NIKA Pipeline output products v1.1

The NIKA collaboration and IRAM

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Abstract

This note describes the data products that the NIKA collaboration intends to provide to external observers for the first NIKA open time observations in February 2014. These products are the calibrated Time Ordered Information, the maps, calibration results (such as the measured beam) and log files. We also describe the NIKA data specifically produced for the IRAM IMBFITS files. v1.1: clarify the clean TOI product

1 NIKA data for IMBFITS

A subset of the raw NIKA data is included in the NIKA IRAM IBMFITS files that contain also pointing and extra observation information. These NIKA data in extension *Params*, include detector information in the form of parameters and flags for each detector. Important parameters are described here: in the header, AF_MOD or BF_MOD give the frequency (Hz) of the modulation. Table data contain: $NUMDET$, the KID official name, $Array$ (= 1 or 2, for 1 and 2mm channels), ACQ_BOX (0 or 1, the electronic readout box index), $FREQUENCY$ the frequency (decaHz) of the tone, $WIDTH$ the width of the resonance (decaHz), $TYPE$ is (= 0 for non-existent KID (that should not happen as data are not transmitted, =1 for useable KIDs, =2 for OFF-resonance tones, $\geq$ 3 KIDs with problems) and finally K_FLAG will contain another diagnosis (Flags per scan are similar to the definition given in the next section, Table 2) .

We also provide Raw Time Ordered Information (rTOI) including common data (sample number and MJD) and detector data. In terms of detector data, in extension *IMBF-backendNIKAxmm* (with x = 1 or 2, per subscan), we include for each detector and for each sample the raw *in phase* (I) and *in quadrature* (Q) values of the transmission of the detector and their derivatives (dI and dQ), the transformed quantities R and PF in Hz that are an estimate of the change of the resonance frequency of the detector (the basic quantity needed to be projected on the sky), $Ftone$ which is the frequency of the KID tone, and $Fres$ that is an estimate of the resonance total frequency of the detector, which is linear with the total power but of lower accuracy, so it is used only for opacity corrections. Only data for valid detectors are included.

Here is a summary description of the parameters of instrument that can be found in the the KidParams extension header:

```
NKCONF00=            946763122 /NOMEXP1
NKCONF01=                    0 /NOMEXP2
NKCONF02=                    8 /NOMEXP3
NKCONF03=                    0 /NOMEXP4
NKCONF04=                    0 /RETARD
NKCONF05=                   32 /DIV_KID
NKCONF06=                   10 /TUNING_IP
NKCONF07=          -1062731299 /A_IP
NKCONF08=                 2611 /A_PORT
NKCONF09=                    2 /A_ETH
NKCONF10=                  616 /A_SYNTHE
NKCONF11=                    2 /A_CODE_HORLOGE
NKCONF12=               524288 /A_MAXBIN
NKCONF13=                    5 /A_NB_BANDE
NKCONF14=                   70 /A_TONE_BANDE
NKCONF15=            195500000 /A_F_BASE
NKCONF16=                10000 /A_F_MOD
NKCONF17=                95367 /A_F_BIN
NKCONF18=                   25 /A_ATT_INJ
NKCONF19=                    0 /A_ATT_MES
NKCONF20=                   15 /A_GAIN_DAC1
NKCONF21=                   15 /A_GAIN_DAC2
NKCONF22=                   20 /A_GAIN_DAC3
```

```
NKCONF23=                   35 /A_GAIN_DAC4
NKCONF24=                   44 /A_GAIN_DAC5
NKCONF25=                    6 /A_GAIN_TONE
NKCONF26=          -1062731298 /B_IP
NKCONF27=                 2612 /B_PORT
NKCONF28=                    2 /B_ETH
NKCONF29=                  216 /B_SYNTHE
NKCONF30=                    2 /B_CODE_HORLOGE
NKCONF31=               524288 /B_MAXBIN
NKCONF32=                    5 /B_NB_BANDE
NKCONF33=                   70 /B_TONE_BANDE
NKCONF34=            136300000 /B_F_BASE
NKCONF35=                 5000 /B_F_MOD
NKCONF36=                95367 /B_F_BIN
NKCONF37=                   20 /B_ATT_INJ
NKCONF38=                    0 /B_ATT_MES
NKCONF39=                   20 /B_GAIN_DAC1
NKCONF40=                   23 /B_GAIN_DAC2
NKCONF41=                   20 /B_GAIN_DAC3
NKCONF42=                   33 /B_GAIN_DAC4
NKCONF43=                   50 /B_GAIN_DAC5
NKCONF44=                    6 /B_GAIN_TONE
NKCONF45=          -1764302789 /C_IP
NKCONF46=                63405 /C_PORT
NKCONF47=                    4 /C_ETH
NKCONF48=                   -1 /D_IP
NKCONF49=                 3000 /D_PORT
NKCONF50=                    3 /D_ETH
NKCONF51=                   -2 /RET_ELV
NKCONF52=          -1062731470 /E_IP
NKCONF53=                 6002 /E_PORT
NKCONF54=                    5 /E_ETH
NKCONF55=                   69 /E_MAPINDEX_TBM
NKCONF56=                   67 /E_MAPINDEX_T4K
NKCONF57=                   49 /E_MAPINDEX_PINJ
EXTNAME = 'KidParams'          /
```

2 Clean Time Ordered Information

The Clean Time Ordered Information (cTOI) is provided for both wavelengths (1 mm and 2 mm) in FITS files named `iram30m-NIKAxmm-scan-clean_imb.fits` where **scan** is scan defines the observed scan using **year + month + day + s + scan number** and x is 1 or 2 (*e.g.* **iram30m-NIKA2mm-20140223s8-clean_imb.fits**). These clean TOI FITS files include both detector (extension CleanNIKAdata) and common data (extension KidParams) as given in Tab. 1. They are written at the same place as for the raw fits files. Only valid detectors are retained (the number of valid detectors is written as NDET in the CleanNIKAdata extension header). This is done within the NIKA analysis pipeline after point-source calibration and without any decorrelation nor filtering. Note that glitches are flagged and interpolated in order not to bias spectral properties of the timelines. Along with the calibrated brightness (Jy/beam) for each detector, we give a flag which means that only data with a flag equal to zero should be projected on maps. The calibration of brightness involves the absolute calibration on Uranus, the opacity correction and the elevation-dependent beam efficiency correction. We then give the absolute RA-DEC instantaneous pointings of each detector (in degrees). For planets, the system is Az-El centered on 0,0 (see the XXYYTYPE keyword). We also give a robust common mode to help with a quick look (by simply projecting brightness minus common mode). That common mode is computed as the average of the detectors far enough of a given detector (20 arcseconds) which are the most correlated with it (we take at least 10 of them). It is computed on a per subscan basis. The OTF, pointing, Lissajous scans can be used. The other types (skydip, track, focus) should not be used (to be improved). In the IMBF-scan extension, we have added the NIKA measured zenith opacities at 1 and 2mm (NIKATAU1, NIKATAU2) as well as the median elevation (degree) of the scan. We have also insured the continuity of the samples across subscans in order to preserve power spectrum analyses. In the extension IMBF-antenna-s we have modified the DATE-OBS and DATE-END keywords to match the proper MJD of the start and end of each subscan. Not all scans could be processed for various reasons, the main one being the issue with recovering the pointing information during the February 2014 campaign.

We also provide overall flags that are computed by summing the powers of two of all the type of flags as $\mathrm{Flag}_{\mathrm{Total}} = \sum_i \mathrm{Flag}_i \times 2^i$, with Flag_i set to one if flagged and zero otherwise. In this way, the overall

Structure row	Content	Units	Array type
1	Point-source calibrated detectors timelines	Jy/beam	$N_{\mathrm{KIDs}} \times N_{\mathrm{sample}}$
2	Flag timelines (see text and Tab. 2)	none	$N_{\mathrm{KIDs}} \times N_{\mathrm{sample}}$
3	R.A. detectors coordinates timelines in the sky	degree	$N_{\mathrm{KIDs}} \times N_{\mathrm{sample}}$
4	Dec. detectors coordinates timelines in the sky	degree	$N_{\mathrm{KIDs}} \times N_{\mathrm{sample}}$
5	Sample index	none	N_{sample}
6	Time	second	N_{sample}
7	MJD	Day	N_{sample}
8	LST	?	N_{sample}
9	Elevation	radian	N_{sample}
10	Paralactic angle	radian	N_{sample}
11	Scan azimuth offset	arcsec	N_{sample}
12	Scan elevation offset	arcsec	N_{sample}
13	Subscan index	none	N_{sample}

Table 1: Time Ordered Information FITS files content. N_{KIDs} represents the total number of valid detectors and N_{sample} the number of samples in the file.

flag value, $\mathrm{Flag}_{\mathrm{Total}}$, can be expressed in a binary basis such that digits correspond to individual flags values Valid data samples have therefore an overall flag value of zero. The meaning of the flag index i is given in Tab. 2. For example, a data sample for a KID that is out of resonance and for which a glitch has been flagged will have an overall flag value of $\mathrm{Flag}_{\mathrm{Total}} = 2^0 + 2^3 = 9$. This is equivalent to 0001001 in a binary basis, in which we identify the digit to the corresponding flag according to Tab. 2.

Flag label i	Flag power	Flag type	Dependency
0	1	Glitch in the reconstructed flux	KID and sample
1	2	Off resonance tone	KID
2	4	Saturated KID	KID and sample
3	8	Out of resonance KID	KID
4	16	Resonance overlap	KID
5	32	Cross talking detector	KID
6	64	Anomalous detector to be discarded	KID
7	128	$RFdIdQ$ is not well computed	Sample
8	256	Not a proper part of the scan	Sample (e.g approach slew in Lissajous
9	512	Interpolated missing pointing data	Sample
10	1024	KIDs tuning	Sample
11	2048	Anomalous scan speed (e.g. between subscans, slews...)	Sample
12	4096	Frequency scanning	Sample
13	8192	Frequency scanning blanking	Sample
14	16384	FPGA frequency change	Sample
15	32768	Tuning error	Sample
16	65536	Wrong resonance	Sample
17	131072	Lost resonance	Sample
18	262144	Scan status	Sample
19	524288	Dilution Temperature Glitch	Sample

Table 2: Description of the meaning of flags. See [2] for more details on the KIDs transfer function. The flag value of 2^i corresponds to the flag type given in the table (see text for more details). Valid (to be projected on the map) data will have a total flag value of zero.

3 Maps

We provide maps as FITS files for all the individual scans and a combination of scans per source. The latter is computed by excluding anomalous scans, for which we estimate the quality to be significantly poor and would reduce the quality of the final combined map. Individual scan files are named with respect to the observed source and the scan number as `IRAM_MAP_source_scan_1mm.fits` and `IRAM_MAP_source_scan_2mm.fits` (*e.g.* `IRAM_MAP_DR21OH_20121120s0161_2mm.fits`). TCombined maps are named as IRAM_MAP_source_combined_1mm.fits and IRAM_MAP_source_combined_2mm.fits (*e.g.* IRAM_MAP_DR21OH_combined_2mm.fits). Three maps are provided in extension 0 of the FITS files and ordered in the following order: surface brightness map (opacity corrected), standard deviation map, and exposure time per pixel (hit map normalized by sampling frequency). The list of the detectors and the scans used to compute the maps are given in extension 1 of the FITS file for both individual scan maps and combined maps. More detailed information is given in tables 3 and 4. We highlight in the following the main issues concerning the map making:

- The standard coordinate system used is Ra.–Dec. (tangential projection: RA—TAN, DEC–TAN) but Azimuth–Elevation maps are done for planets.
- We use a nearest grid point projection with a pixel size of 4 arcsec (this can be adjusted by request).
- A predefined header for map projection can be used upon request if provided by the observers
- Pixels of the maps that have not been sampled are set to dNaN for the flux maps and zero for the time per pixel maps (see Tab. 3). Pixels with less than two measurements are set to dNaN for the standard deviation maps.
- Zero level is set in all detectors timelines outside the source before combining them.
- Timelines are weighted by the inverse variance of the noise, which is computed outside the source.
- In the case of point source data, electronic and atmospheric contributions to the data are decorrelated using the standard method described in [1]. Basically, a common-mode timeline is built by averaging all timelines and avoiding on-source detectors at any sample. The common-mode is first scaled to each detector and then subtracted from the timelines using a simple regression procedure.
- For extended source data two decorrelation methods can be used. The first of them minimizes the noise but removes large scale structures. It is based on the same common-mode method described above but no masking the source. The second one is based in an iterative procedure. First, a simplified map is constructed using the former method so that the location of the source can be infered. Then this information is used to mask the source when computing the common-mode. This method preserves large scales (up to the size of the array) but is noisier. Both methods are described in [1].

Extension	Axis	Content	Units	Comment
0	0	Flux density	Jansky/beam	Opacity corrected
0	1	Standard deviation	Jansky/beam	Estimated form the TOI
0	2	Observing time per pixel	second	Same as hit map normalized by sampling frequency
1		Info structure	–	See Tab. 4

Table 3: Map FITS files extension 0

Structure row	Content	Units	Comment
1	Number of scan used	none	
2	List of the scan used	none	Only one for individual scan maps
3	List of the KIDs used	none	Labeled by the detector number (numdet)
4	List of opacities of the given channel	none	Computed from skydips
5	List of the integration times	second	
6	Scan type	none	*e.g.* azimuth, elevation, lissajous

Table 4: Map FITS files extension 1.

4 Calibration results

The calibration procedure is described in [1]. The main outputs associated to this procedure are listed below.

4.1 Spectral bandpasses

The spectral bandpasses are given for both frequencies in NIKA_bandpass.fits. The first extension contains the 1.25 mm channel and the second extension contains the 2.05 mm channel. For both wavelengths, we provide the sampled frequency in GHz, the corresponding NIKA bandpass transmission and error, and a typical atmospheric transmission model for 2 mm of precipitable water vapor above the telescope. Note that the NIKA bandpass transmission is measured using a Martin-Puplett Interferometer with a Rayleigh-Jeans spectrum. Hence, color corrections have to be computed using a Rayleigh-Jeans spectrum as reference.

4.2 Unit conversion coefficients

Unit conversion coefficients are given for both wavelengths in the file NIKA_unit_conversion.fits. The first extension contains the 1.25 mm channel and the second extension contains the 2.05 mm channel. The following conversion factors are provided by integrating the corresponding spectra over the NIKA bandpasses:

- K_{CMB} to K_{RJ}
- Compton parameter y to K_{CMB}
- K_{RJ} to Jy/beam
- Jy/beam to Jy/sr accounting for the main beam only

4.3 Average beams

Maps of the strong point sources (*e.g.* planets), used by external observers for calibration/focus/pointing, will be used to measure the beam at 1.25 mm and 2.05 mm. This will be done for the total map (all detectors combined) and up to 60 arcsec. We will also compute the solid angle covered by the beam as a function of angular radius. These values are included in the FITS file named NIKA_beam.fits. The explicit content of these files is given in Tab. 5.

Structure row	Content	Units	Comment
1	Angular radius	arcsec	
2	Normalized beam response profile	none	To be trusted up to 60 arcsec
3	Statistical error on the beam response	none	
4	Angular radius up to which the beam is integrated	arcsec	
5	Angular coverage of the beam	arcsec^2	To be trusted up to 60 arcsec
6	Statistical error on the angular coverage	arcsec^2	

Table 5: Beam FITS files content. Values in extension 0 and 1 are for the 1.25 mm and 2.05 mm channels, respectively.

4.4 Focal plane: projection of the array in the sky

Main focal plane properties are given in the file NIKA_focal_plane.fits. Values in extension 0 and 1 are for the 1.25 mm and 2.05 mm channels, respectively. The file includes:

- Position of the KIDs with respect to the telescope pencil beam in Nasmyth coordinates along the X axis.
- Position of the KIDs with respect to the telescope pencil beam in Nasmyth coordinates along the Y axis.
- An estimate of the beam FWHM fitted for all detectors with an elliptical gaussian beam.
- An estimate of the beam FWHM along the X axis, fitted for all detectors with an elliptical gaussian beam.
- An estimate of the beam FWHM along the Y axis, fitted for all detectors with an elliptical gaussian beam.

5 Instrument performance

A summary of basic instrumental performance will be provided in the form of an ascii table.

6 Log file

For every scan, we produce a log file `logfile_scan.txt` (*e.g.* `logfile_20121120s0162.txt`) that contains the list of parameters given in Table 6. This file will also give the list of parameters used in the processing described above (see talbe 7).

7 Data delivery

The IMBFITS files and the clean calibrated TOI are archived by IRAM and can be provided on request. Calibration products will be available on the NIKA wiki page: `http://www.iram.es/IRAMES/mainWiki/NIKA/Main`

The maps, associated figures and logfiles, are delivered to each project account under :

/vis/xxx-13/observationData/nika

where xxx-13 is your project number. During the run, the products of a preliminary offline reduction will be provided as version v0. Then a version v1 will be delivered within a month. Observers may contact their respective NIKA instrument friend of project for information regarding the offline processing (`http://www.iram.es/IRAMES/mainWiki/Continuum/PoolOrganization/1stNIKApool`). Depending on feedbacks, a version v2 may be needed.

References

[1] Performance and calibration of the NIKA camera at the IRAM 30 m telescope, A. Catalano et al., arXiv:1402.0260.

[2] Calvo, M., Roesch, M., Désert, F. X., et al., Improved mm-wave photometry for kinetic inductance detectors, 2012, A&A

Variable	Unit	Comment
Scan number	none	*e.g.* 20121120s0161
Object	none	
$\tau_{1.25\text{mm}}$	none	Measure with NIKA using skydips
$\tau_{2.05\text{mm}}$	none	Measure with NIKA using skydips
Integration time	second	On-source time
Scan type	none	*e.g.* azimuth, elevation, lissajous
Mean elevation	radian	
Mean paratactic angle	radian	
Mean LST	I don't know	
Mean MJD	I don't know	
R.A. pointing coordinates	degree – arcmin – arcsec	
Dec. pointing coordinates	degree – hour – second	
IRAM 30-m latitude	degree	
IRAM 30-m longitude	degree	
IRAM 30-m altitude	meters	
DIR		
FILE		
OPERATOR		
OBSID		
PROJID		
AZ_DEG		
EL_DEG		
PARANGLE_DEG		
DATE		
N_OBS		
N_OBSP		
OBSTYPE		
SYSOFF		
XOFFSET_ARCSEC		
YOFFSET_ARCSEC		
SWITCHMODE		
FOCUSX_MM		
FOCUSY_MM		
FOCUSZ_MM		
PRESSURE_HPA		
TAMBIENT_C		
REL_HUMIDITY_PERCENT		
WINDVEL_MPERS		
TIPTAU225GHZ		

Table 6: Log file parameters.

Parameter	Unit	Comment
glitch_width	sample	
glitch_nsigma	none	
glitch_iq	none	
decor_method	none	
decor_baseline	none	
decor_kid_dist	arcsec	
decor_iq_plane_apply	none	
decor_iq_plane_per_subscan	none	
decor_iq_plane_one_mode	none	
decor_median_width	sample	
decor_source_interpol_d_min	arcsec	
decor_full_per_subscan	none	
decor_full_d_min	arcsec	
decor_dual_band_per_subscan	none	
decor_dual_band_x_calib	none	
decor_dual_band_nsmooth_temp	sample	
decor_dual_band_fcut1	Hz	
decor_dual_band_fcut2	Hz	
decor_common_mode_per_subscan	none	
decor_common_mode_x_calib	none	
decor_common_mode_nsmmoth	sample	
decor_common_mode_d_min	arcsec	
decor_common_mode_map_guess1mm	none	
decor_common_mode_map_guess2mm	none	
decor_common_mode_flag_type	none	
decor_common_mode_flag_lim1mm	none	
decor_common_mode_flag_lim2mm	none	
decor_common_mode_relob1mm	none	
decor_common_mode_relob2mm	none	
filter_apply	none	
filter_width	sample	
filter_nsigma	none	
filter_freq_start	Hz	
filter_low_cut1	Hz	
filter_low_cut2	Hz	
filter_cos_sin	none	
filter_pre	none	
fit_elevation	none	
w8_apply	none	
w8_dist_off_source	arcsec	
w8_per_subscan	none	
w8_map_guess1mm	none	
w8_map_guess2mm	none	
w8_flag_type	none	
w8_flag_lim1mm	snr or Jy/beam	
w8_flag_lim2mm	snr or Jy/beam	
w8_relob1mm	arcsec	
w8_relob2mm	arcsec	
w8_nsigma_cut	none	
zero_level_apply	none	
zero_level_dist_off_source	arcsec	
zero_level_map_guess1mm	none	
zero_level_map_guess2mm	none	
zero_level_flag_type	none	
zero_level_flag_lim1mm	snr or Jy/beam	
zero_level_flag_lim2mm	snr or Jy/beam	
zero_level_relob1mm	arcsec	
zero_level_relob2mm	arcsec	
map_size_x	arcsec	
map_size_y	arcsec	
map_reso	arcsec	

Table 7: Processing parameters