NIKA Run#3 Analysis

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Summary:

The basic characteristics of the NIKA prototype, as measured during Run#3 (October 2011), are given.

Then we analyze the various problems that were encountered during the NIKA run#3 at the IRAM 30m telescope. We give the status of our understanding and solutions that can be applied as a general table, including tests planned for run#4 (June 2012).

A summary of the main features including figures is given here:
http://www.iram.es/IRAMES/mainWiki/NIKA3SummOfflineProcResults

Details and more thorough studies can be found on the wiki :
http://www.iram.es/IRAMES/mainWiki/OffProcNika3

NIKA3 in a Nutshell

Cryocooler 4 K and a closed-cycle dilution reaching 70 mK for the arrays. Warm optics with aluminum mirrors. Cold refractive optics with polyethylene lenses, near the condition of (???) to have planar detector arrays. Filtering (Cardiff University) at all thermal stages. 45 deg dichroic to split the 2 frequencies. A bandpass filter is put in front of the back-illuminated Kid array which has a backshort, according to the wavelength. Detector arrays are made of aluminum MKIDs. Data acquisition rate is 22 Hz synchronously per array. Fits files are provided that contain raw data and the central resonance frequency of each Kid which is assumed to be proportional to the incoming millimeter power. Effective sensitivities are given as measured with a zenith opacity of 0.09@2mm, 0.2@1mm.

Channel	2 mm	1 mm
Center frequency	140 GHz	220 GHz
Number of (valid) detectors	(74) 132	(92) 132
Detector FWHM (arcseconds)	15- 21	11-21
Detector separation in a row (arcseconds)	10.5	10.5
Field-of-view (Diameter)	2’	2’
Effective sensitivity (mJy $s^{1/2}$ per beam)	21	140

#	*Issue*	*Cause*	*Solution for **Run3***	*Status*	*Future: **Run4**,...*
1	Run2: cryogenic fluids	Helium Cryostat	Cryogenerator	Working in Run3	Keep it
2	Run2: jumps in signal	Earth Magnetic field trapped near the detector	Shielding	Done in Run3 No more jumps observed. (except for a flying bug in the cabin that creates streaks of light on the detector, a different phenomenon)	Keep it
3	Run2: Ability to do photometry	KIDs are non-linear devices	Modulation of the tones: the Rf_dIdQ method	The modulation has provided a major improvement in reproducible photometry. Incomplete proof. Some non-linearity still observed in very unstable weather.	Improve on physical understanding (role of feedline), numerical issues (polynomial fits) and simulations. Do complete frequency sweeps.
4	Run3: Focal Plane Geometry and beams are heavily distorted. The beam is not at the diffraction limit in the 1mm band. It was not the case for Run2	Suspected but not proven: unaccounted for optical distortion. The FWHM is linked to the distortion. Both channels are affected. A bad placing of the warm or cold common optics likely guilty.	Take the FPG and beams into account in the data reduction	Run3: The FPG (as measured) is used. An average beam is used in fixed-PSF photometry (not optimal solution).	Run4: brand new optics. The new optics will be tested in May2012 at the telescope A goal for Run4. Not possible to fully test in lab.
5	Run3: Glitches at the rate of several every ten seconds and common to all detectors of the same array.	Likely: over biased amplifiers	A simple deglitching algorithm is applied. Only one sample is affected at a time.	Run3: Done. Low level glitches are still visible on average array timeline.	The glitches have not been reproduced in the lab. We hope it is a one off issue. Run4: tune the amplifiers. Optimize the power levels in the RF circuit. A goal for Run4
6	Plateau of 1.5 arcminute size in response to a strong source	Likely: over biased amplifiers (electronic cross-talk). Same as previous issue?	If not taken into account in the data reduction there would be limitations only for high contrast observations? Work in progress to show that the plateau reduces when decorrelating with the off resonances (done for all sources).	Waiting for Run4	Run4: tune the amplifiers A goal for Run4
7	Cosmetics: 10% of invalid pixels, 10% of cross-talking pixels TBC	Detector fabrication(?) Overlapping resonances	Discard all these pixels from further astronomical analysis	Trade-off between sensitivity and cosmetics	Run4: provide better arrays.
8	Sensitivity at 1mm is not yet at the Mambo level. 2mm sensitivity is now within specs.	1mm bandpass : one filter was found cutting the atmospheric window by 2/3	Live with reduced sensitivity	Martin-Pupplet measurements have shown afterward the origin of the problem.	MP measurements are being done with the new filtering scheme. Real test during Run4
9	Lack of quick offline processing tools	Fits export was not operational	No real-time feedback could be implemented on optical problems	Several versions of Fits export have been made since Run3 to make sure we agree on fits format.	Work on quick offline processing with Mopsic and custom IDL software in Run4
10	Opacity corrections	Atmosphere	Use taumeter values with some scaling	It is shown that the absolute frequency of each kid is linear with the atmospheric power as inferred from the taumeter measurements. Skydips fail due to non-linearity effects	Introduce Kid retuning at each step of the skydip.
11	Pointing model within Pako	Telescope pointing perturbations	The model proved useful. It was recognized that there were non-negligible pointing problems at the telescope with heterodyne receivers too during the run.	Need a more automated way of building the pointing model.	Need continuing efforts IRAM-NIKA to build a consistent pointing model within Pako.

3 - Photometry

Relative photometry

The reproducibility of flux measurements is shown to be at the 10% level in relative photometric terms. This is not yet completely settled as it involves fixed width PSF-fitting whereas other members of the team use peak values and because the dispersion of the FWHM is large.

Opacity corrections (item 10 in the table)

In order to have absolute photometry, we need to correct for opacity effects and elevation gain dependence. In this run, we have only accounted for the former effect. Skydips done in the usual way were performed but do not lead to a consistent picture. We will investigate a new procedure during Run#4 (retuning the Kids at each subscans). An alternative approach has been used for Run#3. It consists in using the absolute frequency of the Kid resonance as a proxy to the power load. This approach leads to results which are consistent with the 225GHz taumeter available at the 30m telescope. We use the taumeter to have the absolute scaling between the Kid frequency and the tau-related sky emission. Then we use the Kid frequency to know the opacity of the sky at each scan (even when the taumeters readout did not work). The estimated error on opacity is 1% at 1.2 mm. The opacity of the sky (see wiki plot) at zenith and 1.2 mm was between 0.2 and 0.5 most of the Run#3, with the 19th and 20th being the most stable at 0.2 and 0.3 respectively. The scaling of opacity from 1.2mm to 2.1 is done by assuming a nu^2 dependence, hence the 2.1 mm opacity is 0.44 the 1.2 mm opacity.

Absolute photometry

Using pointing sources (mostly quasars) measured on the 18th October 2011, we can compare the absolute flux measured with NIKA run3 with an estimate (provided by Samuel Leclercq) obtained using PdB measurements (error bars for PdB is a flat 10% assumption). The assumption for the NIKA photometry is that the Uranus flux is a black-body with a temperature of 132 K and the opacity (as calculated above) is correct (the taumeter values were not available on the 18th October). [See wiki for the spreadsheet and the figure.]
The agreement is reasonable with the fluxes covering from 1.5 to 15 Jy (the straight line is just the one-to-one slope), even though the opacity of the sky was not winter-like. One source 0727-115 is not consistent (disagreement by a factor 2 at both wavelengths). After excluding that quasar, the flux ratio (NIKA/PdB) has an average value of 0.93 (resp. 0.95) and a dispersion of 10% (resp. 30%) at

140 GHz (resp. 220 GHz).

Sensitivity

The sensitivity of the camera is evaluated by eliminating those Kids for which we have found problems (double, shallow resonances). We make maps of weak sources. For example, the source 4C05.19 was detected with a 2mm flux of 27+-2 mJy in just half an hour. Using the effective time spent on source (when valid Kids were on target), we derive a sensitivity at that time and elevation of 30 mJy.$s^{1/2}$ per beam. The range on this number during the run is from 21 to 40. The effective sensitivity for the faint-source scan that was used is 1.9xsqrt(1800)=80 mJy.$s^{1/2}$. It is larger than the quoted 30 because the surveyed area is larger than the array coverage so that the center is not observed at all times by the array. These sensitivities have been reached with heavy sky noise and electronic noise decorrelation. For the same scans, using no decorrelation at all but just baseline removal, the sensitivity is 65 mJy$s^{1/2}$. Using a single common mode decorrelation, the sensitivity goes down to 38 mJy.$s^{1/2}$. In conclusion it is worth decorrelating but the used method is not critical. Our best sensitivity was obtained during the observations of F10214+4724 (the high-redshift IRAS faint source). We got 21 mJy $s^{1/2}$/beam at 140 GHz and 140 mJy $s^{1/2}$/beam at 220 GHz for a zenith opacity of 0.09 and 0.20 .
We do not detect the source (hint of a signal at 2.5 sigma at 2.6+-1.1 and 12+-6 mJy).

4 - Focal Plane Geometry and beams

The focal plane geometry is the distribution of pixels in Nasmyth coordinates as observed with strong point sources. Run#3 has shown a disappointingly distorted array with respect to the (undistorted) array geometry. This is seen for both arrays. Run#2 did not show such a distortion, laboratory measurements neither, albeit without the off-axis mirror. Moreover the beams (as fitted with elliptical Gaussians) seem to be stretched in the same way as the distortion (bigger beams and pixel separations near the center). This points towards a problem in the optical train, although the team disagrees on that issue. We have not been able to pinpoint the origin of this problem with Zemax. Outputs from some data reductions do not fit with that picture (integrated energy flat fields). Another origin could be some electronic cross-talk in a similar way as the plateau (see below).
The FWHM of the beams spans the range of 16 to 21 arcseconds at 2 mm and 10 to 21 at 1 mm. External beams are paradoxically the closest to the diffraction limit. Focus measurements have not yielded clues so far.

5 - Glitches

During Run#3, we detected glitches which are always common to all detectors of the same array and independent from the other array. They are seen at a rate of several every ten seconds with very different intensities and no apparent time regularity. These glitches have not been seen in the laboratory before and after Run#3 nor during Run#2. These glitches are always positive, corresponding to a negative change of the resonance frequency. The glitches extend down to very small levels, well within the noise as we can see by averaging the signal from several Kids. It is as if a small spike of energy, lasting 1 sample (typically 50 msec), hits the whole Kid array. The glitches are not seen on the off-resonances, except when the spike is strong. The glitches are seen with a similar intensity in all detectors of the same array. The appearance of glitches common to all detectors of the same array and independent from the other array leads us to believe that this is an issue with the electronic readout system or the common wafer. In this latter hypothesis, a mechanical origin is not excluded. Cosmic rays can be excluded by a VNA approach in which they did not appear at a much higher rate than in the laboratory.

6 - Plateau

The plateau is a faint glow matching the array imprint seen on all individual Kid maps when scanning Mars. It could be due to the readout system. A feedback from the multiplexing system (due to some non-linearity) could induce a massive cross-talk. This plateau would depend on the settings of the electronics. This is to be tested in Run#4. We see this plateau on off-resonances, hence it is not optical. Optical cross-talk of this magnitude (5-10%) would mean that there is 10 times more light spread on the array than on the main beam, which would mean that each pixel is ten times more sensitive than computed! However, with Jupiter observations (and mostly away from it, by observing its satellites) there are some hints of optical stray-light as well, to be quantified.

7 - Cosmetics (or array inhomogeneities)

Run#3 had the following statistics of pixels. One electronic readout could get only 116 measurements.
Array A (2mm) has 103 measured resonances (out of 132 pixels) and 6 off resonances. 12 are overlapping (they show up as giving a double source on Mars). Out of the 91 single resonances, 17 are dubious for various reasons and not used in the map making *i.e.* 74 detectors are used.
Array B (1mm) has 116 resonances and 0 off resonance (out of 132 pixels). 12 are overlapping. Out of the 104 single resonances, 12 are

dubious. Hence 92 detectors are used in the map making.
Using the 10 scans on F10214+4724, we find an average noise per scan and per kid in mJy/beam of 18 and 114 at resp. 2 and 1 mm. The 1-sigma dispersion among the kid noises amount to resp. 3 and 28. See Fig. in the wiki. These inhomogeneities are clearly to be improved in the following batches of arrays.