A short guide to observations with the MPIfR 37-channel bolometer at the IRAM 30m radio telescope

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Contents

1 General aspects

IRAM provides on the 30m telescope a novel 37-channel bolometer array operating at 1.2 mm wavelength. The bolometer and its auxiliary equipment was built, is owned, and is being operated by the MPIfR bolometer group.
This note describes in a brief form the essential steps in using the multi-beam bolometer for observations.

1.1 Documentation

All available documentation is collected in a folder located in a drawer of the observer's desk at the 30m telescope and near the remote observing terminal in the office in Granada.
IRAM documentation is also accessible electronically on our local computers. Use `netscape` on the HP's. You find the documentation, information on most recent changes, and more general visitor information, etc. on the `IRAM Spain Homepage`. Note that postscript documentations (e.g. this manual) can easily be printed out from within `netscape` i.e. from `ghostview`.
This document can be found at `http://granada.iram.es/Telescope/manuals/Observ/mbol.ps`

- For a more general description of the 30m user interface the observer is referred to the **OBS and OBSINP manuals** available at the observatory.
- A general overview on continuum observations is given in chapter 5 of the **30m manual**.
- Data reduction using the package NIC described in the **NIC Bolometer Users Guide**. NIC is developed in a joint effort by IRAM, the Observatoire de Grenoble, the MPIfR in Bonn, and the Service d'Astrophysique de Saclay.
- Data reduction using the package MOPSI is described in the **'Pocket Cookbook' for the mapping software** by R. Zylka.
- The principal layout of the MPIfR bolometers is described in a paper by E. Kreysa:
Kreysa, E. 1990, Proc. 29th Liege International Symposium, 3-5 July, ESA SP-314.
- A more detailed technical description can be found in:
"Bolometer array develepment at the MPIfR" **Kreysa, E. et al. 1998, SPIE, Vol. 3357, 319**.

1.2 Beam configuration

The 37 beams are arranged in the form of a hexagon around a central beam. Each beam is diffraction limited (ca. 11″ FWHP), separation between beams is ca. 22″. The telescope pointing is referred to the central beam. It is available in OBS as **channel 1** for on-line analysis of pointing, focus, and skydip observations.

1.3 Chart recorder

Not yet available with BOGLE.

2 Start up

- **Preparation:** Enter the IRAMEA computer on your account e.g. V_123_95.
  Ask the operator for the password. You will find a few useful files in your subdirectory, e.g. a model source catalog `MODEL.CAT`. When you start from scratch, i.e. at your very first login, a few additional essential files have to be copied to your subdirectory by executing the following commands:

  ```
  copy [mbol_save]get.com []
  @get
  copy [mbol_save]mbol.30m []    ! this is an empty 30m data file
  ```

  Now you have all basic observing files (*.PRO files for use as OBS macros) in your subdirectory. In addition, you will find `IBOL.CAT`, the observatory's catalog of 1mm pointing sources. A backup of all these files is kept in various subdirectories of `OBS$DISK:[MBOL_SAVE]`.

- **Observations:** Start the observing software by typing OBS. There are a lot of messages on the screen, don't worry about them. Next, enter the initials of the observer and operator when prompted. When loading is finished, OBS shows its prompt: OBS>

- inside OBS:

  ```
  OBS> @WSTART                      ! loads WSTART.OBS (see appendix)
  OBS> @WBOLO                       ! loads WBOLO.PRO (see appendix)
  OBS> SET WOBBLER throw period     ! default: 32", 0.5 sec
  OBS> CATA SOUR mycata.cat         ! loads your source catalog
  OBS> SET BOLGAIN g                ! gain g= 1...9 (see below)
  ```

- OBS is thus set up to record bolometer data. We recommend to save this command configuration in a personal memory file:

  ```
  OBS> save last
  ```

  In future starts of OBS (e.g. when starting you next observing session) it will then suffice to load the memory file:

  ```
  OBS> @WSTART
  OBS> @last
  ```

  You should have the same configuration as before.

3 Calibration

The on-line display, the RED program, always shows the data of the central channel, designated No. 1, of the array. Pointing corrections, as well as focus offsets and atmospheric opacities (see below) are calculated from center channel data. Offline data reduction of calibration scans (pointing, focus, skydip) can be done with the NIC software package running on both HP/Unix workstations.

3.1 Pointing

```
OBS> SOUR name [/cata IBOL]     ! enter source name from user catalog
                                ! (or from the observatory's catalog)
OBS> SET BOLGAIN g              ! gain g= 1...9 (see below)

OBS> POINTING/NOCAL/LENGTH L    ! L is scan length, 40" recommended.
     or simply e.g.
OBS> P40                        ! "P40" is defined within WBOLO.PRO

OBS> CORR F F                   ! as usual if the gaussfit is okay
```

Remark: The NOCAL option for POINTING is essential, since the RED process may crash when trying to calibrate bolometer data. `WBOLO.PRO` defines abbreviated pointing commands (P40, P60, P110, P150) by e.g.

```
SYMBOL P40 "pointing/nocal/len 40"
```

Note that symbol definitions are not retained in the OBS memory file, so they have to be redefined after each start of OBS, which is done by `@WBOLO`.
Gain: The MPIfR amplifier uses 9 gain steps (g=1...9) each providing amplification by decreasing powers of 2 i.e. $[2^{(g-1)}]$. Lowest gain (rather attenuation), g=9, is used for the strongest signals (skydip, Jupiter), g=6 for Mars, g=1 or 2 for the weakest signals (good resolution of the noise). The gainfactor is displayed on the operators color display or by the command `OBS> SHOW BOLGAIN` on the observers terminal.

3.2 Focus

```
OBS> FOCUS          ! this is a symbol defined as "focus/length 0.8"
OBS> CORR * * F     ! as usual if fit okay
```

Remark: Focus values for the 37-channel bolometer were found between -0.6 and -2.1 mm. The focus may change rapidly and should be checked frequently.

3.3 Skydip

```
OBS> BOLOTIP [Az]
```

Remark: If the azimuth is not specified the skydip is done at the current azimuth. The gain is set to 9 during the skydip and then reset to its previous value. The source name is cleared and needs to be specified before starting a new observation. CAUTION: For Az $>$ 420 degrees, the telescope will slew to Az$-$360 degrees. A turn of 360 degrees currently takes 12 minutes!

```
OBS> SOURCE name (/cata IBOL)
```

Continue with pointing or onoff, DO NOT FORGET to reenter a source name. CHECK the gain.

4 On-Off Observations

In this observing mode, if used with the parameters described below (i.e. symmetrical wobbling), the telescope executes repeated On-Off cycles in a sequence: $+--+$.
The recommended OBS procedure is:

```
OBS> SOUR name                      ! enter new source name?
OBS> SET BOLGAIN g                  ! reset gain?
OBS> SET SUBS n                     ! change number of subscans?
OBS> ONOFF /NODISP /TIME 10 /SYM    ! see on-line HELP
OBS> START

or shorter:
OBS> SOUR name              ! enter new source name?
OBS> SET BOLGAIN g          ! reset gain?
OBS> @ONF n                 ! symmetric on-off with n subscans of 10 sec each.
```

Remark: you can use the NODISplay option of the ONOFF command to disable display of the individual On-Off cycles. You will still get a display of the average On-Off and its error at the end of each scan. The flux indicated is half the On-Off signal and thus equivalent to the flux obtained on a cross scan.
Note: It is possible to do On-Offs at a position offset from the source position commanded by entering:

```
OBS> SET OFFSET BASIS            ! selects RA,Dec (see manuals)
OBS> OFFSET delta_RA delta_Dec
```

5 On-the-fly maps

The procedure `WMAP.PRO, WMAP6.PRO` creates a map by scanning the source with constant velocity along lines of constant azimuth (the direction of wobbling). The center of the map is given by the source coordinates in the catalog.

```
Within OBS use either
OBS> @WMAP  Az  El  ! Az and El are the map sizes ["] in azimuth and elevation
                    ! where the scanning speed is VAZM = 4 "/sec.
or

OBS> @WMAP6  Az  El ! Az and El are the map sizes ["] in azimuth and elevation
                    ! where the scanning speed is VAZM = 6 "/sec

and then start the observation
OBS> START
```

The spacing of the azimuth tracks in elevation is $4''$. The azimuth scans need to be at least one array diameter $122''$(for the 37-channel bolometer) plus one wobbler throw longer than the source size in order to permit the entire array to move off source so that scan baselines can be reliably measured.

There are two more procedures prepared for special cases:

```
OBS> @WMAP_SKEW  Az  El  Skew  !Az and El as before and Skew in ["].
```

Each successive subscan of the map is displaced by 'Skew' seconds of arc in azimuth. In horizontal coordinates the shape of the map is a parallelogram, the azimuth offsets are adjusted such that the central subscan is symmetrical to the center of the map.

```
OBS> @WMAP_NEO  Az  El   !Az and El as before in ["].
```

This map starts at positive elevation offset from the map center and the elevation is decreased with each subscan (just the reverse of the default setting)

6 Data Reduction

Off–line data reduction on the HP/Unix workstations:
• **NIC software package:** Reduction of pointing, focus, skydip, on–off and on–the–fly maps.
• **MOPSI program:** Reduction of cros–scans, skydip, on–off (experimental) and on–the–fly maps.

Some off–line data reduction on one of the VAX/VMS computers is offered, but not developed further:
• Reduce **pointing** data of the **center channel** with CLASS (e.g. `PBOL.CLASS`).
• Reduce On-Offs with the program `ONOFF7` (all 37 channels). To start it just type '`ONOFF7`'.
Use the program `ONOFF7_CAL` to calibrate (in Jy) the data reduced by `ONOFF7`.
• Take a look at the changing opacities during a bolometer run by using the program `TAUS`.

6.1 Where are my data?

- **HP/Unix workstations** *NEW* The raw data created by the telescope control computer IRAMEA are copied subscan by subscan to the HP workstations. You should find them e.g. on `/mrt_data/123_98/r19990127/` for project `v_123_95`. As the raw data is copied, it is also converted to NMB format and copied to `/mrt_data/123_98/nmb/`.

  If you use NIC on one of the HP/Unix workstations, you will find the NMB files on `$HOME/nmb` if this is a link to `/mrt_data/123_98/nmb/`

  Please check that all raw data has been copied/created on your data directories. In case you miss some of the data please contact the astronomer or the operator on duty. At the end of the observing run you may backup your data on DAT using e.g. the tar backup utility on the HP. Alternatively you can make a backup on CD–ROM.

- The bolometer VAX **raw data** are recorded by the antenna computer `IRAMEA` on the directory `MRT$NEW_DATA`. While the recent data are being saved onto tape you have to use `MRT$OLD_DATA`. (Or use the logical device names i.e. `DATA:[RAWDATB]` and `DATA:[RAWDATA]`. Ask the operator in case you do not find your data on these devices.) We recommend you to save your raw data after the observations.

- All calibration observations (pointing, focus, and skydip) are recorded in the archive files `POINTING.DAT, FOCUSING.DAT, BOLOTIP.DAT` (in ASCII format) on the directory `OBS$ARCHIVES:` (the physical device name is `IRAMEA$DUA0:[REDU.ARCHIVES]`).

6.2 Pointing, Focus and Skydips

These are OBS procedures which trigger an on-line display. You can get screen copies by typing on the OBS terminal HARDCOPY/PLOT. All these calibration scans can be reduced within the NIC package.

6.3 On-Off Observations

If the `ONOFF` command of OBS is used an on-line display is provided. The result of each scan (i.e. the average On-Off, its rms and some book keeping information are written on a file `ONOFF.DAT` in your subdirectory (channel 1 only).
Off-line reduction is unavoidable if ONOFF data from all 37 channels need to be analysed.

- We recommend using the NIC task ONOFF described in the NIC Users Documentation.
- You may also use the programs `ONOFF7` and `ONOFF7_CAL`. Note that these programs are supported only as backup on the VMS computers and are not further developed. Ask A. Sievers for the latest information.
- Toolbox **Note that this package might well be outdated!**
  It offers, in principle, a comprehensive set of continuum reduction routines, including ONOFFs. It works off-line and needs the data to be converted into a specific format. The conversion is done in the following way (enter DCL on a second terminal):

```
$ assign mrt$new_data:   tbx$raw      (or other data directory)
$ @tbx$convert:convert scan_no        (4-digit scan number)
                                      (‘%%%%’ for all scans)
```

  The converted data are found in files TOOLBOXIn (n=0...3). They serve as input to the TOOLBOX programs. To start the TOOLBOX type

```
$ @toolbox
cont2          ,now @tbx$program:cont2vpico
```

  This gets you into the continuum reduction program. Consult a TOOLBOX manual to proceed from here. Note, however, that the 30m version of Toolbox has not yet been tested with 7-channel data.

6.4 On-the-fly Maps

- Use NIC and its dedicated tasks described in the NIC Users Documentation.
- Alternative use the MOPSI program by R. Zylka which can read now the raw telescope data directly, i.e. **no** TOTD or MARMAP is needed on the VAX to “transform” the raw telescope data into ATD (Ascii Telescope Data).