC ...ufCh

Table 5.1: List of user methods with abbreviations. Don't forget to add the round brackets () at the end of the commands.

6. BoGLi : THE BoA GRAPHIC LIBRARY

6.1 Introduction

The **BoA** Graphic Library (**BoGLi**) is an object-oriented software package for the graphical display of data. It is written in Python and uses pgplot, the python binding to pgplot. The main parts (classes) of the software are self-consistent and may independently be used from any python programme. Nevertheless, **BoGLi** comes with features which especially customise its use for the display of astronomical data from multi-channel receivers. Its main goal is to provide a graphic tool tailored for the use with **BoA** for the display of data from LaBoCa, Simba and Mambo.

6.2 Command handling

BoGLi has its own command handler. Nevertheless, anytime the **BoA** command handler encounters a graphic command this is automatically passed to the BoGLi command handler. Therefore, the user does not have to care about the separation between **BoA** and **BoGLi** commands. Table 6.1 gives an overview of some of the available commands.

BoGLi provides a variety of attributes that may be changed by the user. The attribute name is then used as command followed by the desired value as argument (see Sect. **??** for details.)

Table 6.1: List of useful BoGLi commands.

`DeviceHandler.openDev`	open a device
`DeviceHandler.closeDev`	close a device
`Plot.clear`	clear the active plot window
`DeviceHandler.selectDev`	select a device
`DeviceHandler.resizeDev`	resize the plotting area, after plot window resized using mouse
`Plot.plot`	make a single plot
`MultiPlot.plot`	plot multiple plots
`Plot.draw`	draw on an image
`MultiPlot.draw`	draw on plots of multiple channels

6.3 Device handling

BoGLi is based on pgplot and as a consequence the number and type of available devices depends on the actual configuration. A list of supported devices is given at http://www.astro.caltech.edu/ tjp/pgplot/devices.html. During installation the device drivers have to be selected by editing the file *drivers.list*. As many device drivers are available on selected operating systems only, you should ensure that drivers you do not want are commented out (place ! in column 1) to avoid installation failures. A version of *drivers.list* used for a Linux PC can be found in Sect **??**.

The command handler of BoGLi provides a set of commands to manage output devices. A detailed description of these commands is given below.

6.3.1 Opening a plot window

DESCRIPTION: Open a graphics device for pgplot output and make it the current device. The default, when no argument is provided, is to open an XWindow.

USAGE: `DeviceHandler.openDev(`*optional argument*`)`

The relevant abbreviations can also be used (see Table 5.1).

OPTIONAL ARGUMENT: *pgplot device type*

If the device is opened successfully, it becomes the selected device to which graphics output is directed until another device is selected (see 6.3.4) or the device is closed (see 6.3.2). If no device argument is specified PGPLOT will open the default graphics device (an XWINDOW). Alternatively, the graphics device may be selected using any of the following as arguments:

(1) A complete device specification of the form 'device/type' or 'file/type', where /type is one of the allowed PGPLOT device types (installation-dependent, e.g. /xwindow) and 'device' or 'file' is the name of a graphics device or disk file appropriate for this type. The 'device' or 'file' may contain '/' characters; the final '/' delimits the 'type'. If necessary to avoid ambiguity, the 'device' part of the string may be enclosed in double quotation marks.

Example: `'plot.ps/ps', 'dir/plot.ps/ps', '"dir/plot.ps"/ps', 'user:[tjp.plots]plot.ps/PS'`

(2) A device specification of the form '/type', where /type is one of the allowed PGPLOT device types, e.g. /xwindow. PGPLOT supplies a default file or device name appropriate for this device type.

Example: `'/ps'` (PGPLOT interprets this as 'pgplot.ps/ps')

(3) A device specification with '/type' omitted; in this case the type is taken from the environment variable PGPLOT_TYPE, if defined (e.g., setenv PGPLOT_TYPE PS). Because of possible confusion with '/' in file-names, omitting the device type in this way is not recommended.

Example: `'plot.ps'` (if PGPLOT_TYPE is defined as 'ps', PGPLOT interprets this as 'plot.ps/ps')

(4) A blank string (' '); in this case, PGOPEN will use the value of environment variable PGPLOT_DEV as the device specification, or '/NULL' if the environment variable is undefined.

Example: `'  '` (if PGPLOT_DEV is defined)

(5) A single question mark, with optional trailing spaces, i.e. ('?'). In this case, PGPLOT will prompt the user to supply the device specification, with a prompt string of the form 'Graphics device/type (? to see list, default XXX):' where 'XXX' is the default (value of environment variable PGPLOT_DEV).

Example: `'?  '`

(6) A non-blank string in which the first character is a question mark (e.g. '?Device: '); in this case, PGPLOT will prompt the user to supply the device specification, using the supplied string as the prompt (without the leading question mark but including any trailing spaces).

Example: `'?Device specification for PGPLOT: '`

In cases (5) and (6), the device specification is read from the standard input. The user should respond to the prompt with a device specification of the form (1), (2), or (3). If the user types a question-mark in response to the prompt, a list of available device types is displayed and the prompt is re-issued. If the user supplies an invalid device specification, the prompt is re-issued. If the user responds with an end-of-file character, e.g., ctrl-D in UNIX, program execution is aborted; this avoids the possibility of an infinite prompting loop. A programmer should avoid use of PGPLOT-prompting if this behavior is not desirable.

The device type is case-insensitive (e.g., '/ps' and '/PS' are equivalent). The device or file name may be case-sensitive in some operating systems.

6.3.2 Closing a plot window

DESCRIPTION: Close a plotting device. The default, where no argument is supplied, is to close the current device.

USAGE: `DeviceHandler.closeDev(`*optional argument*`)`

OPTIONAL ARGUMENT:

device number (integer)
'all'
'current'...'curre'...'cur'

Example:

`DeviceHandler.closeDev(2)`	Close the device with identifier 2
`DeviceHandler.closeDev('all')`	close all devices
`DeviceHandler.closeDev('current')`	close current device (the default if no argument specified)

6.3.3 Clearing a plot window

DESCRIPTION: Clear the output of the current device. To clear the output of a different device change to that device first (see 6.3.4).

USAGE: `Plot.clear()`

6.3.4 Selecting a device

DESCRIPTION: Select an open device for graphical output. The selected device has to be previously opened with *open* (see 6.3.1).

USAGE: `DeviceHandler.selectDev(`*argument*`)`

ARGUMENT: *device number* (integer)

Example:

`DeviceHandler.selectDev(2)`	Make device number 2 the current device for graphical output

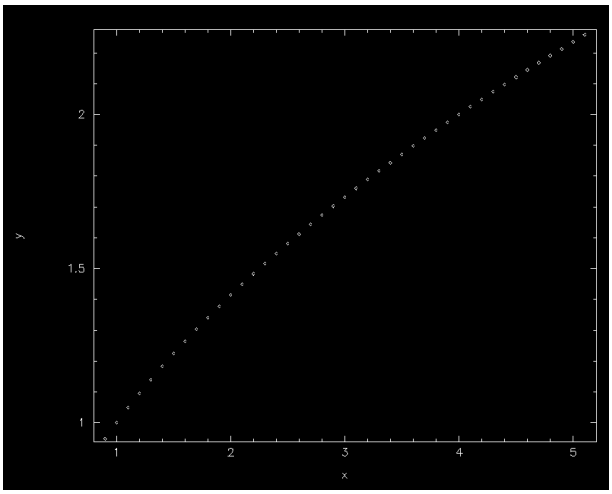


Figure 6.4.1: Example 1 of graphics produced using Plot.plot

6.3.5 Resizing a device

DESCRIPTION: Resize the plotting area after resizing of the graphics display window using the mouse. This is applicable to some interactive devices (e.g. /xwindow).

USAGE: `DeviceHandler.resizeDev()`

6.4 Plotting graphics

This section lists some of the graphics plotting capabilities of **BoGLi** .

6.4.1 Plotting single plots

DESCRIPTION: Make a single plot of x versus (optional) y.

USAGE: `Plot.plot( dataX`, *[dataY, limitsX, limitsY, labelX, labelY, caption, style, ci, width, overplot, aspect, logX, logY, nodata]*)

ARGUMENTS:

dataX	values to plot along X
dataY	values to plot along Y (optional - default: plot dataX vs. running number)

OPTIONAL ARGUMENTS:

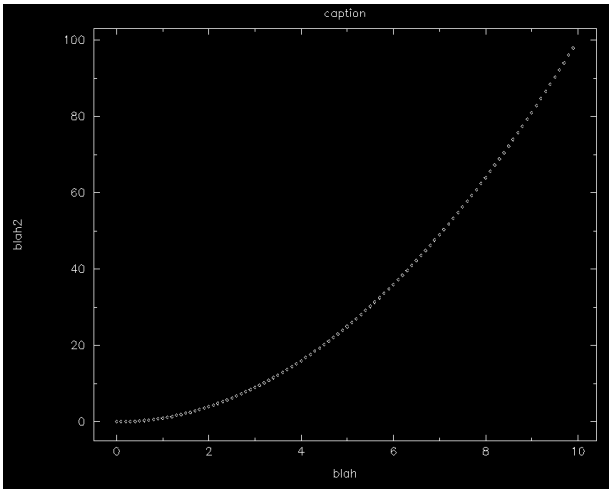


Figure 6.4.2: Example 2 of graphics produced using Plot.plot

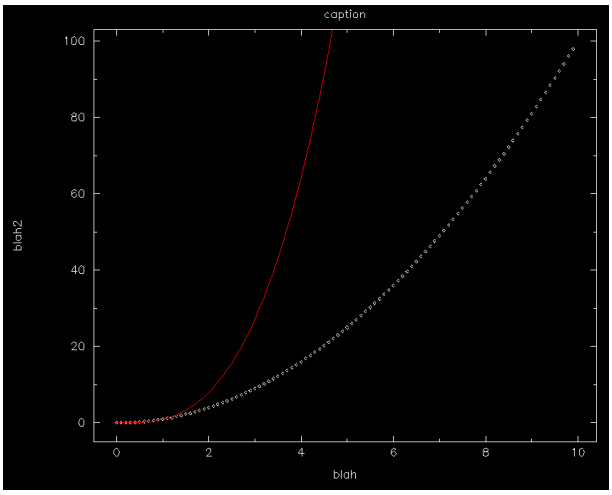


Figure 6.4.3: Example 3 of graphics produced using Plot.plot

limitsX	limits to use in X for the plot
limitsY	limits to use in Y for the plot
labelX	x label (default 'x')
labelY	y label (default 'y')
caption	the caption of the plot (default ' ')
style	the style used for the plot ('l': line, 'p': point (default), 'b': histogram)
ci	color index (default 1)
width	linewidth (defaut 0 = use previous)
aspect	keep the aspect ratio in 'physical' unit
overplot	set overplot=1 to overplot (default no)
logX	set logX=1 to use a log scale (default no)
logY	set logY=1 to use a log scale (default no)

These are also described in Section **??**. Note *dataY* is also optional – if no *dataY* is supplied the default is to plot dataX versus running number.

Example:

```
x = Numeric.array(range(100),Numeric.Float)/10
```

```
Plot.plot(x,Numeric.sqrt(x),limitsX=[1,5])
```

Note that Y limits are then computed according to this X range.

The graphic output produced in this case is shown in Figure 6.4.1.

Example:

```
Plot.plot(x,x*x,labelX='blah',labelY='blah2',caption='caption')
```

Note that plot clear the screen first, you need to use the new 'overplot' keyword (see below).

The graphic output produced in this case is shown in Figure 6.4.2.

Example:

```
Plot.plot(x,x*x*x,overplot=1,ci=2,style='l')
```

The graphic output produced in this case is shown in Figure 6.4.3.

6.4.2 Plotting multiple channels

DESCRIPTION: Make a plot of x versus (optional) y for several channelssimultaneously.

USAGE: `MultiPlot.plot(chanList, dataX, dataY,` *[limitsX, limitsY,labelX,labelY, caption, style, ci, overplot, logX, logY, nan]*)

ARGUMENTS:

chanList	list of channels, of the form [1,2,3]
dataX	values to plot along X
dataY	values to plot along Y

OPTIONAL ARGUMENTS:

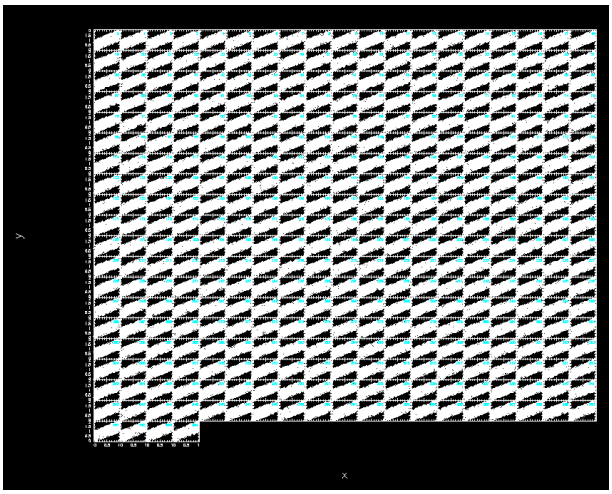


Figure 6.4.4: Example of graphics produced using MultiPlot.plot

limitsX	limits to use in X for the plot
limitsY	limits to use in Y for the plot
labelX	x label (default 'x')
labelY	y label (default 'y')
caption	the caption of the plot (default ' ')
style	the style used for the plot ('l': line, 'p': point (default), 'b': histogram)
ci	color index (default 1)
overplot	set overplot=1 to overplot (default no)
logX	set logX=1 to use a log scale (default no)
logY	set logY=1 to use a log scale (default no)

These are also described in Section **??**.

Example:

```
n_point = 365
chanlist=range(n_point)

x2 = RandomArray.random([n_point,n_point])
y2 = RandomArray.random([n_point,n_point])

MultiPlot.plot(chanlist,x2,y2+x2,style='p')
```

The graphic output produced in this case is shown in Figure 6.4.4.

6.4.3 Drawing on an image

DESCRIPTION: Draw on an image

USAGE: `Plot.draw( map_array`, *[sizeX, sizeY, WCS, limitsX, limitsY, limitsZ, nan, labelX, labelY, caption, style, contrast, brightness, wedge, overplot, aspect, doContour, levels, labelContour]*)

ARGUMENTS:

map_array	map to display

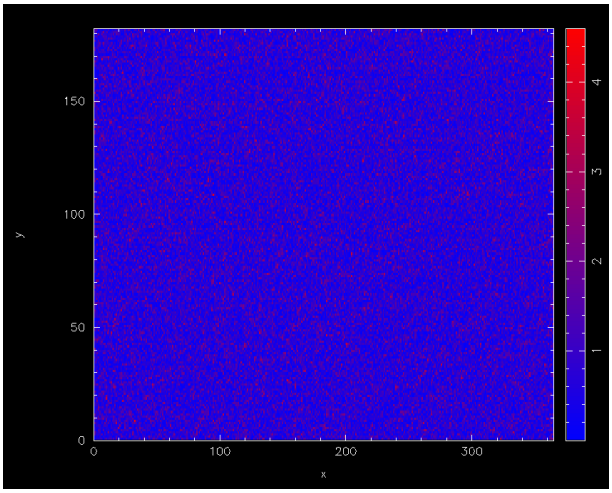


Figure 6.4.5: Example 1 of graphics produced using Plot.draw

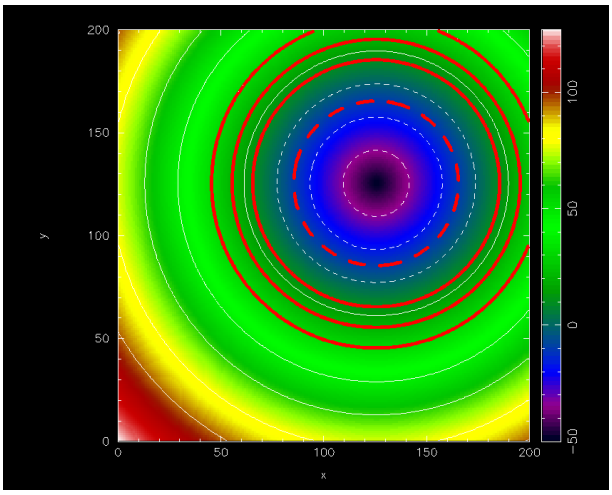


Figure 6.4.6: Example 2 of graphics produced using Plot.draw: drawing contours

OPTIONAL ARGUMENTS:

sizeX	the 'physical' size of the array (default pixel numbers), defined by the center of the two extreme pixels
sizeY	the 'physical' size of the array (default pixel numbers), defined by the center of the two extreme pixels
limitsX	limits to use in X for the plot
limitsY	limits to use in Y for the plot
nan	set =1 if NaN are present in the array
labelX	x label (default 'x')
labelY	y label (default 'y')
caption	the caption of the plot (default ' ')
style	the color used for the plot (default 'g2r', see Plot.Plot.setImaCol())
wedge	set wedge=1 to draw a wedge (default no)
aspect	keep the aspect ratio in 'physical' unit
overplot	set overplot=1 to overplot (default no)
doContour	set =1 to draw contour instead of map (default no)
levels	the levels for the contours (default nContour, within plotLimitsZ)
labelContour	set =1 to label the contours (default no)

These arguments are also described in Section **??**.

Example:

```
n_point = 365

mapping = Numeric.absolute(RandomArray.standard_normal([n_point,n_point/2]))

Plot.draw(mapping,style='b2r',wedge=1)

# You can also define 'physical' unit for your plot and still use
# limitsX/Y and aspect:

Plot.draw(mapping,sizeX=[-1,1],sizeY=[-2,2],limitsY=[-1,1],aspect=1, wedge=1)
```

The graphic output produced in this case is shown in Figure 6.4.5.

Example:

You can also use `Plot.draw()` to plot contours.

```
def dist(x,y):
    return (x-125)**2+(y-125)**2

image = Numeric.sqrt(Numeric.fromfunction(dist,(200,200)))-50

Plot.draw(image,wedge=1,aspect=1,style='rainbow')    # display an image
Plot.draw(image,doContour=1,overplot=1)              # overlay some contours
Plot.contour['color'] = 2                            # change the colour and
Plot.contour['linewidth'] = 10                       # linewidth attributes

Plot.draw(image,doContour=1,overplot=1,levels=[-10,10,20,30])  # plot some
      # more contours with the new attributes
```

The graphic output produced in this case is shown in Figure 6.4.6.

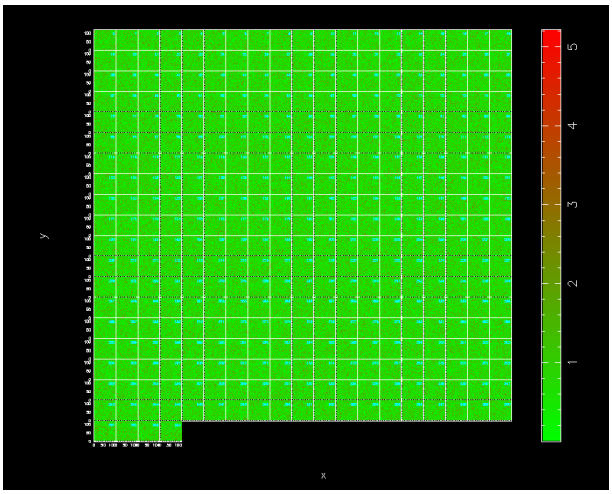


Figure 6.4.7: Example of graphics produced using MultiPlot.draw

6.4.4 Drawing on plots of multiple channels

DESCRIPTION: Draw on a multi-channel image

USAGE: `MultiPlot.plot.draw( chanList,map_arrays,` *[sizeX, sizeY, WCS, limitsX, limitsY, limitsZ, nan, labelX, labelY, caption, style, contrast, brightness, wedge, overplot]*)

ARGUMENTS:

chanList	list of channels
map_arrays	lits of map to display

OPTIONAL ARGUMENTS:

sizeX	the 'physical' size of the array (default pixel numbers)
sizeY	the 'physical' size of the array (default pixel numbers)
limitsX	limits to use in X for the plot
limitsY	limits to use in Y for the plot
labelX	x label (default 'x')
labelY	y label (default 'y')
caption	the caption of the plot (default ' ')
style	the color used for the plot (default 'g2r', see Plot.Plot.setImaCol())
wedge	set wedge=1 to draw a wedge (default no)
overplot	set overplot=1 to overplot (default no)

These are also described in Section **??**.

Example:

```
mapping_array = []
n_map = 365
for i in range(n_map):
    mapping_array.append(Numeric.absolute(RandomArray.standard_normal([120,120]))

MultiPlot.draw(range(n_map),mapping_array,wedge=1)
```

The graphic output produced in this case is shown in Figure 6.4.7.

6.5 Keywords

BoGLi provides a variety of parameters which allow the graphical output to be customised, as regards primitives such as colours, linestyles, character sizes, as well as text output and general appearance.

ci *colour index*

The colour index is an integer in the range 0 to a device-dependent maximum. The default colour index is 1, usually white on a black background for monitor displays or black on a white background for printed hardcopies. Colour index 0 corresponds to the background colour. If the requested color index is not available on the selected device, colour index 1 will be used.

ls *line style*

The line style is an integer in the range 1 to 5 with the following codes:

1: full line

2: dashed

3: dot-dash-dot-dash

4: dotted

5: dash-dot-dot-dot

The line style does not affect graph markers, text, or area fill.

lw *line width*

The line width is specified in units of 1/200 (0.005) inch (about 0.13 mm) and must be an integer in the range 1-201. This parameter affects lines, graph markers and text.

limitsX *limits to use in X for the plot*

limitsY *limits to use in Y for the plot*

labelX *x label*

(default 'x')

labelY *y label (default 'y')*

caption *caption label*

(default ' ')

style *linestyle*

('l': line, 'p': point (default), 'b': histogram)

width *linewidth*

(defaut 0 = use previous)

aspect *aspect ratio*

keep the aspect ratio in 'physical' unit

overplot *allow/prohibit overplotting*

set overplot=1 to overplot (default no)

logX *logarithmic scale*

set logX=1 to use a log scale (default no)

logY *logarithmic scale*

set logY=1 to use a log scale (default no)

sizeX *set the 'physical' size of the array*

the 'physical' size of the array (default pixel numbers), defined by the center of the two extreme pixels

sizeY *set the 'physical' size of the array*

the 'physical' size of the array (default pixel numbers), defined by the center of the two extreme pixels

nan set =1 if NaN are present in the array

wedge set wedge=1 to draw a wedge (default no)

doContour *draw contours*

set =1 to draw contour instead of map (default no)

levels *set the levels for the contours*

the levels for the contours (default nContour, within plotLimitsZ)

labelContour *label the contours*

set =1 to label the contours (default no)

Part II

Reference Manual

7. DATA ORGANISATION

7.1 Data input: the MB-FITS format

A complete description of the Multi-Beam FITS Raw Data Format is given in the reference document APEX-MPI-IFD-0002. In this section, we only give a brief description of this file format.

7.1.1 The hierarchy for a full scan

For a given observing sequence, corresponding to one scan, a set of tables are generated and stored in a hierarchical way in the MB-FITS format. Three tables are created on top of this hierarchy, where informations related to the full scan are gathered:

- Primary header: here, some general informations are stored, such as telescope name, project ID, date of observation start, versions of MB-FITS format and FitsWriter software
- SCAN-MBFITS: the header of this table contains a description of the scan pattern (type, geometry, line length in case of a raster map...), the source name and coordinates, together with a description of the referential used, and some generic informations about the telescope (coordinates, pointing coefficients). In addition, a binary table lists the names of frontend-backend (hereafter FEBE) combinations in use for this observation.
- FEBEPAR-MBFITS: one such table is created for each FEBE in use (in general, only one FEBE is active for bolometer observing). It contains the FEBE name and the number of available channels for this FEBE in its header. The associated binary table gives all relevant information about the instrument: relative gains, positions, gain/attenuation factors, polarisation angles...

7.1.2 Tables for each subscan

For each subscan within a scan, three tables are generated:

- MONITOR-MBFITS: this table gathers all the monitoring information sent by the control system during the observation. Each datapoint has an associated timestamp in MJD. In particular, this monitor stream contains commanded and actual telescope positions sampled every 48 ms. It also contains data related to the weather conditions, the subreflector angle and position, and the LST values.
- DATAPAR-MBFITS: this table also contains the telescope positions, subreflector angles and positions, and LST values, but interpolated to the timestamps corresponding to the data stream. It also contains a PHASE column, which can for example contains a succession of “ON” and “OFF” for a wobbler-switching observation.
- ARRAYDATA-MBFITS: here the raw data are stored. While some basic informations are stored in the header (e.g. central frequency of the observation), the binary table only contains two columns:

the timestamps (in MJD), and a vector with length equal to the number of channels in use containing the raw data for each integration.

Note: in case several FEBE are in use at the same time, then a DATAPAR table and an ARRAYDATA table are generated for each subscan and for each FEBE.

7.2 BoA Data objects

The manipulation of data within BoA is done with data objects of one class that inherits from the DataEntity class (Sect. 3.2; see also Section **??**). Such objects contain the current version of the data, as well as associated parameters related to the scan and to the bolometer array. On top of this, the DataAna and Map classes define additional attributes, as described in the next subsections.

7.2.1 DataEntity

A DataEntity object has a number of attributes, listed in the following tables. Two of them are objects of classes BolometerArray and ScanParameter.

BolometerArray

The BolometerArray object defines the attributes listed in Table 7.1. They are read in from the file, or computed when reading, except for CurrChanList (contains the current list of channels on which any processing or plotting function is applied) and Flags (can be altered by the user).

Table 7.1: Attributes of a BolometerArray object

Name	Type	Description
Telescope	object	see Table 7.2
FeBe	string	Frontent-Backend name
EffectiveFrequency	float	Observing frequency, in Hz
BeamSize	int	Beam size, in arcsec
NChannels	int	Total number of pixels in the instrument
Gain	float array	1D array with relative gains (flat field)
Offsets	float array	relative (X,Y) offsets, in arcsec
Channel_Sep	float array	matrix of channel to channel separations, in arcsec
TransmitionCurve	float array	
Flags	int array	Flag value for each channel (0 = unflagged)
RefChannel	int	Reference channel number
NUsedChannels	int	Number of channels in use for this observation
UsedChannels	int array	List of channels in use for this observation
CurrChanList	int array	Current list of channel numbers

Telescope

Attributes of a Telescope object are shown in Table 7.2.

Table 7.2: Attributes of a Telescope object

Name	Type	Description
Name	str	Telescope name, e.g. APEX-12m
Diameter	float	Antenna diameter, in m
Latitude	float	Latitude, in deg
Longitude	float	Longitude, in deg
Elevation	float	Elevation, in m

ScanParam

Attributes of the ScanParam object (class ScanParameter) are listed in Table 7.3.

Data arrays

In addition to the scan parameters and bolometer array related informations, a DataEntity object contains some general informations about the observation, and 2D arrays of data and related numbers, with sizes number of pixels in use $\times$ number of integrations. These are described in Table 7.4.

Note: for observations performed with wobbler switching, pairs of ON–OFF integrations are extracted from the Wobbler_Sta attribute, and the phase differences are computed. By default, after reading, only the differentiated signals are stored in the Data attribute. The user can specify the phase number in the read command, in order to get only the 'ON' or the 'OFF' data.

7.2.2 DataAna

On top of the DataEntity, the DataAna layer defines additional attributes, related to statistics and flagging of the data. They are listed in Table 7.5.

7.2.3 Map

Finally, any kind of observation is stored in **BoA** in a Map object, that defines many methods for data reduction (see the Appendix for reference). It also contains an attribute called 'Map', of class Image, where the results of a map-making routine are stored.

7.2.4 Storing a data object

At any time during a **BoA** session, the user can dump the content of the current data object to a file. It can later be loaded again into **BoA** , in order to continue with the data reduction. This is done with:

```
boa> dump()
boa< I: current data successfully written to BoaData.sav
```

or:

```
boa> dump('myMap.data')
boa< I: current data successfully written to myMap.data
```

to give another filename that the default BoaData.sav. Then to reload the data object, one has to do:

Table 7.3: Attributes of the ScanParam object

Name	Type	Description
ScanNum	int	Scan number
ScanType	string	Scan type, e.g. 'FOCUS−Z
ScanMode	string	Scan mode, e.g. 'RASTER'
ScanDir	string	Scanning direction
Line_Len	float	Line length for a raster, in arcsec
Line_Ysp	float	Y-step between lines in a raster, in arcsec
Az_Vel	float	Scanning speed in Az, in arcsec/s
Object	string	Target name
Basis	tuple	Pair of strings describing basis frame - e.g. ('RA− − −SFL', 'DEC−−SFL')
Coord	tuple	Target coordinates in basis frame
Date_Obs	string	Date of observation
Equinox	float	Equinox
Nula, Nule	floats	X, Y pointing settings at scan start
Colstart	float	Focus-Z setting at scan start
DeltaCA, DeltaIE	floats	Accumulated pointing corrections CA and IE
NObs	int	Number of subscans
SubscanNum	int list	Subscans numbers
SubscanIndex	int array	Integration numbers at subscans starts and ends
SubscanEpo	float array	Epochs of subscans starts, in year
SubscanTime	float array	LST times of subscans starts, in s
SubscanType	string list	Types of subscans - e.g. 'ON', or 'REF'
WobUsed	int	Boolean: is a wobbler used?
WobCycle	float	Wobbler period, in s
WobblerPos	float array	Wobbler positions, in arcsec
WobThrow	float	Wobbler throw, in arcsec
WobblerSta	string list	Wobbler status
Nodding_Sta	int array	Nodding status
WobMode	string	Wobbler mode, e.g. 'SQUARE'
AddLonWT	int	Wobbler throw to be added in Az, in arcsec
AddLatWT	int	Wobbler throw to be added in El, in arcsec
OnOffPairs	int list	List of pairs of integration numbers (if wobbler)
Nint	int	Number of integrations
Baslon, Baslat	float arrays	Absolute coordinates in basis frame, in deg
Track_Az, Track_El	float arrays	Tracking errors in Az and El, in arcsec
Lon, Lat	float arrays	Offsets w.r.t. the source in Az and El, in deg
FocX, FocY, FocZ	float arrays	Subreflector positions in X, Y, Z, in mm
PhiX, PhiY	float arrays	Subreflector rotation angles in X and Y, in deg
Az, El	float arrays	Absolute coordinates in Az, El, in deg
Lonpole, Latpole	float array	Coordinates in user frame of basis pole
Rot	float array	Rotation angle between user and basis frames, in deg
MJD	float array	Timestamps in MJD, in days
UT	float array	Timestamps in UTC, in s
LST	float array	Timestamps in LST, in s
Flags	int array	Flagging in time domain (0 = unflagged)

Table 7.4: Other attributes of a DataEntity object

Name	Type	Description
FileName	string	Input file name
RefGain	float	Frontend gain/attenuation factor
JyPerCount	float	Counts to Jy conversion factor
Data	float array	Current version of the data
DataBackup	float array	Previous version of the data
DataWeights	float array	Relative weights of the datapoints
DataFlags	array	Flagging of individual datapoints (0 = unflagged)
CorMatrix	float array	Channel to channel correlation matrix
FFCF_Gain	float array	1D array of relative gains (flat field) derived from skynoise
FFCF_CN	float array	Channel to channel correlated skynoise
SkyNoise	float array	Skynoise present in the signal

Table 7.5: Other attributes of a DataAna object

Name	Type	Description
ChanMean	float array	Mean values of signal per channel
ChanRms	float array	R.M.S of signal per channel
ChanMed	float array	Median values of signal per channel
ChanMean_s	float array	Mean values of signal per channel and per subscan
ChanRms_s	float array	R.M.S. of signal per channel and per subscan
ChanMed_s	float array	Median values of signal per channel and per subscan
flagValue	int	Currrent default flag value when calling a flagging routine
flagValueList	int list	Allowed values for flagging

```
boa> dd = newRestoreData()
```

Note: it is not possible in its present state to apply this restore method to the default *data* object. Therefore, after reloading a data object to a new variable (*dd* in the above example), one has to use the extended syntax (Chapter ...) instead of the abbreviations defined in BoaShortcuts.py.

7.3 Data output

7.3.1 Converting the raw data

BoA provides a procedure to convert an MB-FITS file to a FITS file with the same format as for MAMBO-ABBA data. The aim of this procedure is to be able to compare the results of a data reduction performed with **BoA** with those obtained with existing packages (e.g. NIC, MOPSI). *Note: This procedure has not been extensively tested recently...*

7.3.2 Saving a map

Once a mapping observation has been read in and processed with **BoA** , the user can store the results, i.e. a map in sky coordinates, in a standard 2D FITS image, including a header with World Coordinate System (WCS) infromations. This is done with the following command:

```
boa> data.writeFITS()     # default file name: boaMap.fits
boa> data.writeFITS('LABOCA_1234.fits') # give a file name
```

8. DEVELOPMENT

8.1 Basic programming rules

8.2 Adding classes

8.3 Adding methods

8.4 Adding Fortran90 code

FB040510

General

We are using Fortran 90/95 subroutines, wrapped to be called from python using the f2py package. This is because f90 code executes much faster than python scripts. There are some subtelties to pay attention to when wrapping fortran code, else you will add large overheads from the py-f90 interface, as arrays are copied and reindexed. For an introduction to F90/95 (only minor differences between the two), I recommend the compact and rather comprehensive (and free!) "Fortran 90 course notes"[1] by AC Marshall from the University of Liverpool. It contains all you probably need to know. I wrote a simple fortran method in BoA/fortran/BoaTest1.f90 to illustrate some basic features and give you a chance to test the wrapper without BoA. Look at its header for details. For an online F90/95 language reference[2] the best I found is at the NCSA resources page, describing IBM's XL Fortran for AIX 8.1 – which is close to the Intel compiler.

F90 in BoA

For BoA our general idea is to have one f90.so extension module, which includes all the f90 methods (called subroutines and functions in fortran). This is necessitated by that the f90.data module, which contains much of a scans data, is connected (through an "use data") to the other f90 program modules, and therefore they all need to be linked together.

The f90 methods may be split into different modules (classes) for convenience. We now have the first operational modules BoaF1.f90, BoaChannelAnalyser.f90, BoaBaseLine.f90, and the data module BoaData.f90. Each module may include any number of subroutines or functions. The data module BoaData.f90 is like a common block that contains all the data which does not change during data reduction. All data which does change is passed to the fortran subroutines as call arguments.

The BoaData.f90 (f90.data from python) module is filled in BoaDataEntity.FillF90. It must be refilled if you change data object, else the fortran methods will work on a different scan. This re-filling must be implemented still. Currently the f90.data is only filled upon read of a new data file.

The CVS directory BoA/fortran contains the fortran source code. You will need to wrap/compile the BoA

[1] http://math.nist.gov/~WMitchell/f90course/CourseNotes.pdf

[2] http://www.ncsa.uiuc.edu/UserInfo/Resources/Hardware/IBMp690/IBM/usr/share/man/info/en_US/xlf/html/lr02.HTM#CONTENT

modules on your local system (see below), since it links to local libraries that have no standard address. This will create the extension module f90.so which you import to BoA. From the CVS directory BoA start BoA, then

```
>>> from fortran import f90
```

This is how to import any module from a subdirectory, which for this needs to include an empty file __init__.py

The python script fortran/ftest.py contains a series of calls to the fortran subroutines. To run it:

```
>>> read()  # read in some scan
>>> op()    # open plot device
    [enter]
>>> execfile('ftest.py')  # start the script
```

which is followed with lots of output. To illustrate the use of new python methods that use fortran, you find BoA/TestFB.py, which you run like ftest.py. It goes through a number of data reduction steps and plots the data.

Wrapping F90 code with f2py

To wrap the f90 modules to produce f90.so:

```
ifc -c -w svd.f90
f2py -c -m f90 BoaData.f90 BoaF1.f90 BoaChannelAnalyser.f90 BoaBaseLine.f90 svd.o
     or on some installations alternatively:
f2py -c --fcompiler=intel -m f90 BoaData.f90 BoaF1.f90 BoaChannelAnalyser.f90 BoaBa
```

The first command recompiles the svd.o. On the f2py line there are some diagnostic options you may add if you debug your code:

```
-DF2PY_REPORT_ATEXIT : gives time statistics upon exit from python.
-DF2PY_REPORT_ON_ARRAY_COPY=1000 : reports when the f2py interface copies an array.
-DNUMARRAY : must be used for numarray support. Default is Numeric.
```

If the wrapping fails, one of the following may be wrong:

1. You have not initiated the ifc compiler properly. In your shell initialization file (e.g. .cshrc for tcsh) you need

```
if (-e /opt/intel/compiler60/ia32/bin/ifcvars.sh) then
  source /opt/intel/compiler60/ia32/bin/ifcvars.csh
endif
```

or something equivalent.

2. Your python path does not include the intel fortran compiler:

```
setenv PYTHONPATH ".:/opt/intel/compiler60/ia32/lib/:
                    /usr/local/lib/python2.3:
                    /usr/local/lib/python2.3/site-packages:
                    /home/bertoldi/bin:
                    /opt:
                    /usr/lib"
```

3. You use an old version of f2py.

```
<fortran> f2py -version
2.39.235_1644
```

Once you have successfully imported f90 in BoA, you can inquire about the use of a given method by typing

```
print f90.f1.NAME.__doc__
```

Fortran attributes are called f90.data.name_of_attribute. To inquire which ones are available:

```
boa> print f90.data.__doc__
el - 'f'-array(218)
track_el - 'f'-array(218)
ffcf_gain - 'f'-array(120)
subscan_time - 'f'-array(4)
az_p - 'f'-array(109,3)
lst - 'f'-array(218)
lon_p - 'f'-array(109,3)
track_az - 'f'-array(218)
lat - 'f'-array(218)
az - 'f'-array(218)
lat_p - 'f'-array(109,3)
lst_p - 'f'-array(109,3)
array_gain - 'f'-array(120)
lon - 'f'-array(218)
ffcf_cn - 'f'-array(120)
ut_p - 'f'-array(109,3)
nodding_sta - 'i'-array(218)
subscan_index - 'i'-array(4)
subscan_num - 'i'-array(4)
weights - 'f'-array(0), not allocated
el_p - 'f'-array(109,3)
ut - 'f'-array(218)
wobbler_pos - 'f'-array(218)
```

They are filled in in BoaBusiness.py: BoaB.FillF90

Use f90 methods in BoA

To call a fortran method, here an example:

```
compressed_array,nmax = f90.f1.compress(array,flag_array,0)
```

Two objects are returned as a tuple, an array and an integer. They both are not in the call argument list, they are hidden to python, but are listed in the f90 code call argument list – have a look at the source code.

Limitations

This particular example illustrates one of the limitations of wrapping f90 code: you cannot return an array with a length that is determined upon execution. The wrapper needs to specify the size of an array somehow. It does not have to be fixed, but specified through the size of an input attribute at least. In this example we try to return an array that is a compression of the input array, determined by the condition that the corresponding flag is 0. The trick to still do this here is to return a comressed_array with the

same size as array, plus an integer telling the size of the compressed array, so that the final answer is compressed_array[0:nmax].

Fortran vs. C-contiguous

If a Numeric array is proper-contiguous and has a proper type then it is directly passed to the wrapped Fortran function. Otherwise, an element-wise copy of an input array is made and the copy, being proper-contiguous and with proper type, is used as an array argument. There are two types of proper-contiguous Numeric arrays: Fortran-contiguous arrays when data is stored column-wise, i.e. indexing of data as stored in memory starts from the lowest dimension; C-contiguous when data is stored row-wise, i.e. indexing of data as stored in memory starts from the highest dimension. For one-dimensional arrays these notions coincide. To transform input arrays to column major storage order before passing them to Fortran routines, one may use the function as_column_major_storage(<array>) that is provided by all F2PY generated extension modules, such as the BoA f90. If you call a fortran method repeatedly with the same input array, you should convert the array first to avoid conversion by the wrapper interface on each call – which could dominate the execution time here. If you add the option -DF2PY_REPORT_ON_ARRAY_COPY=1000 when wrapping, you will be informed on each copy that the wrapper interface performs. The option -DF2PY_REPORT_ATEXIT gives an execution time summary upon exit that splits up the time used in fortran and in the interface. If the interface time is large or comparable to the fortran execution time, your code is not efficient because it copies arrays too often. Look at examples in BoaBaseLine.py, e.g.:

```
Data = f90.as_column_major_storage(self.Data.Data_Red_p)
Flag = f90.as_column_major_storage(self.Data.Data_Flag_p)
...
for i_ch in ch_range: # loop over channels and phases
    for i_ph in ph_range:
      Data = f90.baseline.addpoly(Data,Poly,Mean,Rms,i_ph,i_ch)
```

The input arrays are copied once into fortran-contiguous arrays before the loop, so in the loop there is no overhead from copying. Note also the general scheme of calling a fortran method here: Data is in- and output argument.

8.5 Interfacing

8.5.1 ScientificPython-2.4.5

ScientificPython is a collection of Python modules that are useful for scientific computing. Almost all modules make extensive use of Numerical Python (NumPy,Numeric), which must be installed prior to Scientific Python. Scientific constist of about one dozen modules, which contain methods written in Python that may come handy, but may be slow. The following lists a number of them.

stat() statistics() command calculates the statistics for all the channels in the range. Using plotmean() plotrms() we can plot mean and RMS values of each channels. The examples are as shows below:

You need to import Numeric for Scientific. You can access the methods by importing the class or all methods:

```
>>> from Numeric import *
>>> import Scientific.Statistics
>>> Scientific.Statistics.median([1,2,3,5,6])
3.0
```

or alternatively

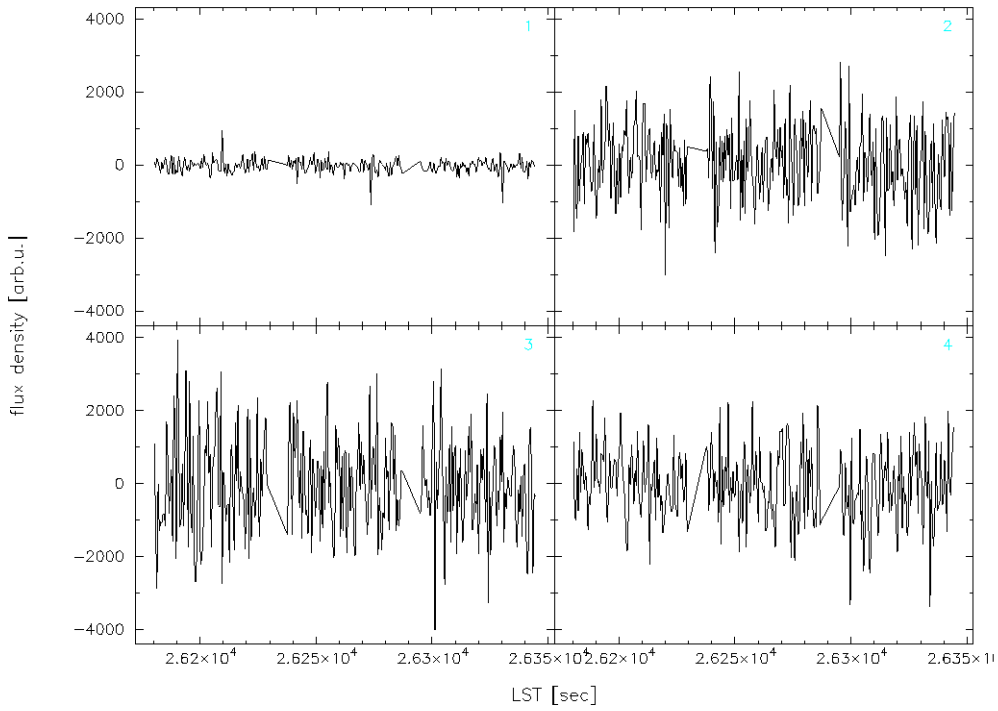


Figure 8.5.1: Plotting the Signal for channels in the range.

```
>>> from Scientific.Statistics import *
>>> median([1,2,3,5,6])
3.0
```

Available method in class Scientific.Statistics:

```
moment(data, order, about=None, theoretical=1)
mean(data)
weightedMean(data, sigma)
variance(data)
standardDeviation(data)
median(data)
mode(data)
normalizedMoment(data, order)
skewness(data)
kurtosis(data)
correlation(data1, data2)
```

There are also two classes for histograms:

```
Histogram
WeightedHistogram(Histogram)
```

The following explains only those Scientific methods which are useful for Boa. Consult the scripts or the (very sparse) documentation for more info.

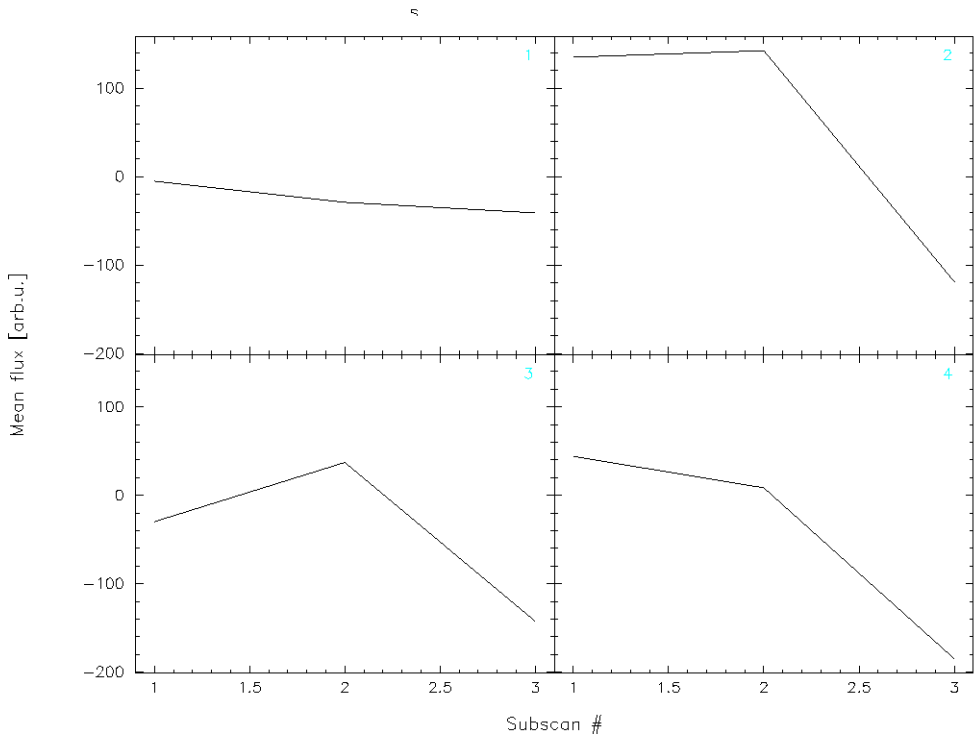


Figure 8.5.2: Plotting the Mean values of signal.

Scientific.Statistics.median

Description: Computes the median of a 1-d array.

Example:

```
>>> median([1,2,3,5,6])
3.0
```

Scientific.Statistics.mean

Description: Returns the mean (average value) of a 1-d array.

Example:

```
>>> mean([1,2,3,5,6])
3.3999999999999999
```

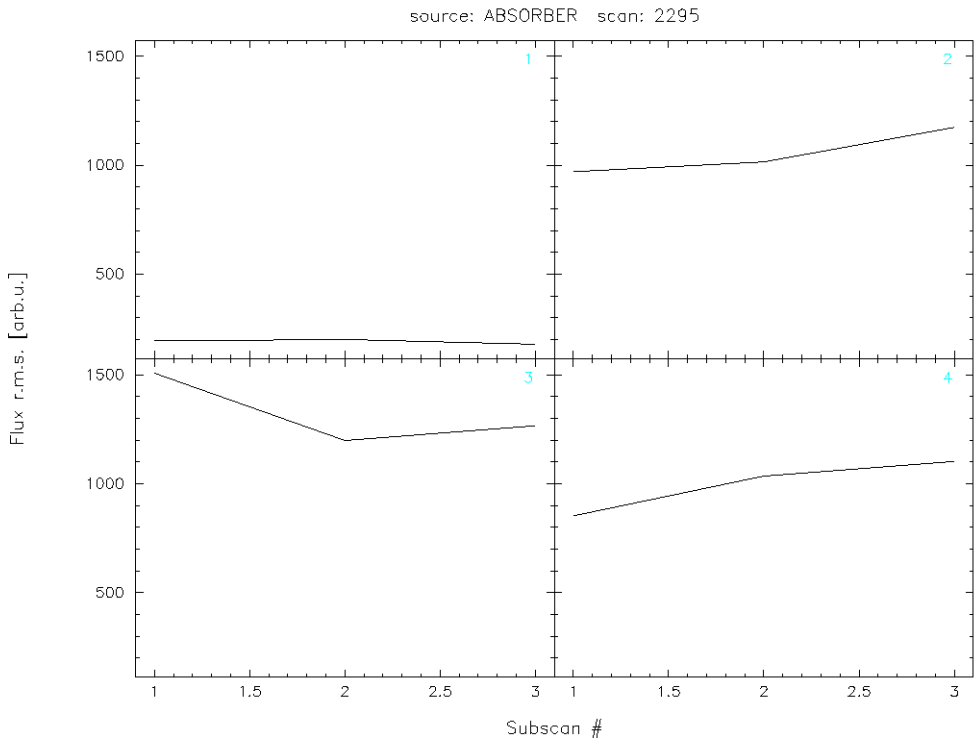


Figure 8.5.3: Plotting the RMS values of signal.

Scientific.Statistics.correlation

Description: Computes the correlation coefficient between two 1-dim arrays a and b according to

$$c_{ab} = \frac{\langle (a-\bar{a})(b-\bar{b})\rangle}{\langle (a-\bar{a})^2\rangle^{1/2}\langle (b-\bar{b})^2\rangle^{1/2}} \tag{8.5.1}$$

Example:

```
>>> correlation([1,2,3,4,5],[1,2,3,4,5])
1.0
>>> correlation([1,2,3,4,5],[1,2,3,5,5])
0.96476382123773219
>>> correlation([1,2,3,4,5],[5,4,3,2,1])
-1.0
```

Scientific.Functions.LeastSquares

Description: General non-linear least-squares fit using the Levenberg-Marquardt algorithm and automatic derivatives. The parameter model specifies the function to be fitted. It will be called with two parameters: the first is a tuple containing all fit parameters, and the second is the first element of a data point (see below). The return value must be a number. Since automatic differentiation is used to obtain the derivatives with respect to the parameters, the function may only use the mathematical functions known to the module

FirstDerivatives. The parameter parameter is a tuple of initial values for the fit parameters. The parameter data is a list of data points to which the model is to be fitted. Each data point is a tuple of length two or three. Its first element specifies the independent variables of the model. It is passed to the model function as its first parameter, but not used in any other way. The second element of each data point tuple is the number that the return value of the model function is supposed to match as well as possible. The third element (which defaults to 1.) is the statistical variance of the data point, i.e. the inverse of its statistical weight in the fitting procedure. The function returns a list containing the optimal parameter values and the chi-squared value describing the quality of the fit.

Example:

```
>>> from Numeric import exp
>>> def f(param, t):
...     return param[0]*exp(-param[1]/t)
...
>>> data = [(100, 4.999e-8),(200, 5.307e+2),
  (300, 1.289e+6),(400, 6.559e+7)]
>>> print leastSquaresFit(f, (1e13,4700), data)
([8641551709749.7666, 4715.4677901570467], 1080.2526437958597)
```

Part III

All BoA classes and functions

A. BoA Module Index

A.1 BoA Modules

Here is a list of all modules:

B. BoA Hierarchical Index

B.1 BoA Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

C. BoA Class Index

C.1 BoA Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

D. BoA Module Documentation

D.1 Fortran subroutines

D.1.1 Detailed Description

List of Fortran subroutines

Modules

- Fortran subroutines

safeExp(x,y,n)

```
NAM: safeExp (subroutine)
DES: Attempt to create a fast exponential for python
```

modelBaseEllipticalGaussian(p,n_p,position,n_position,returned_result)

```
NAM: modelBase2dgauss (subroutine)
DES: Compute a model of a 2D gaussian + gradient
     (see corresponding python routine)
```

compress(data, flag, flag_value, dataOut, nData, nOut)

```
NAM: compress (subroutine)
DES: compress array based on mask
INP: data_input (f): 1-D array with data to be returned where flag = flag_value
    flag       (i): 1-D array, must be same size as data_input
    flag_value (i): select data where flag=flag_value
OUT: tuple (x,nData): 1-D array of same size as data_input where first n elements are
                 those of data_input where flag = flag_value
USE:
    Unfortunately it is not possible to pass from fortran to python an output
    array the size of which is computed in fortran. Therefore we must truncate
    the returned array at the size of the selected true mask elements.

    Example:
          input_array = array(range(5),'f')
          flag_array  = array([0,1,0,1,0],'i')
          compress_array,nmax = f90.f1.compress(input_array,flag_array,1)
          compress_array = compress_array[0:nmax]
```

icompress(data, flag, flag_value, dataOut, nData, nOut)

```
NAM: compress (subroutine)
DES: compress array based on mask
INP: data_input (i): 1-D array with data to be returned where flag = flag_value
    flag       (i): 1-D array, must be same size as data_input
    flag_value (i): select data where flag=flag_value
OUT: tuple (x,nData): 1-D array of same size as data_input where first n elements are
                 those of data_input where flag = flag_value
USE:
    Unfortunately it is not possible to pass from fortran to python an output
    array the size of which is computed in fortran. Therefore we must truncate
    the returned array at the size of the selected true mask elements.

    Example:
          input_array = array(range(5),'f')
          flag_array  = array([0,1,0,1,0],'i')
          compress_array,nmax = f90.f1.compress(input_array,flag_array,1)
          compress_array = compress_array[0:nmax]
```

ncompress(data, flag, flag_value, dataOut, nData, nOut)

```
NAM: compress (subroutine)
DES: compress array based on mask
INP: data_input (f): 1-D array with data to be returned where flag != flag_value
    flag       (i): 1-D array, must be same size as data_input
    flag_value (i): select data where flag=flag_value
OUT: tuple (x,nData): 1-D array of same size as data_input where first n elements are
                 those of data_input where flag = flag_value
USE:
    Unfortunately it is not possible to pass from fortran to python an output
    array the size of which is computed in fortran. Therefore we must truncate
    the returned array at the size of the selected true mask elements.

    Example:
          input_array = array(range(5),'f')
          flag_array  = array([0,1,0,1,0],'i')
          compress_array,nmax = f90.f1.compress(input_array,flag_array,1)
          compress_array = compress_array[0:nmax]
```

minmax(array,nx,extrema)

```
NAM: fMin
DES: return minimum of a 1D array
```

replaceNaN(array,nx,ny)

```
NAM:
DES: replace the NaN in a 2D array by a value below
    the minimum value of the array
```

MreplaceNaN(array,nx,ny,nz)

```
NAM:
DES: replace the NaN in a 3D array by a value below
    the minimum value of the array
```

D.2 Utilities

Classes

- class boa::Utilities::Timing

Functions

- def boa::Utilities::array2list
- def boa::Utilities::as_column_major_storage
- def boa::Utilities::attrStr
- def boa::Utilities::baseCircularGaussian
- def boa::Utilities::baseEllipticalGaussian
- def boa::Utilities::compress2d
- def boa::Utilities::compressNan
- def boa::Utilities::Cp2r
- def boa::Utilities::Cr2p
- def boa::Utilities::cropped_circular_gaussian
- def boa::Utilities::detStartParaParabola
- def boa::Utilities::distsq
- def boa::Utilities::fitBaseEllipticalGaussian
- def boa::Utilities::fitParabola
- def boa::Utilities::gaussian
- def boa::Utilities::lCompressNan
- def boa::Utilities::max2D
- def boa::Utilities::min2D
- def boa::Utilities::modelBaseEllipticalGaussian
- def boa::Utilities::modelparabola
- def boa::Utilities::parabola
- def boa::Utilities::prettyPrintList
- def boa::Utilities::safeExp
- def boa::Utilities::solvePoly

D.2.1 Function Documentation

def boa::Utilities::array2list (a)

```
NAM: array2list (function)
DES: convert a list of 1D arrays to a single 1D array
```

def boa::Utilities::as_column_major_storage (classIn)

```
DES: save all the attribute as column major to avoid copy in fortran
```

def boa::Utilities::attrStr (object, badAttributes = [])

```
DES: return a string representing the attributes of the object
OPT: (str list) badAttributes : list of attributes to remove from the output
```

def boa::Utilities::baseCircularGaussian (p, fjac = None, x = None, y = None, err = None)

```
NAM: baseCircularGaussian
DES: function used by mpfit to fit a Circular gaussian+base
     (5 elmts array) p : parameters of the gaussian
     (2d array)      x : position of  the pixels on the map
                         "x" = x[0] and "y" = x[1]
     (2d array)      y : the map to fit
                         y.shape should be (len(x[0]),len(x[1]))
```

def boa::Utilities::baseEllipticalGaussian (p, fjac = None, x = None, y = None, err = None)

```
NAM: baseEllipticalGaussian
DES: function used by mpfit to fit a 2D gaussian+base
     (5 elmts array) p : parameters of the gaussian (see modelBase2Dgauss)
     (2d array)      x : position of  the pixels on the map
                         "x" = x[0] and "y" = x[1]
     (2d array)      y : the map to fit
                         y.shape should be (len(x[0]),len(x[1]))
```

def boa::Utilities::compress2d (array, indexes)

```
DES: return a 2D sub array based on indexes
INP: (f)   array : square input array
     (i) indexes : the indexes to take from the array
```

def boa::Utilities::compressNan (array)

```
DES: return an array without nan
INP: (array)  array : input array
OUT: (1D array) values of the previous array without Nan
```

def boa::Utilities::Cp2r (amp, phase)

```
NAM: Cp2r (function)
DES: convert complex numbers in polar form to rectangular form (real,imag)
IN:  [float,float]   : module and phase
OUT: (complex)     c : complex number or array
```

def boa::Utilities::Cr2p (c)

```
NAM: Cr2p (function)
DES: convert complex numbers in rectangular form to polar (mod,arg) form
INP: (complex)     c : complex number or array
OUT: [float,float]   : module and phase
```

def boa::Utilities::cropped_circular_gaussian (p, position, threshold = 3)

```
NAM: cropped_circular_gaussian
DES: compute a cropped circular gaussian with intensity=1
     defined by the parameter p wihtin the position an a given threshold given in n*'sigma'
     position should be a list of 2 arrays of the same dimension defining the map
```

def boa::Utilities::detStartParaParabola (x, y)

```
NAM: defStartParaParabola (method)
DES: define the proper start parameter to fit a parabola
INP: (float) x = x data
     (float) y = y data
```

def boa::Utilities::distsq (x1, y1, x2, y2)

```
NAM: distsq (function)
DES: returns distance squared between two points
INP: (float) x1,y1,x2,y2: coordinates of the two points
OUT: (float) distance^2
```

def boa::Utilities::fitBaseEllipticalGaussian (mapArray, x, y, err = 1.0, fwhm = 11.0, gradient = 1, circular = 0, Xpos = 0., Ypos = 0., fixedPos = 0)

```
NAM: fitBaseEllipticalGaussian (method)
DES: fits a 2D Gaussian + 1st order base surface
INP: (arrays) (x,y,mapArray,err)  : the data to fit (arrays of same dimension(s))
     (2els arrays) sizeX/Y : alternative to the x/y array, this limit the size of the
                             mapArray given as regular gridding between the center
                             of the two extreme pixels
     (float)         fwhm  : the first guess for the fwhm
     (logical)   gradient  : should we also fit a gradient in the map (default no) ?
     (logical)   circular  : fit a circular gaussian instead of a elliptical gaussian
     (float)     Xpos,Ypos : source position if using fixed position
     (logical)    fixedPos : if set, don't fit position, but use Xpos, Ypos

OUT: a dictionnary containning the results of the fit
     check 'status' and 'errmsg' to see if the fit was done correctly
     then for each parameters (see the parname variable below) you have the
     'value' 'error' and 'limits' for the fit
```

def boa::Utilities::fitParabola (x, y, err)

```
NAM: fitParabola (method)
DES: fits parabola to the data using mpfit
INP: (float) x = x data
     (float) y = y data
```

def boa::Utilities::gaussian (r2, sig2)

```
DES: Compute value of a Gaussian function
INP: r2 = _array_ of distances^2, sig2 = sigma^2, related to Gaussian width
```

def boa::Utilities::lCompressNan (array, listArray)

```
DES: remove the Nan of an array in a list of array
INP:    array : test array for the Nan
     (l array): the list of array to compress
```

def boa::Utilities::max2D (a)

```
NAM: max2D (function)
DES: return the maximum value from a list of 1D Numeric arrays
```

def boa::Utilities::min2D (a)

```
NAM: min2D (function)
DES: return the minimum value from a list of 1D Numeric arrays
```

def boa::Utilities::modelBaseEllipticalGaussian (p, position)

```
NAM: model2Dgauss
DES: compute a 2D gaussian defined by the parameter p wihtin the position
     position should be a list of 2 arrays of same dimensions defining the map
```

def boa::Utilities::modelparabola (p, x)

```
NAM: modelparabola
DES: compute a model parabola at position x for a given set of parameters p
```

def boa::Utilities::parabola (p, fjac = None, x = None, y = None, err = None)

```
NAM: parabola
DES: function used by mpfit to fit a parabola
```

def boa::Utilities::prettyPrintList (inputList)

```
DES:  Pretty print a list avoiding useless entries
INP: (l) inputList    : the input list, does not need to be sorted
OUT: (s) outputString : the resulting string
```

def boa::Utilities::safeExp (x)

```
NAM: safeExp (function)
DES: correct a bug in Numerical that raise an expection when
     computing exponential of small numbers, this take a lot of time !
     but faster thant converting to nummarray compute the exp and back to numeric !!
```

def boa::Utilities::solvePoly (order, dataX, dataY)

```
NAM: solvePoly (function)
DES: perform polyomial interpolation: solve linear system
     dataY = P_n(dataX)
INP: (int) order : polynomial degree
     (flt arrays) dataX/Y : system to solve
OUT: (flt array) coeff : polynomial coefficients
```

D.3 DeviceHandler

Functions

- def boa::Bogli::DeviceHandler::closeDev
- def boa::Bogli::DeviceHandler::openDev
- def boa::Bogli::DeviceHandler::resizeDev
- def boa::Bogli::DeviceHandler::selectDev

D.3.1 Function Documentation

def boa::Bogli::DeviceHandler::closeDev (devID = 'current')

```
DES: close selected device
INP: (int) device ID, 'all','current' (default)
```

def boa::Bogli::DeviceHandler::openDev (type = '/XWINDOW')

```
DES: open a device, return the device id
INP: (string) type = pgplot device type
```

def boa::Bogli::DeviceHandler::resizeDev ()

```
DES: resize plot area after resizing window with mouse
ABB: resize
```

def boa::Bogli::DeviceHandler::selectDev (devID = '')

```
DES: select an open device
INP: (int) device ID
```

D.4 Interface

Classes

- class boa::Bogli::Interface::Fenetre

Functions

- def boa::Bogli::Interface::fenetreInteractive
- def boa::Bogli::Interface::pgrstr

D.4.1 Function Documentation

def boa::Bogli::Interface::fenetreInteractive (x0 = 600., x1 = 675., y0 = 400., y1 = 480, prevText = '', bgCol = 0)

```
method fenetreInteractive():
INP: (float) x0,x1,y0,y1: box coordinates
     (str) prevText: previous field value
     (int) bgCol: background color

OUT: (str) value: user input
```

def boa::Bogli::Interface::pgrstr (X, Y, ANGLE, FJUST, TEXT, LSTR, BCI)

```
method pgrstr(X, Y, ANGLE, FJUST, TEXT, LSTR, BCI)
Lit une chaine de caractere dans la fenetre courante
INP: X, Y, ANGLE, FJUST = position angle et justification du texte
     BCI = couleur de la fenetre
INP/OUT: TEXT, LSTR = texte et longueur de la chaine TEXT
```

D.5 MultiPlot

Functions

- def boa::Bogli::MultiPlot::detSubDivView
- def boa::Bogli::MultiPlot::draw
- def boa::Bogli::MultiPlot::drawChanNum
- def boa::Bogli::MultiPlot::gloLabelling
- def boa::Bogli::MultiPlot::plot
- def boa::Bogli::MultiPlot::plotBox
- def boa::Bogli::MultiPlot::setLimits
- def boa::Bogli::MultiPlot::setMultiViewPoint

D.5.1 Function Documentation

def boa::Bogli::MultiPlot::detSubDivView (numPlot, wedge = 0)

```
DES: Determine sub-division of plot page into viewpoints/boxes.
INP: (int) numPlot   : number of panels in the plot
OPT: (logical) wedge : if a wedge is present (no by default)
OUT: (ints) (numPlotWinX,numPlotWinY) the number of viewport in both directions
```

def boa::Bogli::MultiPlot::draw (chanList, map_arrays, sizeX = [], sizeY = [], WCS = [], limitsX = [], limitsY = [], limitsZ = [], nan = 0, labelX = 'x', labelY = 'y', caption = ' ', style = 'g2r', contrast = 1.0, brightness = 0.5, wedge = 0, overplot = 0)

```
DES: do a multi channel image drawing
INP: (int list) chanList = list of channels
     (map_arrays)  lits of map to display
OPT: (2elts arrays)   sizeX/Y = the 'physical' size of the array (default pixel numbers)
     (2elts arrays) limitsX/Y = limits to use in X/Y for the plot
     (string)         labelX  = x label (default 'x')
     (string)         labelY  = y label (default 'y')
     (string)         caption = the caption of the plot (default ' ')
     (char)           style   = the color used for the plot (default 'g2r'
                                see Plot.Plot.setImaCol())
     (logical)        wedge   = shall we draw a wedge ? (default no)
     (logical)       overplot = are we overplotting ? (default no)
```

def boa::Bogli::MultiPlot::drawChanNum (c)

```
DES: Draw channel number.
INT: (int) c : the channel number
```

def boa::Bogli::MultiPlot::gloLabelling (wedge = 0)

```
DES: Label x, y, caption and channel number.
OPT: (logical) wedge : if a wedge is present
```

def boa::Bogli::MultiPlot::plot (chanList, dataX, dataY, limitsX = [], limitsY = [], labelX = 'x', labelY = 'y', caption = ' ', style = 'p', ci = 1, overplot = 0, logX = 0, logY = 0, nan = 0)

```
DES: do a multi channel plot
INP: (int list) chanList = list of channels
     (array list)  dataX = values to plot along X
     (array list)  dataY = values to plot along Y
OPT: (2elts array) limitsX/Y = limits to use in X/Y for the plot
     (string)      labelX  = x label (default 'x')
     (string)      labelY  = y label (default 'y')
     (string)      caption = the caption of the plot (default ' ')
     (char)        style   = the style used for the plot ('l': line,
                             'p': point (default), 'b': histogram)
     (int)            ci   = color index (default 1)
     (logical)    overplot = are we overplotting ? (default no)
     (logical)      logX/Y = do we use log scale ? (default no)
```

def boa::Bogli::MultiPlot::plotBox (numPlot, x, y)

```
DES: Draw box and labels.
INP: (int) numPlot : number of panels in the plot
     (int) x,y     : the indices of the panel
```

def boa::Bogli::MultiPlot::setLimits (dataX, dataY, limitsX = [], limitsY = [])

```
DES: compute and/or set the limits for the multiplot
INP: (list arrays)   dataX/Y : the array to be plotted
OPT: (2elts array) limitsX/Y : limits to use in X/Y for the plot
```

def boa::Bogli::MultiPlot::setMultiViewPoint (x = 0, y = 0, wedge = 0)

```
DES: Determine and set view points.
INP: (ints)    x/y      : position of the viewpoint from 0 to numPlotWinX/Y
```

D.6 Plot

Functions

- def boa::Bogli::Plot::clear
- def boa::Bogli::Plot::draw
- def boa::Bogli::Plot::drawLabel
- def boa::Bogli::Plot::drawWedge
- def boa::Bogli::Plot::erase
- def boa::Bogli::Plot::getPixel
- def boa::Bogli::Plot::labelling
- def boa::Bogli::Plot::plot
- def boa::Bogli::Plot::plotBox
- def boa::Bogli::Plot::plotDataXY
- def boa::Bogli::Plot::readLut
- def boa::Bogli::Plot::removeNan
- def boa::Bogli::Plot::setImaCol
- def boa::Bogli::Plot::setLabels
- def boa::Bogli::Plot::setLimits
- def boa::Bogli::Plot::setMapLimits
- def boa::Bogli::Plot::setMapTransformation
- def boa::Bogli::Plot::setViewPoint
- def boa::Bogli::Plot::xyout

D.6.1 Function Documentation

def boa::Bogli::Plot::clear ()

```
DES: clear plot
```

def boa::Bogli::Plot::draw (map_array, sizeX = [], sizeY = [], WCS = [], limitsX = [], limitsY = [], limitsZ = [], nan = 0, labelX = 'x', labelY = 'y', caption = '', style = 'g2r', contrast = 1.0, brightness = 0.5, wedge = 0, overplot = 0, aspect = 0, doContour = 0, levels = [], labelContour = 0)

```
DES: do a image drawing
INP: (map_array)  map to display
OPT: (2elts arrays)   sizeX/Y = the 'physical' size of the array (default pixel numbers)
                                defined by the center of the two extreme pixels !
     (2elts arrays) limitsX/Y = limits to use in X/Y for the plot
     (logical)           nan  = set if NaN are present in the array
     (string)         labelX  = x label (default 'x')
     (string)         labelY  = y label (default 'y')
     (string)         caption = the caption of the plot (default ' ')
     (char)           style   = the color used for the plot (default 'g2r'
                                see BogliPlot.Plot.setImaCol())
     (logical)        wedge   = shall we draw a wedge ? (default no)
     (logical)         aspect = keep the aspect ratio in 'physical' unit
     (logical)       overplot = are we overplotting ? (default no)
     (logical)     doContour  = draw contour instead of map (default no)
     (array)         levels   = the levels for the contours (default nContour
                                withing plotLimitsZ)
     (logical)   labelContour = label the contours (default no)
```

def boa::Bogli::Plot::drawLabel (label)

```
DES: generic function to draw labels/captions
INP: (dict) label : a 'label' attribute like labelX
```

def boa::Bogli::Plot::drawWedge ()

```
DES: Draw a wedge.
```

def boa::Bogli::Plot::erase ()

```
DES: Erase any existing graphics.
```

def boa::Bogli::Plot::getPixel (order = 0)

```
DES: allow user to get pixel values using mouse
INP: (int)  order = for polynomial interpolation
```

def boa::Bogli::Plot::labelling (wedge = 0)

```
DES: Label x, y, caption and channel number.
OPT: (logical) wedge : should we draw a wedge ? (default no)
```

def boa::Bogli::Plot::plot (dataX, dataY = [], limitsX = [], limitsY = [], labelX = 'x', labelY = 'y', caption = '', style = 'p', ci = 1, width = 0, overplot = 0, aspect = 0, logX = 0, logY = 0, nodata = 0)

```
DES: do a plot
INP: (array)  dataX = values to plot along X
     (array)  dataY = values to plot along Y (optional - default:
                                  plot dataX vs. running number)
OPT: (2elts array) limitsX/Y = limits to use in X/Y for the plot
     (string)      labelX  = x label (default 'x')
     (string)      labelY  = y label (default 'y')
     (string)      caption = the caption of the plot (default ' ')
     (char)        style   = the style used for the plot ('l': line,
                             'p': point (default), 'b': histogram)
     (int)            ci   = color index (default 1)
     (int)          width  = linewidth (defaut 0 = use previous)
     (logical)      aspect = keep the aspect ratio in 'physical' unit
     (logical)    overplot = are we overplotting ? (default no)
     (logical)      logX/Y = do we use log scale ? (default no)
     (logical)      nodata = do not plot the data
```

def boa::Bogli::Plot::plotBox ()

```
DES: Draw box and labels.
```

def boa::Bogli::Plot::plotDataXY (dataX, dataY, style = 'p', ci = 1, width = 0)

```
DES: Plot x y data.
INP: (array) dataX/Y : the array to be plotted (same dimension)
OPT: (string) style : the style used for the plot ('l': line,
                      'p': point (default), 'b': histogram)
     (int)    ci    : the color index (default 1)
     (int)   width  : linewidth (defaut 0 = use previous)
```

def boa::Bogli::Plot::readLut (lutFile)

```
NAM: readLut (method)
DES: read a LUT file
INP: (string) lutFile : the name of the input lut file
```

def boa::Bogli::Plot::removeNan (array, value = 0)

```
DES: replace the Nan value by value
INP: (array)  array : input array
     (float)  value : the value to replace
```

def boa::Bogli::Plot::setImaCol (style = 'g2r', contrast = 1, brightness = 0.5, transferFunction = 0, nan = 0)

```
NAM: setImaCol (method)
DES: Set image colours.
OPT: (string) style    : the style (default 'g2r' : green to red)
                         also defined 'r2g' red to green, 'b2r' blue to red,
                         'r2b' red to blue, 'blue' or any lut file define in
                         the BogliConfig.lutDir variable
     (float)  contrast   : the contrast of the plot (default 1)
     (float)  brightness : the brightness of the plot (default 0.5)
     (int) transferFunction : the transfer funtion (linear/log/sqrt)
```

def boa::Bogli::Plot::setLabels (labelX, labelY, caption)

```
DES: check and set labels
INP: (strings) labelX, labelX, caption : the X and Y labels and the caption
```

def boa::Bogli::Plot::setLimits (dataX, dataY, limitsX = [], limitsY = [])

```
DES: compute and/or set the limits for the graph
INP: (arrays)        dataX/Y : the array to be plotted
OPT: (2elts array) limitsX/Y : limits to use in X/Y for the plot
```

def boa::Bogli::Plot::setMapLimits (map_array, limitsX = [], limitsY = [], limitsZ = [])

```
DES: compute and/or set the limits for the map
INP: (2D array)    map_array : the map array
OPT: (2elts arrays)  sizeX/Y : the 'physical' size of the array (default pixel numbers)
                               this define the center of the pixels !!
```

```
     (2elts array) limitsX/Y : limits to use in X/Y for the plot
     (2elts array)  limitsZ  : the plotted color range in unit of the map_arrays
```

def boa::Bogli::Plot::setMapTransformation (map_array, sizeX = [0., sizeY = [0., WCS = [])

```
DES: compute transformation matrix
```

def boa::Bogli::Plot::setViewPoint (wedge = 0, aspect = 0)

```
DES: set the  view point
OPT: (logical) wegde  : if wedge is present (default no)
     (logical) aspect : should we keep the aspect ratio (in 'physical' unit)
                        of the graph (default no)
```

def boa::Bogli::Plot::xyout (X, Y, text)

```
DES: generic function to overplot text
INP: (dict) text : a 'text' dictionary like below
```

E. BoA Class Documentation

E.1 boa::BoaError::BoaError Class Reference

E.1.1 Detailed Description

```
A class used to generate exceptions related to Boa modules
```

Public Member Functions

- def **__init__**
- def **__str__**

Public Attributes

- **msg**
- **value**

E.2 boa::BoaDataEntity::BolometerArray Class Reference

E.2.1 Detailed Description

```
NAM: BolometerArray (class)
DES: Define all the useful parameters of a bolometer array
```

Public Member Functions

- def __init__
- def __str__
- def checkChanList
- def computeChanSep
- def computeChanSepValid
- def fillFromMBFits
- def get
- def getChanIndex
- def getChanSep
- def plotArray
- def plotGain
- def printCurrChanList
- def readAsciiRcp
- def readRCPfile
- def rotateArray
- def setCurrChanList
- def writeRCPfile

E.2.2 Member Function Documentation

def boa::BoaDataEntity::BolometerArray::__init__ (self)

```
DES: Instanciation of a BolometerArray object
```

def boa::BoaDataEntity::BolometerArray::__str__ (self)

```
DES: Defines a string which is shown when the print
     instruction is used.
```

def boa::BoaDataEntity::BolometerArray::checkChanList (self, inList)

```
DES: Return a list of valid channels
INP: (int list/string) inList: list of channel numbers to get, or
     empty list to get the complete list of unflagged channels, or
     'all' or 'al' or 'a' to get the complete list of channels
OUT: (int list) list of channel numbers
```

def boa::BoaDataEntity::BolometerArray::computeChanSep (self)

```
DES: Compute separation between pixels (in arcsec)
```

def boa::BoaDataEntity::BolometerArray::computeChanSepValid (self)

```
DES: Compute separation between VALID (i.e. not flagged -1) pixels (in arcsec)
```

def boa::BoaDataEntity::BolometerArray::fillFromMBFits (self, reader, febe, baseband, subscan)

```
NAM: fillFromMBFits()
DES: fill a BolometerArray object using the MBFitsReader object reader.

Calling sequence: DataEntity.fillFromMBFits(obsEntity)
INP: obsEntity: *LIST* of objects of the Entities.ObsEntity class
     update (logical) if true, do not reset previous entity object
```

def boa::BoaDataEntity::BolometerArray::get (self, dataType, flag = 0, inverse = 0)

```
DES: get bolometers offsets or gain according to flag
INP: (string) dataType : type of data
     (int)       flag  : retrieve data flagged with flag
                 (default 0 : good data, 'None' for all)
     (log)     inverse : retrieve all data without given flag set instead (default no)
OUT: (float array)     : the requested data
```

def boa::BoaDataEntity::BolometerArray::getChanIndex (self, chanList = [])

```
DES: convert from physical channel number to index in UsedChannel
INP: (i list) chanList : the physical channel number
OUT: (i list )           the corresponding index (-1 if failed)
```

def boa::BoaDataEntity::BolometerArray::getChanSep (self, chanList = [])

```
DES: return the channel separation in both direction from the reference channel
```

def boa::BoaDataEntity::BolometerArray::plotArray (self, overplot = 0, num = 0, limitsX = [], limitsY = [], ci = 3)

```
DES: plot the receiver parameters
INP: (optional) overplot (logical) = overplot?
     (optional) num (logical) = indicate chan numbers?
```

def boa::BoaDataEntity::BolometerArray::plotGain (self, style = 'g2r')

```
DES: plot the gain of the Array
INP: (str) style : the style to be used (default g2r)
WAR: the bolometer without know offsets should be flagged
```

def boa::BoaDataEntity::BolometerArray::printCurrChanList (self)

```
DES: print the current channel list in somehow "clever" way
OUT: a string representing the current channel list
```

def boa::BoaDataEntity::BolometerArray::readAsciiRcp (self, filename)

```
DES: update receiver channel offsets from a simple ascii file
     channelNumber AzOffset(arcsec) ElOffset(arcsec)
INP: (string) filename: the filename to read in
```

def boa::BoaDataEntity::BolometerArray::readRCPfile (self, rcpFile)

```
NAM: readRCPfile (method)
DES: update Receiver Channel Parameters (attributes Offsets,
     Gain and ChannelSep) from the content of a file
INP: (string) rcpFile: complete name of file to read in
```

def boa::BoaDataEntity::BolometerArray::rotateArray (self, elevation)

```
DES: rotate array offsets according to elevation
INP: (float) elevation (in degree)
```

def boa::BoaDataEntity::BolometerArray::setCurrChanList (self, chanList = '?')

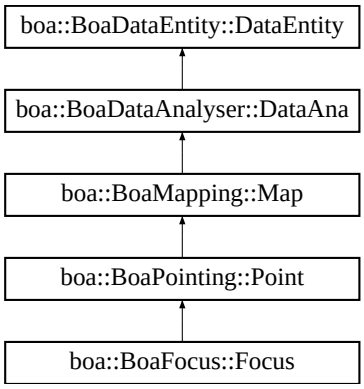
```
DES: set list of channels to be treated
INP: (int list/string) chanList = list of channels, or string '?'
     to get current list of channels, or string 'a' or 'al' or 'all'
     to set current list to all possible channels. Default: '?'
```

def boa::BoaDataEntity::BolometerArray::writeRCPfile (self, rcpFile = 'rcpBoa.rcp')

```
NAM: writeRCPfile (method)
DES: store current Receiver Channel Parameters (Offsets,
     Gain) to a file with mopsi like format
INP: (string) rcpFile: complete name of output file
```

E.3 boa::BoaDataAnalyser::DataAna Class Reference

Inheritance diagram for boa::BoaDataAnalyser::DataAna::



E.3.1 Detailed Description

```
DES: An object of this class is responsible for the flagging of
     individual channels, i.e. it sets the values in the
     Channel_Flag array of the corresponding DataEntity object. It
     provides methods to derive the rms of each channel and to
     automatically search for bad or noisy channels.  Channels might
     be flagged according to a given input file. This object
     provides methods to derive the correlation matrix.
```

Public Member Functions

- def __init__
- def basePoly
- def basePolySubscan
- def computeCorMatrix
- def computeSN
- def computeWeight
- def correlate
- def correlate2
- def despike
- def flag
- def flagChannels
- def flagInTime
- def flagLon
- def flagLST
- def flagPosition
- def flagRms
- def flagSubscan
- def medianBaseline
- def medianFilter
- def plotCorMatrix
- def plotFFT

- def plotMean
- def plotMeanChan
- def plotRms
- def plotRmsChan
- def slidingRms
- def statistics
- def unflag
- def unflagChannels

E.3.2 Member Function Documentation

def boa::BoaDataAnalyser::DataAna::__init__ (self)

```
DES: initialise an instance
```

Reimplemented from boa::BoaDataEntity::DataEntity.

Reimplemented in boa::BoaFocus::Focus, boa::BoaMapping::Map, and boa::BoaPointing::Point.

def boa::BoaDataAnalyser::DataAna::basePoly (self, chanList = [], order = 0, subscan = 0, plot = 0, subtract = 1)

```
DES: polynomial baseline method for single scans or subscans
INP: (i list) channel : list of channel to flag (default: all; [] : current list)
   (i) order    : polynomial order, >0
   (l) subscan  : compute baseline per subscan (default: no)
   (l) plot     : plot the signal and the fitted polynomials (default: no)
   (l) subtract : subtract the polynomial from the data (default: yes)
```

def boa::BoaDataAnalyser::DataAna::basePolySubscan (self, chanList = [], order = 0, plot = 0, subtract = 1)

```
DES: polynomial baseline method, treat each subscan.
INP: (i list) channel : list of channel to flag (default: all; [] : current list)
 (i) order    : polynomial order, >0
 (l) plot     : plot the signal and the fitted polynomials (default: no)
 (l) subtract : subtract the polynomial from the data (default: yes)
```

def boa::BoaDataAnalyser::DataAna::computeCorMatrix (self)

```
DES: compute correlation matrix. CM=1 for identical signals,
 and small symmetric around 0 for uncorrelated noise.
 CM_nm = <D_n*D_m> / [rms(D_n)*rms(D_n)]
 CM has dimension number_of_valid_channels^2
```

def boa::BoaDataAnalyser::DataAna::computeSN (self, subtract = 0)

```
DES: compute correlated noise, run after computeCorMatrix, computeWeight, correlate
INP: (i) subtract=0 : subtract correlated noise from Data
```

def boa::BoaDataAnalyser::DataAna::computeWeight (self, minCorr = 0., wa = 0.95, wb = 1.0, core = 100., beta = 1.)

```
DES: compute weight matrix of the used channels, run after computeCorMatrix
 weight is non-linear rescaling of correlation coefficient

               weight_nm = ( CM_nm - wa * min_m( CM_nm ) )**wb

 an additionnal weighting factor is applied with channel separation

               weight_nm  = weight_nm * 1.0 / ( 1 + ( dist_nm / core )**beta )

INP: (f) minCorr   = minimum correlation coefficient (defaut:0, should be positiv)
 (f) wa        = parameter for weights, usually = 0.90-0.98
 (f) wb        = parameter for weights, usually = 1
 (f) core      = core radius in arcmin for radial weighting (weight = 0.5)
 (f) beta      = beta for beta profile for radial weighting
```

def boa::BoaDataAnalyser::DataAna::correlate (self, channel = 97, chanList = [], skynoise = 0, plot = 0, minSlope = 0.1, maxSlope = 10.0)

```
DES: compute correlation factor relative to given reference channel
INP: (i) channel=114   : reference channel against which to correlate and/or plot
 (l i) chanList=[] : list of channel to correlate (default current list)
 (l) skynoise=0    : correlate skynoise[channel] not signal[channel] to signal
 (l) plot=0        : plot the correlation and the fit
 (f) minSlope=0.1  : limit slope of least squares fit
 (f) maxSlope=10   : limit slope of least squares fit
```

def boa::BoaDataAnalyser::DataAna::correlate2 (self, channel = 97, chanList = [], skynoise = 0, plot = 0, minSlope = 0.1, maxSlope = 10.0)

```
DES: compute correlation factor relative to given reference channel
INP: (i) channel=114   : reference channel against which to correlate and/or plot
 (l i) chanList=[] : list of channel to correlate (default current list)
 (l) skynoise=0    : correlate skynoise[channel] not signal[channel] to signal
 (l) plot=0        : plot the correlation and the fit
 (f) minSlope=0.1  : limit slope of least squares fit
 (f) maxSlope=10   : limit slope of least squares fit
```

def boa::BoaDataAnalyser::DataAna::despike (self, chanList = [], below = -5, above = 5, flag = 2)

```
DES: Flag yet unflagged data below 'below'*rms and above 'above'*rms.
INP: (i list) chanList : list of channel to flag (default: current list)
 (f)      below    :flag data with value < 'below'*rms
 (f)      above    :flag data with value > 'above'*rms
```

def boa::BoaDataAnalyser::DataAna::flag (self, dataType = '', channel = 'all', below = '?', above = '?', flag = 3)

```
DES: flag data based on dataType, general flagging routine, may be slow
INP: (s)     dataType : flag based on this dataType
 (i list) channel : list of channel to flag (default: all)
 (f)        below : flag dataType < below (default max; or 5*RMS)
 (f)        above : flag dataType > above (default min; or -5*RMS)
```

```
 (i)         flag : flag value (default 1 - 0 to unflag)

below and above should be in unit of the flagged data,
except for 'Lon' and 'Lat' where they should be in arcsec
```

def boa::BoaDataAnalyser::DataAna::flagChannels (self, chanList = [], flag = 1)

```
DES: assign flags to a list of channels
 To unflag a channel simply flag with flag=0
INP: (i list) chanList : list of channels to be flagged (default current list)
 (i)          flag : flag value
```

def boa::BoaDataAnalyser::DataAna::flagInTime (self, dataType = 'LST', channel = 'all', below = '?', above = '?', flag = 1)

```
DES: Flag data in time interval
INP: (int list) channel = list of channel to flag (default: 'all')
 (float)    below    = flag data below this value (default end of the scan)
 (float)    above    = flag data above this value (default start of the scan)
 (int)      flag     = flag to be set (default 1)
```

def boa::BoaDataAnalyser::DataAna::flagLon (self, channel = 'all', below = '?', above = '?', flag = 1)

```
NAM: flagLon (method)
DES: Flag data in Longitude interval
INP: (int list) channel = list of channel to flag (default: all)
 (float)    below   = flag data below this value (default end of the scan)
 (float)    above   = flag data above this value (default start of the scan)
 (int)      flag    = flag to be set (default 1)
```

def boa::BoaDataAnalyser::DataAna::flagLST (self, channel = 'all', below = '?', above = '?', flag = 1)

```
DES: Flag data in time interval
INP: (int list) channel = list of channel to flag (default: 'all')
 (float)    below    = flag data below this value (default end of the scan)
 (float)    above    = flag data above this value (default start of the scan)
 (int)      flag     = flag to be set (default 1)
```

def boa::BoaDataAnalyser::DataAna::flagPosition (self, channel = 'all', Az = 0, El = 0, radius = 0, flag = 5, offset = 1)

```
DES: flag a position in the sky within a given radius
INP: (int list) channel : list of channel to flag (default: 'all')
 (float)      Az/El : the horizontal reference position (arcsec for offsets, deg for absolute)
 (float)     radius : aperture to flag in unit of the reference position
 (int)         flag : flag to be set (default 5)
 (logical)   offset : flag on the offsets (default yes,)
```

def boa::BoaDataAnalyser::DataAna::flagRms (self, chanList = [], below = 0, above = 1e10, flag = 1)

```
DES: Flag channels with rms below 'below' or above 'above'
INP: (i list) chanList : list of channel to flag (default: current list)
 (f)      below    :flag channels with rms < 'below'
 (f)      above    :flag channels with rms > 'above'
```

def boa::BoaDataAnalyser::DataAna::flagSubscan (self, subList, flag = 1)

```
DES: flag subscans
INP: (int list) subList = list of subscan numbers (or single number)
                    to be flagged
      (int) flag    = value of flags to set
```

def boa::BoaDataAnalyser::DataAna::medianBaseline (self, chanList = [], subscan = 1)

```
DES: baseline: Remove median value per channel and per subscan
INP: (i list) channel : list of channels to process (default: [] = current list)
 (l) subscan  : compute baseline per subscan (default: yes)
```

def boa::BoaDataAnalyser::DataAna::medianFilter (self, chanList = [], window = 20, subtract = 1)

```
DES: median filtering: remove median values computed over sliding window
INP: (i list) channel: list of channels to process (default: [] = current list)
 (i)       window: number of samples to compute median
 (l)     subtract: subtract from data? (default: yes)
```

def boa::BoaDataAnalyser::DataAna::plotCorMatrix (self, chanList = [], check = 1, distance = 0, weights = 0, xLabel = 'Channels', style = 'g2r')

```
DES: plot the correlation matrix
INP: (i list) chanList : the list of channel to plot
 (l)         check : check the chanList first ( default : yes)
 (l)      distance : sort the second dimension by distance (default : no)
 (l)       weights : plot weights instead of correlation matrix (default: no)
```

def boa::BoaDataAnalyser::DataAna::plotFFT (self, chanList = [], flag = 0, optimize = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, window = 0)

```
DES: plot FFT of signal
INP: (i list) chanList : list of channels
 (i)          flag : flag to be used (default: 0, noflagged data)
 (l)      optimize : optimize or not (default) see FilerFFT.doFFT
 limits, style, ci...: plot parameters (see MultiPlot.plot)
 (i)        window : windowing function to apply (see FilerFFT.windowing)
```

def boa::BoaDataAnalyser::DataAna::plotMean (self, chanList = [], flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, map = 0)

```
DES: plot mean flux value vs. subscan number
TODO: flag handling not implemented yet
INP: (int list) chanList = list of channels
 (int)          flag = flag to be used
 (logical)       map = plot as a 2D map?
```

def boa::BoaDataAnalyser::DataAna::plotMeanChan (self, chanList = [], flag = 0, limitsX = [], limitsY = [], style = 'p', ci = 1, overplot = 0)

```
DES: PLotting the MEAN value for each subscan against channel number.
```

def boa::BoaDataAnalyser::DataAna::plotRms (self, chanList = [], flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, map = 0)

```
DES: plot flux r.m.s. vs. subscan number
TODO: flag handling not implemented yet
INP: (int list) chanList = list of channels
 (int)          flag = flag to be used
 (logical)       map = plot as a 2D map?
```

def boa::BoaDataAnalyser::DataAna::plotRmsChan (self, chanList = [], flag = 0, limitsX = [], limitsY = [], style = 'p', ci = 1, overplot = 0, subscan = 0)

```
DES: PLotting the RMS value for each subscan against channel number.
INP: (logical) subscan: if 0, plot rms of the complete scan, if 1,
                    plot for each subscan and each channel
```

def boa::BoaDataAnalyser::DataAna::slidingRms (self, nbInteg = 10, channel = [], flag = 0)

```
NAM: slidingRms (method)
DES: compute rms in a sliding window
INP: (int)    nbInteg : number of elements on which one rms is computed (= window size)
 (i list) channel : list of channel to flag (default: all; [] : current list)
 (int)       flag : data flag to be used
OUT: (array) the rms are returned
```

def boa::BoaDataAnalyser::DataAna::statistics (self)

```
NAM: statistics (method)
DES: computes mean, median, rms for all scans and subscans for all used channels
```

def boa::BoaDataAnalyser::DataAna::unflag (self, channel = [], flag = 1)

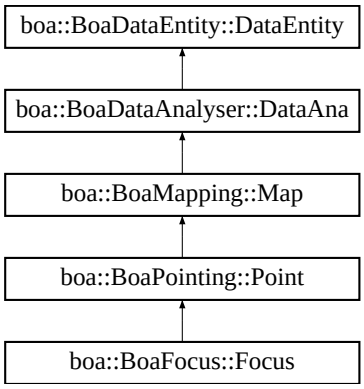
```
NAM: unflag (method)
DES: Unflag data, i.e. reset to 0.
INP: (i list) channel : list of channel to flag (default: current list)
 (i)         flag : unflag only this value (default 1)
```

def boa::BoaDataAnalyser::DataAna::unflagChannels (self, chanList = [])

```
DES: unflags a list of channels
INP: (i list) chanList : list of channels to be unflagged (default current list)
```

E.4 boa::BoaDataEntity::DataEntity Class Reference

Inheritance diagram for boa::BoaDataEntity::DataEntity::



E.4.1 Detailed Description

```
NAM: DataEntity (class)
DES: Objects of this class store the data and associated
     parameters of a scan, which can contain several observations
     (or subscans).
     They also contain additional arrays in which the current
     results of the data reduction are stored.
     This class also provides the interface between the MB-FITS
     files and BoA, by the means of the fillFromMBFits() method.
```

Public Member Functions

- def **__add__**
- def __init__
- def __str__
- def backup
- def computeSubIndex
- def dumpData
- def existData
- def fillFromMBFits
- def getChanData
- def getChanListData
- def phaseDiff
- def plotCorrel
- def read
- def reset
- def restore
- def restoreData
- def saveMambo
- def selectPhase
- def signal
- def writeMBfits

Public Attributes

- **Data**
- **DataBackup**
- **DataFlags**
- **DataWeights**
- **SkyNoise**

E.4.2 Member Function Documentation

def boa::BoaDataEntity::DataEntity::__init__ (self)

```
DES: Instanciation of a new DataEntity object.
     All attributes are defined and set to default values.
```

Reimplemented in boa::BoaDataAnalyser::DataAna, boa::BoaFocus::Focus, boa::BoaMapping::Map, and boa::BoaPointing::Point.

def boa::BoaDataEntity::DataEntity::__str__ (self)

```
DES: Defines a string which is shown when the print instruction is
     used. It contains the sizes and typecodes of all attributes.
```

def boa::BoaDataEntity::DataEntity::backup (self)

```
DES: backup the data
```

def boa::BoaDataEntity::DataEntity::computeSubIndex (self)

```
NAM: computeSubIndex (method)
DES: Compute start and end indices per subscan
```

def boa::BoaDataEntity::DataEntity::dumpData (self, fileName = 'BoaData.sav')

```
DES: save the current DataEntity object to a file
INP: (string) fileName: name of the output file
     optional - default value = 'BoaData.sav'
```

def boa::BoaDataEntity::DataEntity::existData (self)

```
DES: check if the DataEntity object has been filled with data
OUT: (int) result: 0 if no data, 1 otherwise
```

def boa::BoaDataEntity::DataEntity::fillFromMBFits (self, reader, febe, baseband, subscans)

```
NAM: fillFromMBFits()
DES: fill a DataEntity object using the MBFitsReader object reader.

Calling sequence: DataEntity.fillFromMBFits(obsEntity)
INP: obsEntity: *LIST* of objects of the Entities.ObsEntity class
```

def boa::BoaDataEntity::DataEntity::getChanData (self, dataType = ' ', chan = 'None', flag = 0, subscans = [], inverse = 0, flag2 = None)

```
DES: get data for one channel
INP: (string)   dataType : type of data
     (int)          chan : channel number
     (int)          flag : data flag to be used
     (int list) subscans : list of wanted subscan (default all)
OPT: (log)       inverse : if set, return datapoints where flag <> value
     (int array)   flag2 : second array of flags to check
OUT: (float)       array : data of one channel
```

def boa::BoaDataEntity::DataEntity::getChanListData (self, type = ' ', chanList = [], flag = 0, flag2 = None)

```
DES: get data for list of channels
INP: (string) type = type of data
     (int list) chan = channel list
     (int)    flag = data flag to be used
     (int array) flag2 = second array of flags to check (optional)
OUT: (list of float arrays) = data of the input list of channels
```

def boa::BoaDataEntity::DataEntity::phaseDiff (self)

```
NAM: phaseDiff (method)
DES: Compute phase differences: call ScanParam.phaseDiffParam for
     coordinates and times, and compute Data(ON) - Data(OFF)
```

def boa::BoaDataEntity::DataEntity::plotCorrel (self, chanRef = 1, chanList = [], flag = 0, skynoise = 0, limitsX = [], limitsY = [], style = 'p', ci = 1, overplot = 0)

```
DES: plot flux density of a list of channels vs. flux density of a
     reference channel
INP: (int)       chanRef = reference channel number
     (int list) chanList = list of channels
     (int)          flag = flag to be used
     (l)        skynoise = plot against the skynoise of chanRef (default :  no)
```

def boa::BoaDataEntity::DataEntity::read (self, inFile = '', febe = '', baseband = 0, subscans = [], update = 0, phase = 0)

```
DES: fill a data entity object
INP: (string)      inFile: path to the dataset to be read
     (int list) subscans : subscan numbers to read (default: all)
(logical) update : if true, do not reset previous entity object
     (int) phase : phase to be stored (default: phase diff)
```

def boa::BoaDataEntity::DataEntity::reset (self)

```
DES: Reset all attributes - useful before reading a new file
```

def boa::BoaDataEntity::DataEntity::restore (self)

```
DES: backup the data
```

def boa::BoaDataEntity::DataEntity::restoreData (self, fileName = 'BoaData.sav')

```
DES: restore a DataEntity object previously saved in a file, and
     set it as the currData attribute of BoaB
INP: (string) fileName: name of the input file
     optional - default value = 'BoaData.sav'
```

def boa::BoaDataEntity::DataEntity::saveMambo (self, inName = '', outName = '')

```
DES: convert an MB-Fits file to the MAMBO FITS format, readable
     by MOPSIC
INP: (str) inName: name of the MB-Fits file (optional)
     (str) outName: name of the MAMBO output file (optional)
```

def boa::BoaDataEntity::DataEntity::selectPhase (self, phase)

```
NAM: selectPhase (method)
DES: Keep only Data(ON) or Data(OFF)
INP: (int) phase: phase to keep, 1=ON, 2=OFF
```

def boa::BoaDataEntity::DataEntity::signal (self, chanList = [], flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, plotMap = 0, mjd = 0)

```
DES: plot time series of flux density
INP: (int list) chanList = list of channels
     (int)          flag = flag to be used
     (logical)       mjd = if set, use mjd instead of lst
```

def boa::BoaDataEntity::DataEntity::writeMBfits (self, outName)

```
NAM: writeMBfits (method)
DES: write the data (and parameters) contained in the current data
     out to a FITS file in MB-Fits format
INP: outName (str) = output file name (.fits extension may be omitted)
```

E.5 boa::Bogli::Interface::Fenetre Class Reference

E.5.1 Detailed Description

```
classe Fenetre - parametres et methodes pour les boites et boutons
attributs:
int forme    : 0=cercle 1=rectangle 2=rectangle transparent
list pos     : positions (X,Y) des centres dans la fenetre
list float/tuple size: rayon ou (largeur,hauteur)
list label   : messages a apparaitre (vecteur de string) dans ou pres d'une fenetre
tuple txtpos : position des labels relativement a pos
int font     : taille des caracteres
int coltxt   : couleur du texte
int colfond  : couleur de fond des boutons
int family   : police de caracteres
```

Public Member Functions

- def **__init__**
- def dessine
- def saisie

Public Attributes

- **colfond**
- **coltxt**
- **family**
- **font**
- **forme**
- **label**
- **pos**
- **size**
- **txtpos**

E.5.2 Member Function Documentation

def boa::Bogli::Interface::Fenetre::dessine (self, new = 0)

```
method dessine

INP: new : efface la fenetre si non nul
OUT: aucune
```

def boa::Bogli::Interface::Fenetre::saisie (self)

```
method saisie

INP: aucune
OUT: choix : selection (numero du bouton)
```

E.6 boa::BoaDataAnalyser::FilterFFT Class Reference

E.6.1 Detailed Description

```
DES: To easily do FFT filtering
INF: make the assumption that the input signal is real, so do not
     care about negative frequencies...
```

Public Member Functions

- def **__init__**
- def blankAmplitude
- def doFFT
- def invFFT
- def plotfft
- def rebin
- def unbin
- def windowing

Public Attributes

- **amplitude**
- **freq**
- **interpX**
- **interpY**
- **N**
- **phase**
- **X**
- **Y**

E.6.2 Member Function Documentation

def boa::BoaDataAnalyser::FilterFFT::blankAmplitude (self, below = '?', above = '?')

```
DES: blank the amplitude below and/or after a certain frequency
```

def boa::BoaDataAnalyser::FilterFFT::doFFT (self, optimize = 0)

```
DES: perform the FFT
INP: (i) optimize :  0, will use the full data set (default)
             1, will zero-pad the data til the next power of 2
```

def boa::BoaDataAnalyser::FilterFFT::invFFT (self)

```
DES: perform the inverse FFT
```

def boa::BoaDataAnalyser::FilterFFT::plotfft (self, plotPhase = 0, labelX = 'Frequency [Hz]', labelY = 'Amplitude (a.b.u/sqrt(Hz)', \ limitsX=[], limitsY = [], logX = 0, logY = 0, overplot = 0, ci = 1)

```
DES: Plot the fft
INP: (str)  labelX/Y  : the X/Y label
     (2d f) limitsX/Y : the plot limits for X/Y
     (bol)  plotPhase : plot phase instead of amplitude (default no)
```

def boa::BoaDataAnalyser::FilterFFT::rebin (self, interval = 0)

```
DES: linearly interpolate the starting value for the FFT
INP: (f) interval : force the interval (default : median)
```

def boa::BoaDataAnalyser::FilterFFT::unbin (self)

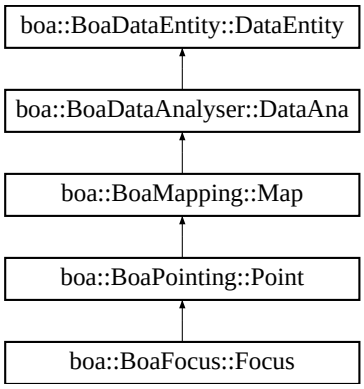
```
DES: Rebin the data to the initial grid
```

def boa::BoaDataAnalyser::FilterFFT::windowing (self, type = 1, undo = 0)

```
DES: apply some window on the signal.
INP: (i) type : the type of desired windowing
           1 - Barlett (default)
           2 - Hann
           3 - Welch
     (l) undo : if set, divide by the window function (default: multiply)
```

E.7 boa::BoaFocus::Focus Class Reference

Inheritance diagram for boa::BoaFocus::Focus::



E.7.1 Detailed Description

```
NAM: Focus (class)
DES: An object of this class is responsible for the focus reduction
     of single or multiple scans and provides the offsets.
```

Public Member Functions

- def __init__
- def reduce
- def solveFocus

E.7.2 Member Function Documentation

def boa::BoaFocus::Focus::__init__ (self)

```
DES: Initialise an instance
```

Reimplemented from boa::BoaPointing::Point.

def boa::BoaFocus::Focus::reduce (self, datasetName = ", obstoProc = [])

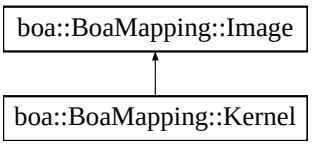
```
DES: Process a Focus scan - this method is called by the apexCalibrator
INP: (string) datasetName: path to the dataset to be reduced
 (i list)   obstoProc: list of subscans to consider (default: all)
```

def boa::BoaFocus::Focus::solveFocus (self)

```
DES: compute the optimal focus position
```

E.8 boa::BoaMapping::Image Class Reference

Inheritance diagram for boa::BoaMapping::Image::



E.8.1 Detailed Description

```
NAM: Image (class)
DES: An object of this class describes an image and its axis
```

Public Member Functions

- def **__init__**
- def computeWCS
- def display
- def physicalCoordinates
- def smoothBy
- def smoothWith
- def wcs2phy
- def wcs2pix

Public Attributes

- **data**
- **rms**
- **WCS**
- **weight**

E.8.2 Member Function Documentation

def boa::BoaMapping::Image::computeWCS (self, pixelSize, sizeX = [], sizeY = [], minmax = [])

```
DES: fill main WCS keywords according to pixel size and map limits
INP: (int) pixelSize = size of pixel in acrsecond
     (float) sizeX = map limits in azimuth, in arcsecond
     (float) sizeY = map limits in elevation, in arcsecond
     (float) minmax = [minAzoff,maxAzoff,minEloff,maxEloff] in this order
```

def boa::BoaMapping::Image::display (self, rms = 0, weight = 0, style = 'g2r', labelX = "\gD Az [”]", labelY = "\gD El [”]", caption = ”, wedge = 1, aspect = 0, overplot = 0, doContour = 0, levels = [], labelContour = 0, limitsX = [], limitsY = [], limitsZ = [])

```
DES: show the reconstructed maps in (Az,El)
INP: (boolean) rms,weight    : plot the rms or weight map instead of signal map
```

```
(string)  style         : the style used for the color (default g2r)
(string) labelX, labelY : the X and Y labels
(string)  caption       : the caption of the plot (default '')
(flt array) limitsX/Y/Z : the limits in X/Y/intensity
(boolean) wedge         : draw a wedge ? (default : yes)
(boolean) aspect        : keep the aspect ratio (default : no)
(boolean) overplot      : should we overplot this image (default : no)
(boolean) doContour     : draw contour instead of map (default : no)
(float array) levels    : the levels of the contours (default : intensity progression)
(boolean) labelContour  : label the contour (default : no)
```

def boa::BoaMapping::Image::physicalCoordinates (self)

```
DES: return arrays with physical units corresponding to the map
```

def boa::BoaMapping::Image::smoothBy (self, beamSize)

```
DES: smooth the image with a 2D gaussian of gived FWHM
INP: (float) beamSize : the FWHM of the smoothing gaussian
```

def boa::BoaMapping::Image::smoothWith (self, kernel)

```
DES: smooth the image with the given kernel
INP: (kernel) : the kernel
```

def boa::BoaMapping::Image::wcs2phy (self, i, j)

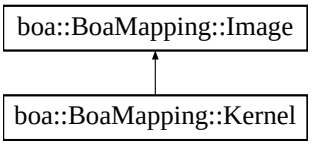
```
DES: Convert from pixel coordinates to physical (world) coordinates
INP: float (i,j) : the pixel coordinate to convert from
OUT: float (X,Y) : the physical coordinate

     We should switch to libwcs at some point
```

def boa::BoaMapping::Image::wcs2pix (self, X, Y)

```
DES: Convert from physical coordinate describe by self.WCS to pixel coordinate
INP: float (X,Y) : the physical coordinate to convert from
OUT: float (i,j) : the pixel coordinate(s)

     We should switch to libwcs at some point
```

E.9 boa::BoaMapping::Kernel Class Reference

Inheritance diagram for boa::BoaMapping::Kernel::



E.9.1 Detailed Description

```
NAM: Kernel (class)
DES: define a kernel
```

Public Member Functions

- def __init__

E.9.2 Member Function Documentation

def boa::BoaMapping::Kernel::__init__ (self, pixelSize, beamSize)

```
DES: Initialise an instance of a Kernel class
INP: (float) pixelSize: the physical size of a pixel
             (float) beamSize : the beam FWHM in the same unit
```

E.10 boa::BoaMessageHandler::Logger Class Reference

E.10.1 Detailed Description

```
NAM: Logger (class)
DES: for compatiliby with the CalibratorLog.Logger class
```

Public Member Functions

- def __init__

E.10.2 Member Function Documentation

def boa::BoaMessageHandler::Logger::__init__ (self, logType = 'ACS')

```
DES: Initiabise an instance
```

E.11 boa::MamboMBFits::MamboMBFits Class Reference

E.11.1 Detailed Description

```
DES: Objects of this class contain two attributes of the FitsFile
class. The 'Mambo' attribute stores the data as they appear in a
MAMBO FITS file, and the 'MBfits' attribute contains the data in
the MB-FITS format. Methods to do conversions in both directions
are provided by this class.
```

Public Member Functions

- def __init__
- def convertFebepar
- def convertMambo2MBFits
- def convertMamboPrimary
- def convertMB2MamboFits
- def ctype2sbas
- def fillFebepar
- def fillMamboData
- def fillMamboPrimary
- def getObsMode
- def getScanType
- def initMambo
- def initMB
- def processMamboData
- def readMambo
- def readMBfits
- def readRCP
- def sbas2ctype

E.11.2 Member Function Documentation

def boa::MamboMBFits::MamboMBFits::__init__ (self, mamboName, mbName)

```
DES: Instanciation of a new MamboMBFits object.
INP: (str) mamboName = name of the Mambo file
 (str) mbName = name of the MB-FITS file
 in both cases, the .fits extension is appended if not present
```

def boa::MamboMBFits::MamboMBFits::convertFebepar (self)

```
DES: This method generates a RCP file, where the relative gains
and offsets of pixels are stored, from the content of the FEBEPAR
table. The output file name is <FE_name>.rcp.
```

def boa::MamboMBFits::MamboMBFits::convertMambo2MBFits (self)

```
DES: This function reads in the content of a Mambo FITS file,
and writes out the data and associated parameters to a file
conforming to the MB-FITS format.
```

def boa::MamboMBFits::MamboMBFits::convertMamboPrimary (self)

```
DES: This generates in the MB-FITS file all the header keywords that
have one direct equivalent in the MAMBO primary header.
```

def boa::MamboMBFits::MamboMBFits::convertMB2MamboFits (self)

```
DES: This function reads in the content of an MB-FITS file,
and writes out the data to a file in the Mambo-FITS format,
and the associated parameters to a RCP file.
```

def boa::MamboMBFits::MamboMBFits::ctype2sbas (self)

```
DES: Converts the infos about the Astronomical basis frame from MB-FITS
keywords (CTYPEj, EQUINOX...) to a SBAS value (+ epoch). The results
are stored and returned in a dictionary.
```

def boa::MamboMBFits::MamboMBFits::fillFebepar (self)

```
DES: This method writes one row in the FEBEPAR-MBFITS table, by
reading the content of a Mambo RCP file, specified by the total
number of pixels (40 or 120).
```

def boa::MamboMBFits::MamboMBFits::fillMamboData (self)

```
DES: This methods fills the subscans and data tables in an output MAMBO
file, using the data previously read in from an MB-FITS file.
```

def boa::MamboMBFits::MamboMBFits::fillMamboPrimary (self)

```
DES: Update the keyword values in the Mambo Primary header,
using the equivalent keywords found in the MB-FITS file.
```

def boa::MamboMBFits::MamboMBFits::getObsMode (self)

```
DES: Convert the scanType (from MB-FITS) to OBSMODE + SRP1FLAG
+ SRP2FLAG as defined in the MAMBO format.
```

def boa::MamboMBFits::MamboMBFits::getScanType (self)

```
DES: Convert the informations about the observing type from
Mambo format (contained in OBSMODE + SRP1FLAG + SRP2FLAG) to
an MB-FITS SCANTYPE. Also return the SCANMODE, SCANGEOM,
SWTCHMOD, WOBSW, OBSTYPE and SCANDIR infos. The results are
stored in the Scantype attribute, which is a Dictionary.
```

def boa::MamboMBFits::MamboMBFits::initMambo (self)

```
DES: Create a file in the Mambo FITS format. This generates only the
Primary header and subscan table, because the number of feeds must be
written in the Primary header before the data table is created.
```

def boa::MamboMBFits::MamboMBFits::initMB (self)

```
DES: This generates the first three tables in the MB-FITS file
(Primary header, SCAN-MBFITS and FEBEPAR-MBFITS tables).
```

def boa::MamboMBFits::MamboMBFits::processMamboData (self)

```
DES: This method generates ARRAYDATA, DATAPAR and MONITOR tables in
the MB-FITS file for every subscan in the MAMBO file.
```

def boa::MamboMBFits::MamboMBFits::readMambo (self)

```
DES: This fills the TableList in the Mambo attribute with the
content of the MAMBO FITS file.
```

def boa::MamboMBFits::MamboMBFits::readMBfits (self)

```
DES: This fills the TableList in the MBfits attribute with the
content of the MB-FITS file.
```

def boa::MamboMBFits::MamboMBFits::readRCP (self)

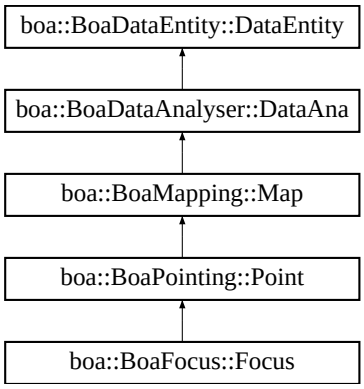
```
DES: Read the Receiver Channels Parameters from the file
'MRT_2002a_120.rcp' if the number of bolometers is 120, or
'MRT_2002s2_40.rcp' if it is 40. These files are supposed
to be in the local directory. Returns a list of tuples,
where each tuple is (Gain,X_off,Y_off).
```

def boa::MamboMBFits::MamboMBFits::sbas2ctype (self)

```
DES: Converts the SBAS value to the MB-FITS keywords that define the
Astronomical basis frame: CTYPEj, WCSNAME, RADESYS, EQUINOX, and
eventually MOVEFRAM. All these are stored in a dictionary.
```

E.12 boa::BoaMapping::Map Class Reference

Inheritance diagram for boa::BoaMapping::Map::



E.12.1 Detailed Description

```
NAM: Map (class)
DES: An object of this class is responsible for the restoration of
     mapping data of single or multiple files.
```

Public Member Functions

- def **__add__**
- def __init__
- def beamMap
- def eq_to_ho
- def fastChanMap
- def fastChanMap2
- def fastMap
- def getPixel
- def reduce
- def showMap
- def slowMap
- def writeFITS

E.12.2 Member Function Documentation

def boa::BoaMapping::Map::__init__ (self)

```
DES: Initialise an instance.
```

Reimplemented from boa::BoaDataAnalyser::DataAna.

Reimplemented in boa::BoaFocus::Focus, and boa::BoaPointing::Point.

def boa::BoaMapping::Map::beamMap (self, chanList = [], flag = 0, oversamp = 2.0, sizeX = [], sizeY = [], style = 'g2r', noSmooth = 0, aspect = 0)

```
DES: build a beam map in (Az,El) coordinates
INP: (int list) chanList = channels to consider
     (int) flag  = flag values to consider
     (float) oversamp = oversampling factor (beam fwhm / pixel size). Default=2.
     (list float) sizeX = limits in Az of the map
     (list float) sizeY = limits in El of the map
```

def boa::BoaMapping::Map::eq_to_ho (self)

```
DES: convert EQ offsets to HO ones: assumes Lon and Lat attributes are
     offsets in RA, Dec, converts them to Az, El offsets and overwrites
                 Lon and Lat - WARNING: not very accurate!
```

def boa::BoaMapping::Map::fastChanMap (self, chanList = [], flag = 0, oversamp = 2., sizeX = [], sizeY = [], noSmooth = 0, style = 'g2r', limitsZ = [], center = 0)

```
DES: plot channel maps (quick method)
INP: (int list) chanList = channels to consider
     (int)         flag  = flag values to consider
     (float)    oversamp = oversampling factor (beam fwhm / pixel size). Default=2.
     (logical)  center =0/1 if set to 1 it will shift each map by the bolometer offset
                from the fits header. Thereby it shifts the source to the center of
        each channel map
```

def boa::BoaMapping::Map::fastChanMap2 (self, chanList = [], flag = 0, oversamp = 2., sizeX = [], sizeY = [], noSmooth = 0, style = 'g2r', limitsZ = [], center = 0)

```
DES: plot channel maps (quick method)
INP: (int list) chanList = channels to consider
     (int)         flag  = flag values to consider
     (float)    oversamp = oversampling factor (beam fwhm / pixel size). Default=2.
     (logical)  center =0/1 if set to 1 it will shift each map by the bolometer offset
                from the fits header. Thereby it shifts the source to the center of
        each channel map
```

def boa::BoaMapping::Map::fastMap (self, chanList = [], flag = 0, oversamp = 2.0, beammap = 0, sizeX = [], sizeY = [], limitsZ = [], style = 'g2r', wedge = 1, noSmooth = 0, noPlot = 0, aspect = 0)

```
DES: reconstruct a map in (Az,El) coordinates combining bolometers
INP: (int list) chanList = channels to consider
     (int)         flag  = flag values to consider
     (float)    oversamp = oversampling factor (beam fwhm / pixel size). Default=2.
     (list float)  sizeX = limits in Az of the map
     (list float)  sizeY = limits in El of the map
     (logical)     noNan = remove NaN in self.Results?
     (str)         style = color table to use in image
     (logical)  noSmooth = do not smooth with beam?
     (logical)    noPlot = do not plot the map?
     (str)       caption = plot caption
     (logical)    aspect = keep aspect ratio?
```

def boa::BoaMapping::Map::getPixel (self, nbPix = 3)

```
DES: allow user to get pixel values using mouse
INP: (int)  nbPix : size of area to compute average
```

def boa::BoaMapping::Map::reduce (self, datasetName = ", obstoProc = [], update = 0)

```
DES: Process a map scan - this method is called by the apexCalibrator
INP: (string) datasetName: path to the dataset to be reduced
     (i list) obstoProc: list of subscans to consider (default: all)
```

def boa::BoaMapping::Map::showMap (self, style = 'g2r', labelX = "\gD Az ["]", labelY = "\gD El ["]", wedge = 1, limitsZ = [], aspect = 0, limitsX = [], limitsY = [])

```
DES: show the reconstructed map in (Az,El)
```

def boa::BoaMapping::Map::slowMap (self, chanList = [], flag = 0, oversamp = 2.0, beammap = 0, sizeX = [], sizeY = [], offsets = [0., style = 'g2r', wedge = 1, noSmooth = 0, noPlot = 0)

```
DES: reconstruct a map in (Az,El) coordinates combining bolometers
INP: (int list) chanList = channels to consider
     (int) flag  = flag values to consider
     (float) oversamp = oversampling factor (beam fwhm / pixel size). Default=2.
     (list float) sizeX = limits in Az of the map
     (list float) sizeY = limits in El of the map
     (list float) offsets = Az,El  to recenter a point source
     (logical) noNan = remove NaN in self.Results?
     (str) style = color table to use in image
```

def boa::BoaMapping::Map::writeFITS (self, outfile = 'boaMap.fits')

```
DES: store the current map (2D array with WCS info) to a FITS file
INP: (str) outfile: output file name - default = boaMap.fits
```

E.13 boa::BoaMBFitsReader::MBFitsReader Class Reference

E.13.1 Detailed Description

```
Reader class for MBFITS 1.60 and earlier.

The only public method is read.
```

Public Member Functions

- def **__init__**
- def getBlankFloat
- def getBlankInt
- def read

E.13.2 Member Function Documentation

def boa::BoaMBFitsReader::MBFitsReader::getBlankFloat (self)

```
Blank value for floats as used in MBFITS
```

def boa::BoaMBFitsReader::MBFitsReader::getBlankInt (self)

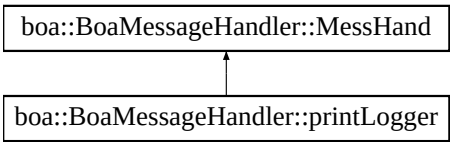
```
Blank value for integers as used in MBFITS
```

def boa::BoaMBFitsReader::MBFitsReader::read (self, itemKey, kargs)

```
Read item itemKey from the dataset, using the additional
arguments in **kargs
```

E.14 boa::BoaMessageHandler::MessHand Class Reference

Inheritance diagram for boa::BoaMessageHandler::MessHand::



E.14.1 Detailed Description

```
NAM: MessHand (class)
DES: An object of this class is responsible for the management of output
     messages as well as the creation of message files.
```

Public Member Functions

- def **__del__**
- def __init__
- def ask
- def closeMessFile
- def debug
- def error
- def info
- def initMessFile
- def longinfo
- def pause
- def **setLogName**
- def setMaxWeight
- def setMess
- def warning
- def Welcome
- def yesno

E.14.2 Member Function Documentation

def boa::BoaMessageHandler::MessHand::__init__ (self, logName = 'Unknown')

```
DES: initialise an instance
```

def boa::BoaMessageHandler::MessHand::ask (self, message = '')

```
DES: ask the user
INP: (sring)  : the question
OUT: (string) : the answer
```

def boa::BoaMessageHandler::MessHand::closeMessFile (self)

```
DES: set self.__existMessFile to 0 and file name to ""
```

def boa::BoaMessageHandler::MessHand::debug (self, message = '')

```
DES: to print an debug message
INP: (sring) message
```

def boa::BoaMessageHandler::MessHand::error (self, message = '')

```
DES: to print an error message
INP: (sring) message
```

def boa::BoaMessageHandler::MessHand::info (self, message = '')

```
DES: to print an info message
INP: (sring) message
```

def boa::BoaMessageHandler::MessHand::initMessFile (self, filename = "boa.mes")

```
DES: set & initialise new message file
OUT: screen output
```

def boa::BoaMessageHandler::MessHand::longinfo (self, message = '')

```
DES: to print an long info message
INP: (sring) message
```

def boa::BoaMessageHandler::MessHand::pause (self, message = '')

```
DES: allow to make a pause in the program
OPT: (sring) : a message to display
```

def boa::BoaMessageHandler::MessHand::setMaxWeight (self, weight = '2')

```
DES: Set the maximum weight of messages to be printed.
INP: (int) weight = maximum weight

          1: errors, queries
          2: warnings
          3: short info
          4: extended info
          5: debug
```

def boa::BoaMessageHandler::MessHand::setMess (self, weight = 1, message = ' ')

```
DES: deposit messages for screen output and message files
INP: (int) weight = weight of transferred message (see setMaxWeight)
 (string) message = message to be printed and added to message file
```

def boa::BoaMessageHandler::MessHand::warning (self, message = '')

```
DES: to print an warning message
INP: (sring) message
```

def boa::BoaMessageHandler::MessHand::Welcome (self)

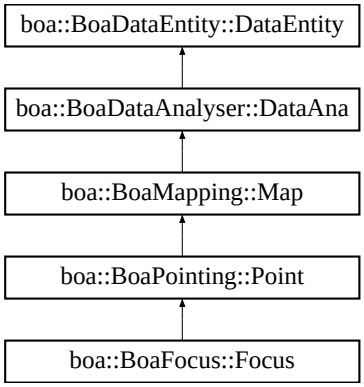
```
DES: print welcome message
OUT: screen output
```

def boa::BoaMessageHandler::MessHand::yesno (self, message = '')

```
DES: ask the user a question with yes/no answer type
INP: (sring)  : the question
OUT: (l) :    : the answer
```

E.15 boa::BoaPointing::Point Class Reference

Inheritance diagram for boa::BoaPointing::Point::



E.15.1 Detailed Description

```
NAM: Point (class)
DES: An object of this class is responsible for the reduction of
     pointing scan(s)
```

Public Member Functions

- def __init__
- def arrayParameters
- def iterMap
- def reduce
- def showPointing
- def solvePointing
- def solvePointingOnMap
- def updateArrayParameters

E.15.2 Member Function Documentation

def boa::BoaPointing::Point::__init__ (self)

```
DES: Initialise an instance.
```

Reimplemented from boa::BoaMapping::Map.

Reimplemented in boa::BoaFocus::Focus.

def boa::BoaPointing::Point::arrayParameters (self, chanList = [], gradient = 0, circular = 0, radius = 0, plot = 0)

```
DES: determine the array parameters from the data
INP: (i list) chanList : the channel list to be used (default: current list)
     (l)      gradient : remove a background gradient in the data (default: no)
     (l)      circular : fit a cricular gaussian instead of an elliptical gaussian
```

def boa::BoaPointing::Point::iterMap (self, chanList = [], phase = 0, flag = 0, sizeX = [], sizeY = [])

```
DES: reconstruct a map in (Az,El) coordinates combining bolometers
     and using varying scale to zoom on signal
INP: (int list) chanList = channels to consider
     (int) phase = phase to plot
     (int) flag  = flag values to consider
     (list float) sizeX = limits in Az of the map
     (list float) sizeY = limits in El of the map
```

def boa::BoaPointing::Point::reduce (self, datasetName = ", obstoProc = [], radius = 100., update = 0)

```
DES: Process a Pointing scan - this method is called by the apexCalibrator
INP: (string) datasetName: path to the dataset to be reduced
     (i list)   obstoProc: list of subscans to consider (default: all)
     (float)       radius: radius (in arcsec) to be used for fitting
```

def boa::BoaPointing::Point::showPointing (self, plot = 1, display = 1, noMap = 0, caption = ", aspect = 1, style = 'g2r')

```
DES: compute the offset
INP: (logical) plot  : display the results on a map (default: no)
     (logical) display : display the result on screen (default: yes)
```

def boa::BoaPointing::Point::solvePointing (self, chanList = [], gradient = 0, circular = 0, radius = -5, Xpos = 0., Ypos = 0., fixedPos = 0, plot = 0, display = 1, caption = ", aspect = 1)

```
DES: compute the offset
INP: (int list) chanList: list of channels to be used (default: all)
     (boolean)  gradient: shall we fit a gradient ? (default: no)
     (boolean)  circular: fit a cricular gaussian instead of an elliptical gaussian
     (float)    radius  : use only bolo inside this radius (negative means multiple of beam) (default 5 be
     (float)  Xpos,Ypos : source position if using fixed position
     (boolean) fixedPos : if set, don't fit position, but use Xpos, Ypos
     (boolean)  plot    : do we plot the results? (default: no)
     (boolean)  display    : display the result of the fit (default: yes)
OUT: store in self.PoitingResult the results of the fit (i.e. all parameters
     as computed by mpfit routine). If mpfit failed, then self.PoitingResult
     is set to -1
```

def boa::BoaPointing::Point::solvePointingOnMap (self, gradient = 1, circular = 0, radius = -5, Xpos = 0., Ypos = 0., fixedPos = 0, plot = 0, display = 1, caption = ", aspect = 1, style = 'g2r')

```
DES: compute the offset on the data.Map object
INP: (boolean)  gradient: shall we fit a gradient ? (default: yes)
     (boolean)  circular: fit a cricular gaussian instead of an elliptical gaussian
     (float)    radius  : use only bolo inside this radius (negative means multiple of beam) (default 5 be
     (float)  Xpos,Ypos : source position if using fixed position
     (boolean) fixedPos : if set, don't fit position, but use Xpos, Ypos
     (boolean)  plot    : do we plot the results? (default: no)
     (boolean)  display : display the result of the fit (default: yes)
OUT: store in self.PointingResult the results of the fit (i.e. all parameters
     as computed by mpfit routine). If mpfit failed, then self.PoitingResult
```

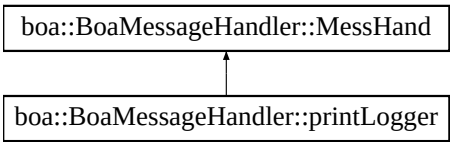
```
is set to -1

WARNING : No Smoothing should be applied to the map
before using this function, or the fitted fwhm will be
useless, use fine oversamp to make reasonable fit
```

def boa::BoaPointing::Point::updateArrayParameters (self)

```
DES: Update the Parameters Offsets with the computed values
```

E.16 boa::BoaMessageHandler::printLogger Class Reference

Inheritance diagram for boa::BoaMessageHandler::printLogger::



E.16.1 Detailed Description

```
NAM: printLogger (class)
DES: for compatibility with the CalibratorLog.printLogger class
```

Public Member Functions

- def **__init__**
- def **logDebug**
- def **logError**
- def **logInfo**
- def **logWarning**

E.17 boa::BoaDataEntity::ScanParameter Class Reference

E.17.1 Detailed Description

```
NAM: ScanParameter (class)
DES: Define all parameters (coordinates, time) for a scan
```

Public Member Functions

- def **__add__**
- def __init__
- def __str__
- def caption
- def computeOnOff
- def fillFromMBFits
- def findSubscan
- def get
- def phaseDiffParam
- def plotAzEl
- def plotAzElOffset
- def plotAzimuth
- def plotAzimuthOffset
- def plotElevation
- def plotElevationOffset
- def plotSubscan
- def plotSubscanOffsets
- def selectPhase

Public Attributes

- **Az**
- **Baslat**
- **Baslon**
- **El**
- **Flags**
- **FocX**
- **FocY**
- **FocZ**
- **Lat**
- **Latpole**
- **Lon**
- **Lonpole**
- **LST**
- **MJD**
- **Nint**
- **NObs**
- **Nodding_Sta**
- **PhiX**
- **PhiY**

- **Rot**
- **SubscanEpo**
- **SubscanIndex**
- **SubscanTime**
- **Track_Az**
- **Track_El**
- **UT**
- **WobblerPos**

E.17.2 Member Function Documentation

def boa::BoaDataEntity::ScanParameter::__init__ (self)

```
DES: Instanciation of a new ScanParameter object
```

def boa::BoaDataEntity::ScanParameter::__str__ (self)

```
DES: Defines a string, shown when the print instruction is used.
```

def boa::BoaDataEntity::ScanParameter::caption (self)

```
DES: Return a short caption of the scan
```

def boa::BoaDataEntity::ScanParameter::computeOnOff (self)

```
DES: determine ON-OFF pairs from content of WobblerSta, and fill
     OnOffPairs attribute with pairs of integration numbers.
     The result is a 2 x Nb_Integ. array of integers.
```

def boa::BoaDataEntity::ScanParameter::fillFromMBFits (self, reader, febe, baseband, subscans)

```
NAM: fillFromMBFits()
DES: fill a ScanParam object using the MBFitsReader object reader.

Calling sequence: DataEntity.fillFromMBFits(obsEntity)
INP: obsEntity: *LIST* of objects of the Entities.ObsEntity class
     update (logical) if true, do not reset previous entity object
```

def boa::BoaDataEntity::ScanParameter::findSubscan (self, threshold = 1.)

```
DES: compute subscan indices from steps in az, el
INP: (float) threshold = value (in arcsec^2) of (d_az^2 + d_el^2) step
                 used to detect turnovers / stationnary points
```

def boa::BoaDataEntity::ScanParameter::get (self, dataType = ' ', flag = 0, inverse = 0)

```
DES: get data of the ScanParam class
INP: (string) dataType : type of data
                 LST MJD Az El AzOff ElOff focX focY focZ
     (int)       flag  : retrieve data flagged with flag
                 (default 0 : good data, 'None' for all)
     (log)     inverse : retrieve all data without given flag set instead (default no)
OUT: (float array)     : the requested data

returned data are in the stored unit except for offsets which are
converted to arcsec
```

def boa::BoaDataEntity::ScanParameter::phaseDiffParam (self)

```
NAM: phaseDiffParam (method)
DES: Compute the phase differences for data associated parameters.
     Times are average of ON and OFF, coordinates are ON positions.
```

def boa::BoaDataEntity::ScanParameter::plotAzEl (self, flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, aspect = 0)

```
DES: plot azimuth vs. elevation
INP: (int)  flag : flag to be plot (default 0 : valid data, -1 plot all)
```

def boa::BoaDataEntity::ScanParameter::plotAzElOffset (self, flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, aspect = 0)

```
DES: plot elevation offset versus azimuth offset
INP: (int) flag : flag to be plot (default 0 : valid data, -1 plot all)
```

def boa::BoaDataEntity::ScanParameter::plotAzimuth (self, flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, aspect = 0)

```
DES: plot time series of azimuth
INP: (int)   flag : flag to be plot (default 0 : valid data, -1 plot all)
```

def boa::BoaDataEntity::ScanParameter::plotAzimuthOffset (self, flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, aspect = 0)

```
DES: plot time series of elevation offset
INP: (int) flag : flag to be plot (default 0 : valid data, -1 plot all)
```

def boa::BoaDataEntity::ScanParameter::plotElevation (self, flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, aspect = 0)

```
DES: plot time series of elevation
INP: (int)  flag : flag to be plot (default 0 : valid data, -1 plot all)
```

def boa::BoaDataEntity::ScanParameter::plotElevationOffset (self, flag = 0, limitsX = [], limitsY = [], style = 'l', ci = 1, overplot = 0, aspect = 0)

```
DES: plot time series of azimuth offset
INP: (int) flag : flag to be plot (default 0 : valid data, -1 plot all)
```

def boa::BoaDataEntity::ScanParameter::plotSubscan (self)

```
DES: generate a plot showing starting and ending times of subscans
```

def boa::BoaDataEntity::ScanParameter::plotSubscanOffsets (self, overplot = 0)

```
DES: Use four colours to show subscans on the Az, El pattern
INP: (logical) overplot : if set, do not plot AzElOffset - assume
                  these have been plotted already
```

def boa::BoaDataEntity::ScanParameter::selectPhase (self, phase)

```
NAM: selectPhase (method)
DES: Keep only parameters (times, positions) associated with
     Data(ON) or Data(OFF)
INP: (int) phase: phase to keep, 1=ON, 2=OFF
```

E.18 boa::BoaDataEntity::Telescope Class Reference

E.18.1 Detailed Description

```
NAM: Telescope (class)
DES: Define all the useful parameters of a telescope
```

Public Member Functions

- def __init__
- def __str__
- def set

E.18.2 Member Function Documentation

def boa::BoaDataEntity::Telescope::__init__ (self)

```
DES: Instanciation of a Telescope object
```

def boa::BoaDataEntity::Telescope::__str__ (self)

```
DES: Defines a string which is shown when the print
     instruction is used.
```

def boa::BoaDataEntity::Telescope::set (self, name = "", diameter = 0.0, longitude = 0.0, latitude = 0.0, elevation = 0.0)

```
DES: set all the parameters
```

E.19 boa::Utilities::Timing Class Reference

E.19.1 Detailed Description

```
NAM: Timing (class)
DES: easily profile time computation in program
```

Public Member Functions

- def **__init__**
- def **__str__**
- def **getTime**
- def **resetTime**
- def **setIter**
- def **setTime**
- def **timeLeft**

Public Attributes

- **initTime**
- **lastTime**
- **nIter**

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