"Pocket Cookbook" for the MOPSI Software

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To Glyn Haslam,

the father of NOD 2

Contents

1 Introduction

The data reduction software briefly described below has been written originally for my private purposes to reduce spectroscopy and continuum maps. It consists of two main programs: the telescope dependent data conversion program **TOTD**, which reads the telescope "raw" data and produces the telescope independent data files in **TD** format (Telescope-Data format) for further reduction, and the data reduction program **MOPSI** (MapOn-offPointingSkydipImage), which is (almost) telescope independent. The program **MOPSI** can be used to reduce images, raster maps, ON-OFFs, pointing scans and SKYDIPS, however in this "Pocket Cookbook" I present only a very abbreviated description for preparing of observations (section 2), determinig the array-parameters (section 3) and for reduction of SKYDIPS and of "double-beam" maps (section 5).
In the following I assume that the reader is already familiar with the problematic of the "double-beam" observing, therefore will present only a small collection of the basic and more sophisticated procedures to reduce "double-beam" and raster maps.
For more detailed information please ask the IRAM, SMTO or CSO staff, or contact me directly:

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The software is available for non-facility usage under request from the Max-Planck-Institut für Radioastronomie in Bonn.

In all publications resulting from data processed with this software package I request the following acknowledgement:
"The data have been reduced with the mapping software package developed by Robert Zylka. This software uses the "restoring" algorithm of Emerson, Klein and Haslam (1979), the "converting" algorithm of Chris Salter (1983), and partly the NOD2 and the GILDAS libraries."

2 Preparing observations

If the source is known to be structured or at least elongated in one direction, it is desirable to check the orientation of the maps to be observed in the equatorial system. The maps are normally observed in the horizontal system, with the scanning direction in azimuth. The "golden rule" of "double-beam" mapping is that the scanning direction should be perpendicular to the elongation of the source. The orientation of the maps observed in the horizontal system can be checked using **MOPSI** (command: [**show**] **ae_maps**) for the following telescopes: Effelsberg 100-m, IRAM 30-m, SEST, HHT, JCMT and CSO. The easiest way to do this is to first create a plot of the source in equatorial coordinates and then overlay the horizontal map to be observed (see Fig. 1). If you do not have a map of the source to be observed, you will have to specify the equatorial region in which the horizontal maps will be shown:

```
greg\lim ra_east_off ra_west_off dec_south_off dec_north_off     (in arc sec)
greg\set box match
```

as well as additional information about the telescope and the mapping parameters. **SHOWAEM** will inform you, which parameters are still not defined (see also the list of commands within this subprogram). Note that **SHOWAEM** assumes the scanning velocity of $4''$/sec (standard at IRAM 30-m) and the pixel size of the last map read in as defaults.

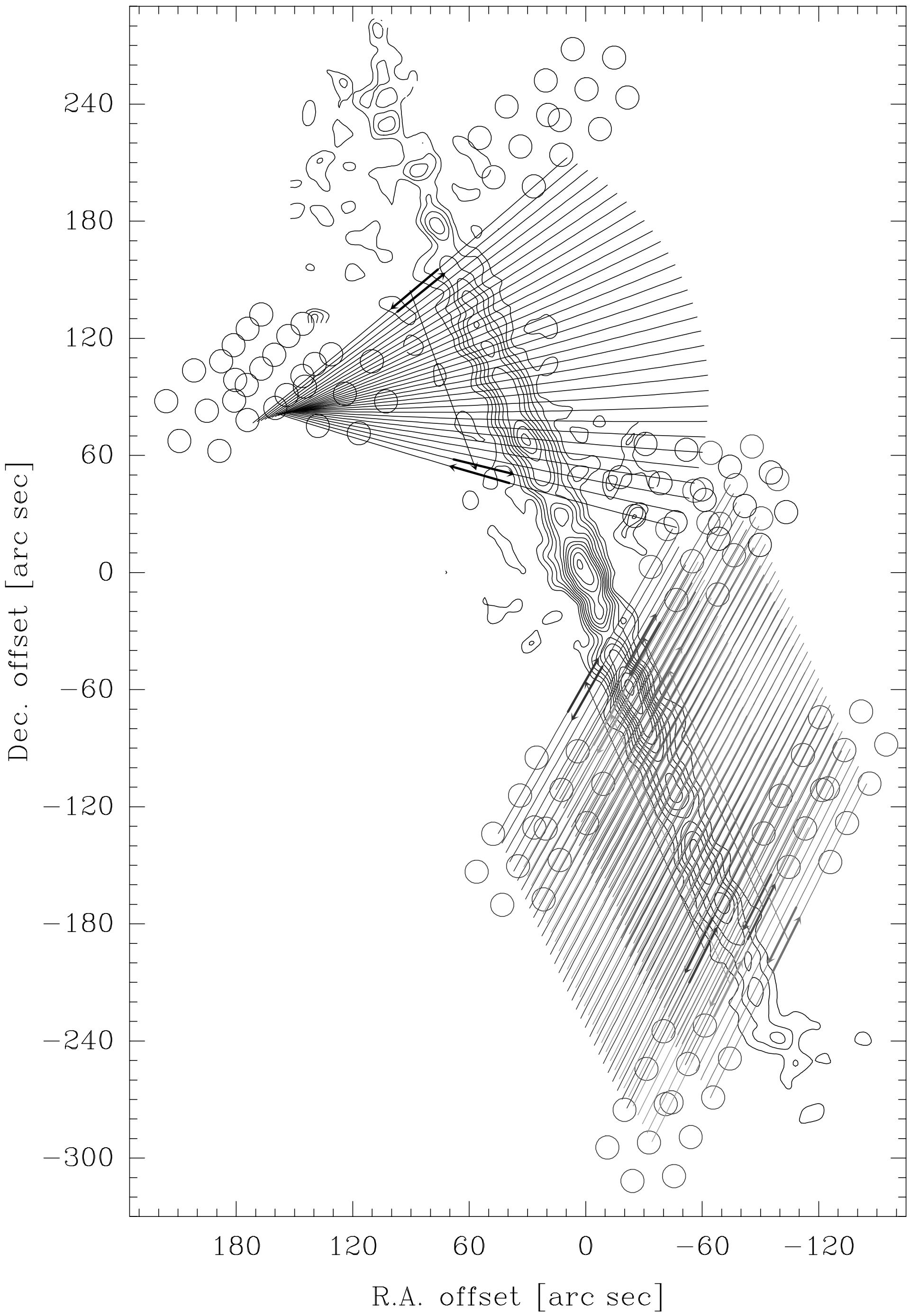

Figure 1: Orientation of two maps of NGC 891 to be observed in the horizontal system during the transit of NGC 891 (northern map) and after the transit (southern map). The southern map is optimally placed using the "skewing" capabilities of the telescope steering programs used at the Effelsberg 100-m RT, the IRAM 30-m MRT, and the SMTO 10-m HHT.

3 Creating the TD-files

The program **TOTD** converts the telescope "raw" data into **TD** format (Telescope-Data format). It can be used for different receivers (single channel and arrays) and choppers. It can also produce gridded "double-beam" maps in **NOD2** format (ASCII or BINARY) which may be reduced either with **MOPSI** or any other software able to read data in this format. For data obtained at the IRAM 30-m and HHT telescopes I strongly suggest **not** to use the gridded "double-beam" maps for data reduction.
To convert the the telescope "raw" data into **TD** format, you have just to specify the scan number:

```
scan #[/dir DIR_NAME]
[file FILE_NAME]
run
.
further scans (e.g. single channel or array maps)
.
exit
```

NOTES:

i) You **MUST** specify the ZIG-ZAG correction in arc seconds for IRAM 30-m data prior to 1994 and for HHT data (command: **zig-zag CORRECTION**). Because the "raw" data lacks some specific information, the **TOTD** program cannot calculate it. For data taken at IRAM 30-m the correction is:
CORRECTION = −0.5∗CHOPPER_PERIOD∗SCANNING_VEL∗HARD_INTEGR,
which for the standard values of 2 Hz, $4''$/sec and 1 correpondingly gives CORRECTION = $-1''$. At HHT the above formula gives only the approximate value for CORRECTION. It depends further on the blanking value used with the chopping secondary. The correct value of CORRECTION has to be determined experimentally using the gridding in one dimention (command: **grid 1**) and writing out the maps in **NOD2** format (command: **write nod [FILE_NAME]**). By displaying a map of a strong source in the **NOD2** format, you will easily be able to determine the optimum value for CORRECTION, which corresponds to smooth (i.e. not "zig-zag") contour lines.

ii) You **SHOULD** specify the beam separation in arc sec for IRAM 30-m data prior to 1994 (command: **beam_separation VALUE**). This will simplify the following data reduction.

iii) The command: **file FILE_NAME** is optional. If not specified, **TOTD** opens an **ASCII TD** file (extension .atd) with the name equal to the scan number.

v) The 19-channel maps can not be further reduced with **MOPSI** on the VAX VMS computers because of lacking memory. For the data reduction the ASCII **TD**-data can be put via ftp to any UNIX computer with larger memory.

4 Determinig the receiver array parameters

Use maps of strong compact sources (e.g. planets) to determine the array parameters, i.e. the relative bolometer gains (the "flat fielding" of the array) and they relative positions. The necessary commands are listed below:

file in #.atd
read/no-channel_arameters
device image black
base-range 1 last
base-surface 0
initialize gfits
ch-parameters/gfits

You can write out the parameters to a file with wr ch-p filename or just store them in the memory with store ch-p. To get back the parameters:

ch-parameters filename or ch-parameters stored
apply ch-parameters

5 Data reduction

5.1 Reduction of SKYDIPS

Read in the SKYDIP data (e.g. atd #), select the central channel (take chan #) and reduce it with the command skydip[/commands]. If the option /commands is present **MOPSI** reduces the SKYDIP and will stay in the SKYDIP-subprogram. You will get a graphic fit only if you have opened the plotting device (command device ...). The most convenient way to use the SKYDIP-data is within a loop, having defined a list of observations:

```
initialize in-list
initialize out-list
select type skydip map
select SKY* ... (all sources you want)
sort list
for i 1 to last
    read next skydip
    take chan # (1 for IRAM 30-m data beginnig with 1994)
    skydip
next
for i 1 to last
    read next map
    tau skydip TIME_INTERVAL (in seconds)
    correct extinction
    ....
    reduction of maps
    ....
next
```

5.2 Internal MOPSI procedures for reduction of maps

The quickest and easiest method (although usually not giving the optimal results) to reduce the "double-beam" maps is to use the internal **MOPSI procedures**. The **procedures** are to start with the command: **procedure NAME**. Two procedures with different options are currently available: **basic**[**/mask SYSTEM_NAME**] (see also section 4.3.2 and 4.3.3) and **spikes** (see section 4.3.1). If **NOD2** maps are to be reduced, which were not created with **TOTD**, some restrictions may apply. In this case the values of the **variables** must be usually specified with the call to the procedure. Example:

proc*edure* basic/nchans NUMBER/restor_pars BEAM_SEPARATION THETA UNBALANCE

The command calling the **procedure** will not be written to the log-file but the content of the **procedure**, i.e. the sequence of commands defining the **procedure** instead. This log-file can be edited and used for more sophisticated data reduction. Command-files can be processed with "@":

@command_filename

The default extension for command-files within **MOPSI** is "MOPSI" (capital letters in UNIX).

5.3 Basic data reduction

You can use the **MOPSI** internal **procedure basic** to perform the basic data reduction of "double-beam" maps (command: **procedure basic**). It works only with **TD** or **NOD2** files. Prior to calling this procedure you have to read in the data either in the general way using the commands **fil***i* **NAME** + **rea***d* or shorter by giving the default extention of these files, e.g **btd NAME**.
NOTE:
The general way to read in the data in other formats is the following:
fil*e* **i***n* **FILE_NAME** [**FILE_KIND**]
rea*d*
The **procedure basic** is different for **TD** and **NOD2** files. Below I list the content of this procedure for **TD** files: (the extensions to the abbreviations are written in *italic*).

base_r*ange* 1 10 las*t*-9 las*t*
base_s*urface* 1
res*tore* !
conv*ert*

NOTES:

i) To correct the effects of the atmospheric extinction you should define the optical depth of the atmosphere (commands **tau1 VALUE1/st HOUR1 MINUTE1** & **tau2 VALUE2/st HOUR2 MINUTE2** or just **tau/st ...** if only one value availaible and apply them with the command **corr***ect* **ext***inction*.

ii) The exclamation mark after the **res***tore* command forces the software to continue, even if some blanked data are found within the map (these should appear only at the map edges).

iii) The command **convert** calls the **HORTOEQ** routine if horizontal maps are to be processed.

iv) To correctly take into account the different receivers of an reveiver array and different weather conditions, the maps should be weighted within **AVERAGE** or **HORTOEQ** with the noise calculated in emission-free regions and stored before masking (see 4.3.2) with the commands
store wei*ghting* **rms ...**, ie. weighted with 1/rms
store wei*ghting* **rms2 ...** ie. weighted with 1/rms**2).
Following **store wei***ghting* commands are available (see also the similar **base_r***ange*, **mask**, **neglect** and **noise** commands) :
using azimuth distance in arc seconds from the map centre (or defined projection) -

store weighting rms az_offset < VALUE1 > VALUE2/pa ANGLE/projection H M S D AM AS
using ellipses defined in system NAME centered on the map centre (or defined projection) -
store weighting rms VALUE1 [VALUE2 [PA]]/syst NAME/proj*ection* **H M S D AM AS**
or using polygons defined in system NAME centered on the map centre (or projection) -
store weighting rms in|out/syst NAME/proj*ection* **H M S D AM AS**.
The option /system NAME must be present for data of array-receivers. Only in this case **MOPSI** takes into account the "off-beam" off-sets.
The default weighting is a function of the atmospheric extinction (command: **wei***ghting* **tau**), and therefore all receivers of the array-receiver have the same weight.

To display the reduced map, define the plotting device (if not done previously) and enter the command **plo***t* to get a color display. If you wish a contour plot too, you have to specify the levels also (command: **lev***els*).

5.4 More sophisticated data reduction

To optimally reduce the data, you should begin with cleaning the signals. However note the following:

i) "de-spiking" is important.

ii) The sky-noise algorithm implemented within **MOPSI** is still in the developmental stage and is not well tested; it can reach usually the receiver noise if the optimal array-parameters were defined and the effect of anomalous refraction is negligible (see Fig. 2).
However currently it should not be used for very weak sources (< 50 mJy) and for mosaics.

iii) A great improvement can also be obtained by applying the MASKING and the special "mask-and-shift" RESTORING.

iv) The pointing offsets due to pointing errors and/or anomalous refraction should be corrected within **HORTOEQ** (commands: **shi***ft* **az***imuth* **VALUE** and **shi***ft* **el***evation* **VALUE**).

5.4.1 Removing spikes and sky-noise

The "de-spiking" and "de-skynoising" algorithms allow different modes. The current defaults however are my best suggestions. These defaults may change according to the development of the software.
To illustrate the basic concept of the "de-spiking" procedure and the "de-skynoising" of the data within **MOPSI**, I first list the commands and explain them further below (some of the commands are not strictly necessary):

using **procedures**:	single **commands**:
td ?	td ?
proc*edure* spik*es* mask LOW_LIMIT UP_LIMIT CHECK_LEVEL	base_r*ange* 1 20 last-20 last
	base_s*urface* 1
	initiatize spike_pointer
	[mask] lower LOW_LIMIT
	[mask] higher UP_LIMIT
	base_s*urface* 1
	mask spikes CHECK_LEVEL
base_r*ange* ?	base_r*ange* ?

base_? ?
sky_noise/iter N/mode M
db_*filter* [beam_separation] !
base_r*ange* ?
base_? ?

base_? ?
sky_noise/iter N/mode M
db_filter [beam_separation] !
base_r*ange* ?
base_? ?

Explanations:

Read the data:

td ?

Set the base range and order to remove base-level offsets.

base_r*ange* ?

base_? ?

To see where the data end at the map edges, don't put the signals into the GreG plotting buffers (command **put**, "commented out" below with "!"). If the command **put** is not issued, plotting the signals (e.g. as histograms within **STRIP**) vertical lines going to the plot bottom will then be drawn at the end of the signals.

!put

You may check the action of the de-spiking routines by displaying the signals (e.g. in **STRIP** row by row). After "de-spiking", by changing the color of the pen and overplotting the original signals, you will easily see the difference. To compare the behaviour of the different receivers, choose the columns to be displayed.

The command **pause** gives you the possibility to enter auxilary commands. To continue with a command-file, enter **continue** or just **c**.

IMPORTANT: you MUST continue with the command-file within the same (sub)program in which the **pause** command have been entered (here **MOPSI**) and not within any other (sub)program (**AVERAGE**, **COMBINE**, **PLANETS**, **STRIP**, ...). Nesting of command-files is currently not possible.

!pause

Initialize a pointer array used internally before any masking. This array is affected by different masking commands:

ini*tialize* spike_pointer

The next step is IMPORTANT: mask the largest spikes (at least those larger than any signal) before using the "de-spiking" routines. The word **mask** is optional here.

[mask] low*er* LOW-LIMIT

[mask] hig*er* UP-LIMIT

Repeat the base corrections:

base_? ?

Mask the smaller spikes. This should in general improve the skynoise correlation. A CHECK_LEVEL of 3−5∗r.m.s. is usually a good choice. Different modes are possible. The current defaults are **mode=5** and **dimension=2**.

mas*k* spik*es* CHECK_LEVEL

Correct the base in the "de-spiked" data:

base_r*ange* ?

base_? ?

Remove the skynoise. Different modes are possible. The current default is a combination of **mode=9** with 3 iterations and **mode=7** with 5 iterations. For **mode=7** the numner of iterations should not be larger than 10. There is no restriction for number of iterations in **mode=9**, but after 3 iterations the data will not change anymore.

sky_*noise*

Correct the base in the "de-skynoised" data:

base_*range* ?
base_? ?

Perform the "double-beam" filtering. If you defined the beam separation in the **TOTD** program or reduce MRT data from 1994 on or HHT or CSO data from 1995 on, the BEAM_SEPARATION below is not necessary.

db_*filter* [BEAM_SEPARATION] !

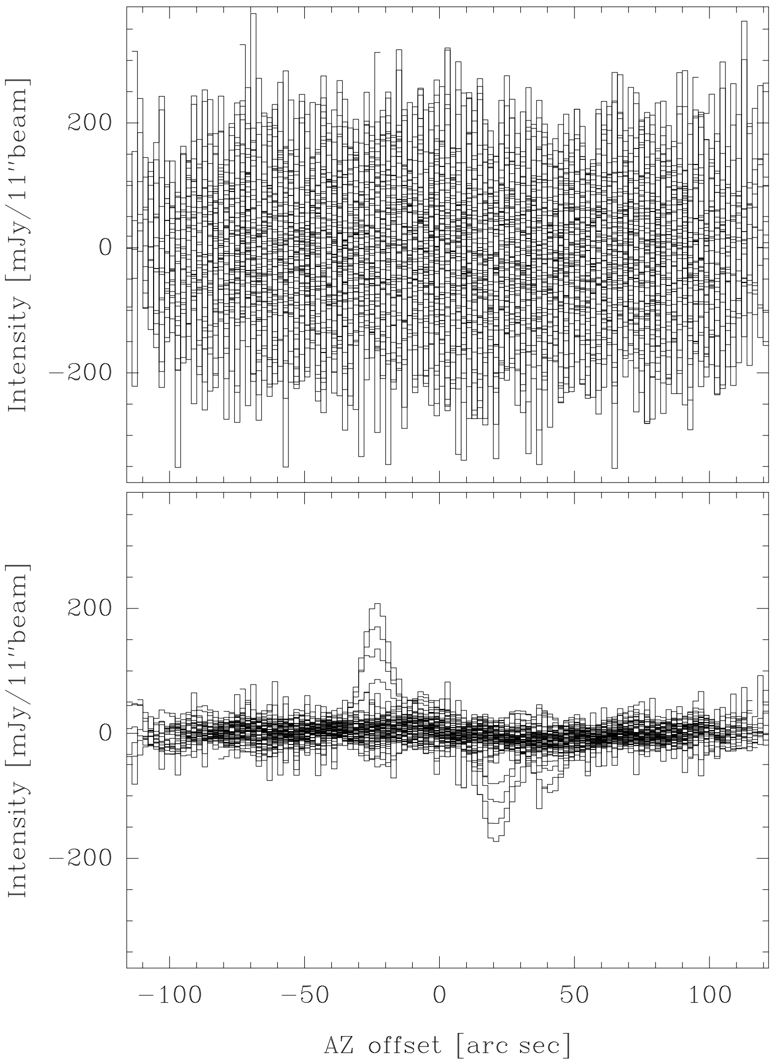

Figure 2: Improvement of the 19-channel data (only 18 channels used) after "de-skynoising" with default parameter settings.

5.4.2 Masking not relevant regions

Because only rectangular or "skewed" areas of the sky can be mapped (see Fig. 1), there will almost always be some regions in the maps where no emission from the source is present. These regions thus only contribute to (i.e. increase) the noise in the final map. A considerable improvement of the final map can be obtained by removing, e.g. masking of these regions BEFORE RESTORING (see Fig. 3). A really severe problem occurs if there is a source at the edge of the map that appears only in one of the "double-beams". This region CANNOT be restored, and therefore MUST be masked

in order to not destroy the rest of the map. The most general way to define the regions to be masked is by using a masking polygon (command: **polygon**; the same action as in GreG or GRAPHIC). For the receiver-array data, the polygon must be defined in the offset coordinates of the central channel (for MRT data: 1993 - channel #3, beginning with 1994 - channel #1). The masking is performed via the command: **mask in/sys***tem* **NAME/proj***ection* **H M S D AM AS** or **mask out/sys***tem* **NAME/proj***ection* **H M S D AM AS**. The option **/system** must be defined for this purpose. It describes in which coordinate system (HORIZONTAL or EQUATORIAL) the masking polygon is defined. Only in this case does **MOPSI** take into account the offsets of the off-beams. The projection centre (option **/projection**) is ALWAYS in equatorial coordinates.
You may use the procedure **basic** with the option **/mask NAME** (of the system) to perform the data reduction of masked maps. Note that in this case the base range is set using the polygon (command: **base_r***ange* **out/sys***tem* **NAME**) and that the restoring of the maps is split into two parts: first the "double-beam" filtering and then restoring without filtering after subsequent masking. See the listing of the **procedure bas***ic***/mask ho***rizontal* below (note that the commands **fil***e* **i***n*, **read** and **pol***ygon* are not the content of the procedure).

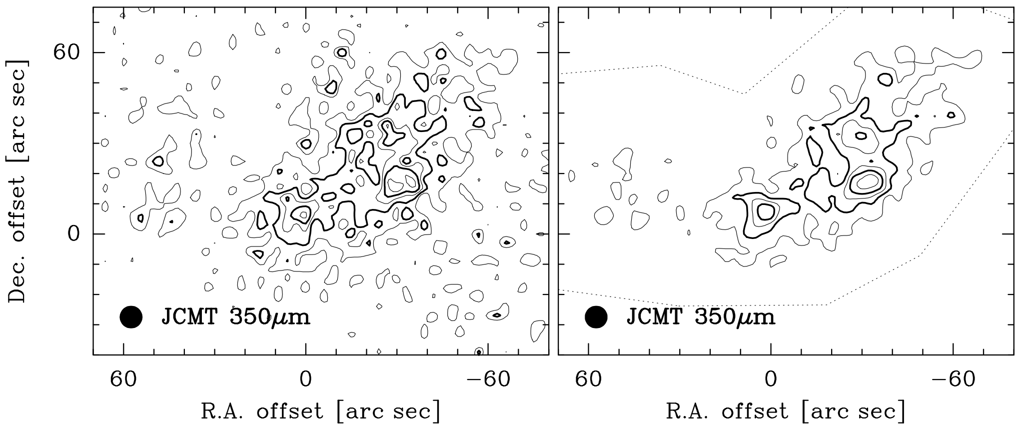

Figure 3: The improvement of the map obtained by masking regions contributing only to the noise. The masking polygon (dotted line) is shown in the right panel. The same contour levels are used in both maps.

```
td ?
polygon ?

base_range out/system horizontal
base_ssurface 1
mask out/system horizontal
db_filter !
mask out/system horizontal
restore/nofilter !
mask out/system horizontal
convert
```

5.4.3 Special cases

For some special cases ("elliptical" or "linear" sources) **MOPSI** calculates the masking polygon using just a few parameters defined with special masking commands.

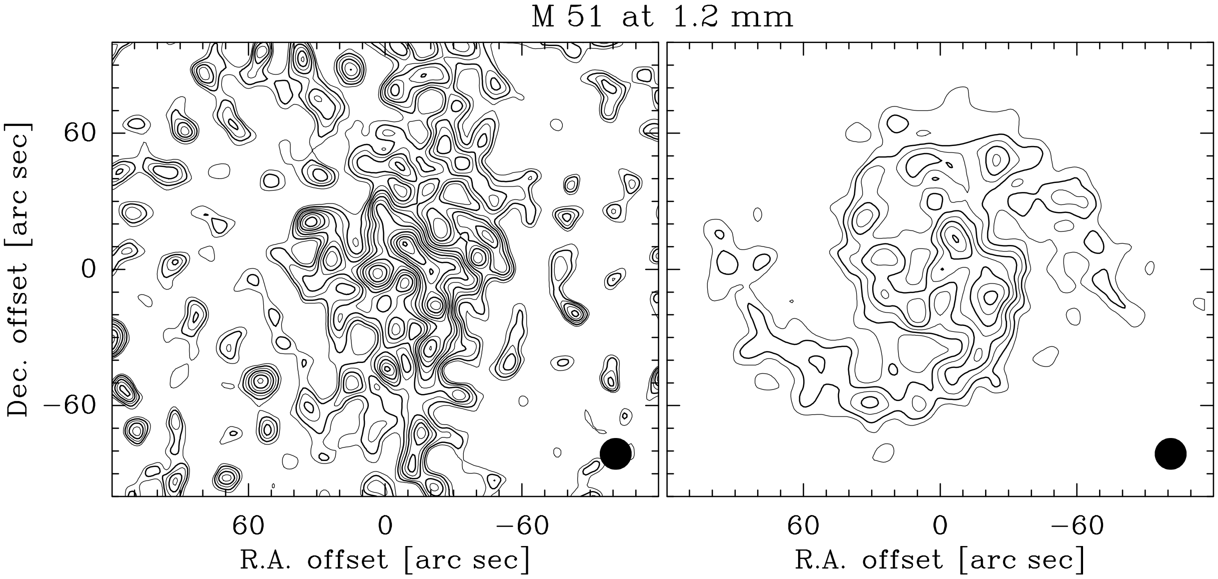

Figure 4: Left: map reduced in the basic mode; right: map after applying of the automatic "de-spiking", "de-skynoising", and masking the regions outside a radius of 120″ from the centre obtained with the current **MOPSI** version. Note the improvement compared to the published map (A&A, 298, L29). The same contour levels are used in both maps starting at 8.5 and in steps of 3 mJy/14″ beam. The final r.m.s. noise level is ~1.5 mJy/14″ beam.

1) for "elliptical" sources (see Fig. 4), regions outside or inside a specified radius in the EQUATORIAL system can be masked with:
mask in|out VALUE1 [VALUE2][PA]/sys*em* eq*uatorial*[/proj*ection* H M S D AM AS]
In this case **MOPSI** transforms the HORIZONTAL coordinates of a pixel into the EQUATORIAL system and checks the distance from the defined projection centre (default is the projection centre of the map). The option /system must be present for data obtained with receiver-arrays.

2) for "linear" sources (see Fig. 5), regions outside a specified distance along the scanning direction (azimuth) from a line defined via the position angle and the projection centre in the EQUATORIAL system can be masked with:
mask az_*offset* < VALUE1 [> VALUE2][/pa ANGLE][/proj*ection* H M S D AM AS]
In this case **MOPSI** checks if the distance of a pixel along the scanning direction from the line defined in the EQUATORIAL system satisfies the defined conditions. The default projection centre is that of the map.

5.4.4 Special "mask-and-shift" restoring

If the mapped sources are less extended in the scanning direction than the chopper throw (BEAM_SEPARATION), the maps can be restored and converted at once within **HORTOEQ** using the "mask-and-shift" method. This will in general give lower noise than the standard restore (see Fig. 6). The sequence of commands to restore a map with a source located at AZ_OFF [arc seconds] is listed below:

```
mask azimuth > AZ_OFF[/pa ANGLE][/projection H M S D AM AS]
shift azimuth 0.5*BEAM_SEPARATION
run
```

```
map 1 !
read
mask azimuth < AZ_OFF[/pa ANGLE][/projection H M S D AM AS]
shift azimuth -0.5*BEAM_SEPARATION
multiply -1.0
run
```

At the time of writing this document the value 0.5∗BEAM_SEPARATION must be specified by number (no variable calculations are possible).

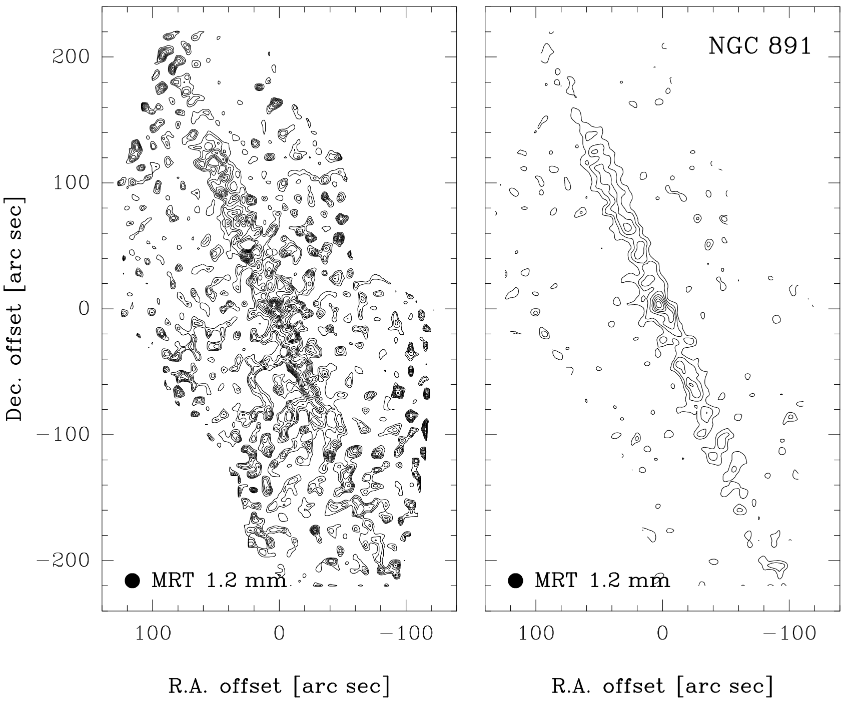

Figure 5: Left: map reduced in the basic mode; right: map after applying of the automatic "de-spiking", "de-skynoising", and masking the regions outside a specified distance from the major axis of NGC 891 in the scanning direction. The same contour levels are used in both maps starting at 10 and in steps of 8 mJy/12″ beam. The final r.m.s noise level is ∼4.0 mJy/12″ beam.

5.4.5 Filtering the data

To improve the signal to noise ratio in the final maps the data can be filtered at different stages of the reduction. The skynoise can be filtered out (see section 4.3.1). The next stage is the "double-beam"-filtering (see sections 4.3.1 and 4.3.2). The final filtering can be performed during the conversion of the horizontal maps into the equatorial system within **HORTOEQ** (command **g_filter LEVEL**). The skynoise-filtering can actually reach already the receiver noise if the array-parameters are optimally defined. The "double-beam"-filtering can give a further improvement of ∼ 15% - 30%. For mosaic maps and for maps obtained with the array-receivers, the filtering within **HORTOEQ** can reduce the noise by ∼ 25%. I obtained the best results for the 19-channel array (only 18 channels used) for LEVEL=0.05 - 0.15. Because the value of this parameter depends on the data itself and should be used together with a different convolution function, the user may experiment to get the best results.

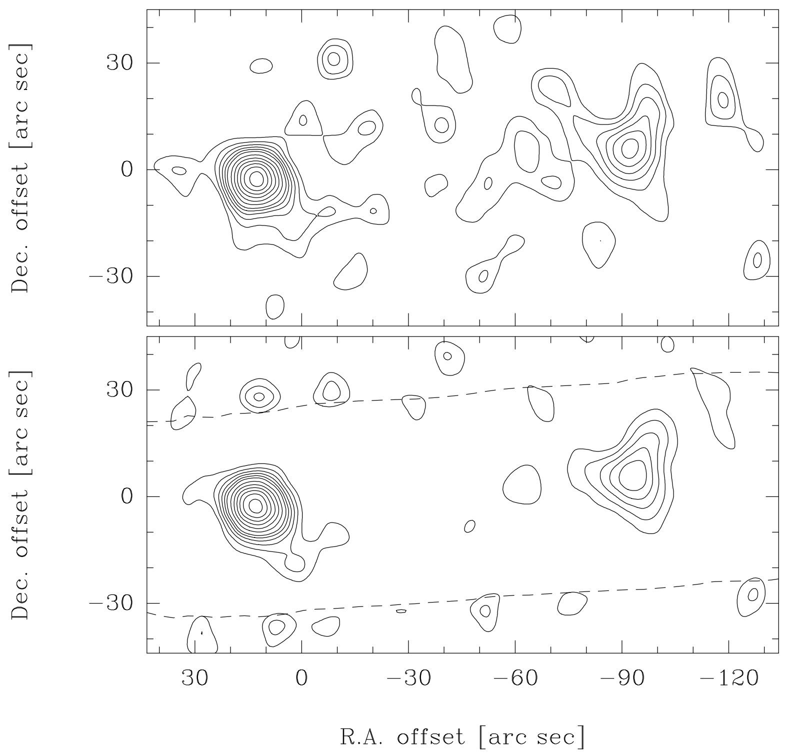

Figure 6: Up: map reduced in the basic mode; down: map restored with the "mask-and-shift" method. The same contour levels are used in both maps starting at 17.5 in steps of 10.5 up to 70 and from 88 in steps of 17.5 mJy/11″ beam. The final r.m.s noise level obtained in one coverage of the 19-channel bolometer array (only 18 beams used) is ∼5 mJy/11″ beam. WARNING: the noise must be calculated either in the regions of the highest weights (shown as dashed lines), or outside and divided by $\sqrt{2}$.

5.5 Transformation into equatorial system and averaging of maps

The maps in horizontal (restored or "double-beam") can be transformed into equatorial system within the subprogram **HORTOEQ** called with the command **conv***ert*. **HORTOEQ** can also average maps of the same field and create a mosaic. See the internal help for available commands. The easiest way to average maps/create a mosaic is while having a list of observations:

```
repl*ace* in-list out-list
read 1
conv*ert*/comm*ands*
    [ext*ent* RA-extent DEC-extent (in arc sec)]
    [proj*ection* HOUR MIN SEC DEG ARCMIN ARCSEC]
    convert all
    quit
```

Horizontal maps can be also averaged without co-ordinate transformation within **AVERAGE**, maps in equatorial and galactic system within **COMBINE**.

5.6 Calibration

5.6.1 SKYDIPS

You can fit the optical depth of the atmopsphere either as described in section 5.1 or alternatively with the program **SKYDIP** which reads directly the "raw" data (currently running only under VAX VMS). Upon executing **SKYDIP** the user is asked to answer a few questions, after which the program enters the command-mode. At this stage any parameter can be changed. See the short help page within **SKYDIP** for the list of commands.
WARNING: If the optical depths are very high (> 1.0), SKYDIP will not give correct fits, because the model used by this program is to simple to describe the optically thick atmosphere.

5.6.2 Calibrators

The standard calibrators are the planets. You can use the **MOPSI** subprogram **PLANETS** to calculate their fluxes, source angles and positions. **PLANETS** can also perform a convolution of a given planet with a Gaussian beam and create a resulting map. Upon executing the **PLANETS** subprogram the user is asked to answer a few questions, after which the program enters the command-mode. At this stage any parameter can be changed. See the short help page within **PLANETS** for the list of commands, and also "A Small Guide to NOD2 at the 30-m Telescope" by Albrecht Sievers for details.

5.7 Random and raster maps

MOPSI can produce regular grid maps from randomly distributed data (**XYZ**-like files) using two different algorithms. For noisy but fully sampled data, the command **rand***om* **... /type 1** (the default) in general gives much better results than the **rand***om* **... /type 2** or the **random** command within **GreG**. Especially for raster maps obtained with ON-OFFs or the **7MAP/19MAP** procedures written by H.P. Reuter (see "A short quide for Observations with the MPIfR 7-Channel Bolometer at the IRAM 30-m Radiotelescope") I suggest to use **random** of **type 1** within **MOPSI**. Although **MOPSI** accepts several **XYZ** data formats (see below), the raster maps obtained with the bolometer array can be reduced in the simplest (but not the quickest) way, when the data files are read in within **GreG**:

greg col x 4 y 5 z 6/file ?
take xyz
proj*ection* H M S D AM AS eq*atorial*
lim*its* xmin xmax ymin ymax   (in arc sec)
rand*om* XINC [YINC][/nei*ghbours* WCFX [WCFY]][/wei*ght_lim* VALUE]

NOTES:

i) The option **/nei***ghbours* defines the neighbourhood for the interpolation. It should be roughly one-half the HPBW of the telescope but not smaller than the XINC and YINC pixel size (in the same units).

ii) The option **/wei***ght_lim* defines the lower weight-limit for the data that contribute to the result.

iii) The reading of the data within **GreG** takes quite a long time. Reading the data in **MOPSI XYZ** format (.xyz files) is a few hundred times quicker. You may transform the data into one of the **XYZ** formats in the following way:

fil*e* o*ut* ?.xyz
write

5.8 Appendix A: Examples of commandfiles

The data can be read in either with the general command **fil***e* **i***n* **FILE_NAME** [**FILE_KIND**] + **rea***d* or in the case of TD, NOD2 or FITS files with the name of the default extention, i.e. **btd NAME**, **atd NAME**, **nod NAME**, **mpr NAME** or **fits NAME** respectively.
Bad channels can be removed with the **bad_c***hannel* # command.

5.8.1 Commandfile for standard reduction.

```
! MOPSI  version 10.02.1996, Robert Zylka, ITA Heidelberg
btd NAME
tau1 VALUE1/st st   (i.e. start_of_map)
tau2 VALUE2/st end  (i.e. end_of_map)
corr ext
base_r o BEAM_SEPARATION+40 40/sy ho
base_s 2
stor wei rms2 i base_r
res !
conv
```

5.8.2 Commandfile to reduce strong sources (e.g. planets)

```
! MOPSI  version 10.02.1996, Robert Zylka, ITA Heidelberg
btd NAME
tau1 VALUE1/st st   (i.e. start_of_map)
tau2 VALUE2/st end  (i.e. end_of_map)
corr ext
base_r o BEAM_SEPARATION+60 60/sy ho
base_s 0
res !
aver (or conv)
```

5.8.3 Commandfile to reduce weak compact sources

```
! MOPSI  version 10.02.1996, Robert Zylka, ITA Heidelberg
btd NAME
tau1 VALUE1/st st   (i.e. start_of_map)
tau2 VALUE2/st end  (i.e. end_of_map)
corr ext
base_r o BEAM_SEPARATION+30 30/sy ho
base_l 2
stor wei rms2 i base_r
fil o ?.btd
wr
btd ?
conv/comm
    res [[BEAM_SEPARATION] WIDTH]][/off AZ_OFF][/pa VALUE][/pro H M S D AM AS]
    run
```

5.8.4 Commandfile to reduce maps of "linear" narrow sources, restore and create a mosaic within HORTOEQ

```
! MOPSI version 12.02.1997, Robert Zylka, ITA Heidelberg

ini in-list
ini out-list
list n891_95
sort list

close dev
for i 1 to las
    read next skyd
    take chan 1
    skyd
next

for i 1 to las
    rea next map
    tau skyd 10000
    corr ext
    base_r 1 las
    base_surface 1
!    init spike_pointer
    mask lower -2500.0
    mask higher 2500.0
    base_r az < -35 > 35/pa 23.3/proj 2 19 24.3 42 7 17.0
    base_l 2
    mask spik 1000/mod 4
    base_l 2
! You may call SKYNOISE here.  But remember: weak sources and
! mosaics currently should not be processed.
!    stor wei rms2 az < -35 > 35/pa 23.3/proj 2 19 24.3 42 7 17.0
!    skyn
! SKYNOISE uses internally the same pointer array as BASE_RANGE, therefore
! the base_r command must be repeated here.
!    base_r az < -35 > 35/pa 23.3/proj 2 19 24.3 42 7 17.0
!    base_l 2
    db_f !
    base_l 2
    mul 0.22
    stor wei rms2 i base_r
    wr .btd +dfbl2
next
!
! End of reduction of individual maps. Averaging the maps in equatorial
! sytem is performed in HORTOEQ called by the command convert.
!
repl in-list out-list
read 1
conv/comm
  ext 500 800
  proj 2 19 24.3 42 7 17.0
```

```
  res 59 64/off 0/pa 23.3/proj 2 19 24.3 42 7 17.0
  run
!
! further maps
! fil i ?
! rea
! ...

   quit

fil o n891dfbl2cr_95.nod
wri
```

5.9 Appendix B: Selection of useful commands and subprograms

It is beyond the scope of this document to describe all possibilities of **TOTD** and **MOPSI**. Use the internal HELP to get a list of the commands and subprograms within them. Here I list just a selection of – as I believe – the most often used commands and subprograms within **MOPSI**.

atd NAME: opens an input file with ASCII **TD** data and reads them

average[/commands]: averages maps in the current system (no coordinate transformation); to change the defaults the option **com***mands* must be present

bad_channel NUMBER: deletes channel number NUMBER in receiver-array data (only ONE number); to delete more than one channel this command MUST be applied sequentially

base_range COLLEFT(1) COLRIGHT(1) ... COLLEFT(n) COLRIGHT(n): sets base range in columns, $0 < n < 6$

base_range az_offset $<$ **VALUE1** [$>$ **VALUE2**][**/pa ANGLE**][**/projection H M S D AM AS**]: sets base range for data with az-offsets outside (or inside) the defined range

base_range in|out [**/syst NAME**][**/proj H M S.S D M S.S**]: sets base range inside|outside a polygon [in system NAME]

base_range in|out VALUE1 [**VALUE2** [**PA**]][**/syst NAME**][**/projection H M S D AM AS**]: sets base range inside|outside the defined ellipse centered on map centre [or /projection] [in system NAME]

base_line ORDER: sets base-lines of order ORDER row by row in arrays

base_surface ORDER: sets base-surfaces of order ORDER in arrays

btd NAME: opens an input file with BINARY **TD** data and reads them

ch_gains: defines|overwrites the relative gains of individual channels in a receiver-array

ch_offsets: defines|overwrites the focal plane offsets of individual channels in a receiver-array

ch_parameters: defines|overwrites the channel parameters (ie. gains & offsets) of individual channels in a receiver-array

coldens: converts flux densities into column densities

combine [**FILE_NAME**]: map operations (coordinate transf.) [with second map in file FILE_NAME]

convert[/commands]: coordinate transformations; to change the defaults or to create **MOSAICS**, the option **com***mands* must be present

db_filter [**BEAM_SEPARATION THETA**][**!**]: filters a double beam map (action only on arrays)

correct base_lines: as **base_lines**

correct base_surface: as **base_surface**

correct ch_gains: corrects the relative gains of individual channels in a receiver-array

correct ch_offsets: corrects the focal plane offsets of individual channels in a receiver-array

correct ch_parameters: corrects the channel parameters (ie. gains & offsets) of individual channels in a receiver-array

correct extinction: corrects for the atmospheric extinction

extremes [**/compute/UNIT/scale VALUE**]: shows [computes] extremes [in UNIT], [scales data to VALUE]; UNIT can be: rad, deg, min, sec, mas

file in|out filename [**FILE_KIND**]: opens an in|output file [of kind FILE_KIND]

gfit [**AMPLITUDE/auto/no_auto/cursor/field SIZE/subtract**]: Gaussian fits

grid: plots the grid of columns and rows

gsm HPBWx [**HPBWy/weight_lim VALUE/gauss_lim VALUE**]: Gaussian smoothing (XYZ & NOD2-data)

gsou: creates or subtracts Gaussian sources (max 10)

higher VAL_LIM [**VAL_SET**]: sets intensities $>$ VAL_LIM to blanking value [VAL_SET]

integrate: integrations

interpolate: map interpolations

levels LEV1 LEV2 to LEV3 by STEP LEV4 ... : defines levels to plot

lower VAL_LIM [VAL_SET]: sets intensities < VAL_LIM to blanking value [VAL_SET]
map [N]: shows [defines] the map number to read from the input file
mask: masks pixels with weight = 0
mask az_offset < VALUE1 [> VALUE2][/pa ANGLE][/projection H M S D AM AS]: masks data with az-offsets outside (or inside) the defined range
mask in|out [/syst NAME][/proj H M S.S D M S.S]: masks data within|outside defined polygon [in system NAME]
mask in|out VALUE1 [VALUE2 [PA]][/syst NAME][/projection H M S D AM AS]: masks data inside|outside the defined ellipse centered on map centre [or /projection] [in system NAME]
mask spikes [/convolution /dimension /mode /neighbours /weight_lim /width]
multiply VALUE[/sub BLC TRC]: multiply the map [subfield] with VALUE
nod[/FILE_NAME]: changes any array into NOD2 format [read NOD2 data from FILE_NAME]
noise: calculates r.m.s. noise, mean and sum in a map within regions defined in different ways
noise [BLC TRC]: in a box defined by the pixel numbers of the BLC & TRC
noise az_offset < VALUE1 [> VALUE2][/pa ANGLE][/projection H M S D AM AS]: for az-offsets outside (or inside) the defined range
noise in|out [/syst NAME][/proj H M S.S D M S.S]: within|outside a defined polygon [in system NAME]
noise in|out VALUE1 [VALUE2 [PA][/pos X Y]][/syst NAME][/projection H M S D AM AS]: inside|outside the defined ellipse centered on map centre [or /position or /projection] [in system NAME]
noise in|out base_range: inside|otside the defined base range
nod NAME[/ascii]: opens an input file with BINARY[ASCII] **NOD2** data and reads them
pause: action only on COMMANDFILES
place signals [! /back /columns NCOLS]: places the signals (.atd or .btd files) according to the scanning coordinate
planet: estimates a planet flux in a defined beam; can also create a convolution map of a planet with a Gaussian beam
plot[/...]: scales the aspect ratio, gives a color display and plots the contours and box; options as for the GreG commands rgm and plot
polygon [file_name] [/pl]: defines [plots] a polygon
procedure NAME: starts an internal procedure; NAME=basic[/mask SYSTEM_NAME[/nchans NUMBER[/restore BEAM_SEPARATION THETA UNBALANCE]]], spikes, skynoise
put: puts the current map into GreG buffer
random [XINC [YINC]/neighbours WCFX [WCFY]/weight_lim VALUE/convolution NR[/type 1][!]]
random [XINC [YINC]/neighbours NX [Ny]/weight_lim VALUE/type 2][!]
read [next [TYPE]][/no_ch/not_packered/packered FORMAT]: reads the data set N [the next [of type TYPE]] [in format FORMAT]
restore [BEAM_SEPARATION THETA UNBALANCE][!]: restores a double beam map (action only on arrays)
rgm[/...]: plots the contours; options as the GAG command rgm
rms: the same as **noise** or **stat**
rotate ALPHA|back: rotates the map by ALPHA degrees clockwise (or back)
set base_range: as **base_range**
set mode bolometer|regular: set automatically, mode=bolometer only for NOD2 maps
set telescope NAME: NAME can be: effelsberg, veleta/iram-30m, sest, hht/smt, jcmt, cso, eso22
show ae_maps, blanking, command_file, files, polygon, range, spikes
sky_noise /convolution /dimension /iteration /mode /weight_limit /width /neglect ...
stat: the same as **noise** or **rms**

strip: calls the **STRIP** routine

subfield [**BLC TRC**]: calls the **SUBFIELD** routine [selects a subfield from the current map]

take_channel NUMBER: selects channel number NUMBER in receiver-array data, i.e. deletes all other channels

tau skydip TIME_INTERVAL: takes taus reduced within **MOPSI**

tau[**i**]**/st HOUR**[**i**] **MINUTE**[**i**] or **tau**[**i**]**/ut HOUR**[**i**] **MINUTE**[**i**]: defines the optical depth of the atmosphere

td NAME[**/ascii**]: opens an input file with BINARY[ASCII] **TD** data and reads them; or shorter: atd NAME or btd NAME

write [**FORMAT**] [**+TEXT**]: writes data [in format FORMAT] to the opened file [to a file with name = input_nameTEXT

write ch_par file_name: writes out the receiver channel parameters

write polygon file_name: writes out the defined polygon

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7 Literature

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