IRAM NOEMA interferometer

Observing Capabilities and current status

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February 12, 2015

This document is updated twice a year to reflect the new capabilities of the interferometer at the time of the Call for Proposals publication. Non-trivial changes with respect to the previous version are marked in red. Note that this document contains active links marked with a different font for an easy access to documentation, e.g. on the `IRAM web pages`.

1 Progress of NOEMA

With the inauguration of the seventh antenna in September 2014, the Plateau de Bure observatory has started its transformation into NOEMA, the NOrthern Extended Millimeter Array. With the upcoming summer semester, the name of the interferometer has therefore officially changed and the current document is the first Call for Proposals at NOEMA.

1.1 Antenna 7 construction

During the last months assembly of the reflector back structure was finished and the reflector was equipped with aluminum panels. The subreflector is put in place, the receiver was installed in the cabin, cooled down, and aligned with the optical axis. Commissioning of antenna 7 started on February 5th and the antenna should soon become available for regular observations. For the summer semester 2015, proposers are therefore asked to assume that six antennas will be available during the antenna maintenance period and seven antennas for the end of the semester, when C configuration will be scheduled.

1.2 Correlator upgrades

The IF processor has been extended to feed the signals of up to eight antennas to the wide-band correlator WideX, and the corresponding real-time software was adapted accordingly. The narrow-band correlator, being a separate system, will remain able to process the signals of up to six antennas.

2 Weather conditions and observing during the winter semester

The interferometer entered into the current winter semester with the antennas arranged in the six-antenna C configuration. Weather conditions were very good to excellent during the second half of December. In order to work off a number of detection projects requesting high frequencies and in particular observations in band 4, the interferometer was moved on December 21 into a compact, D-like configuration. The switch to a special seven-antenna A configuration is foreseen for the second half of February, when commissioning of antenna 7 will be sufficiently advanced. The array is supposed to be kept in the A configuration until mid of March when we plan to move back into the second most extended configuration B. We currently anticipate to switch to the C configuration by mid of April and to schedule the compact D configuration again in May. Global VLBI observations, which include the array in the 3 mm phased-array mode, are scheduled from May 14 to 20, 2015.

As far as A-rated projects requiring the compact configurations are concerned, we hope to bring most of them to completion before the end of the current winter semester. B-rated projects are likely to be observed only if they fall in a favorable LST range. We remind users of the interferometer that B-rated proposals and time-filler projects which are not started before the end of the winter semester have to be resubmitted.

Investigators, who wish to check the status of their project may consult the `interferometer schedule` on the Web. This page is updated daily.

3 Conditions for the next summer period

During the antenna maintenance period, scientific observations will mostly be carried out with the six element array. We plan to start the regular antenna maintenance around mid of May and to schedule essentially the 7D6 configuration between June and October. At the end of the summer semester, seven antennas will be available for regular science observations.
We strongly encourage observers to submit proposals that can be executed during summer operating conditions. To keep the procedure as simple as possible, we ask you to put emphasis on:

- observations requesting the use of the 2 mm and 3 mm receivers
- circumpolar sources or sources transiting at night between June and September,
- ∘ observations that qualify for the 7D, 7D6, 7C, and 7C6 configurations

We tentatively plan to schedule an extended A-configuration for a few days in August, including stations E68, N46 and W27, to exploit the potential of self-calibration for high-resolution and high-dynamic range imaging in conditions of poor phase stability. These observations would be executed on a **best effort basis**. If you are interested, please submit a proposal dedicated to A configuration observations in the proposal category "Special" and focus on: i) observing in band 1, band 2, or band 3, ii) source declinations above $-10°$ and sources visible in August, iii) compact, strong sources (size < 1arcsec, flux $> 0.4 - 0.5$Jy) and iv) request not more than one track with 4 hr of on-source time.

3.1 General Proposal Considerations

Please give high importance to the quality of your proposal. The NOEMA interferometer is a powerful, but complex instrument, and proposal preparation requires special care. In particular, your proposal should not only justify the scientific interest, but also the need for NOEMA. Proposers should also note in their application whether the same or a similar proposal was or is intended to be submitted to ALMA, in which case a special justification is required why IRAM interferometer time is needed.
Don't hesitate to contact the NOEMA Science Operations Group (sog@iram.fr) in case of doubts and for questions related to the preparation of a proposal.

3.2 Proposal category

Proposals should be submitted through the `Proposal Management System PMS` for one of the four categories:

STANDARD: Proposals that ask for a total of less than 100 h of observing time and to use the interferometer within its guaranteed capabilities (see the following sections and the documentation `An Introduction to the IRAM NOEMA interferometer`).

TIME FILLER: Proposals that have to be considered as background projects to fill in periods where the atmospheric conditions do not allow mapping, to fill scheduling gaps, or even to fill in periods when only a subset of the standard antenna configurations will be available. These proposals will be carried out on a "best effort" basis.

SPECIAL: Exploratory proposals, whose scientific interest justifies the attempt to use the array beyond its guaranteed capabilities. This category includes for example non-standard frequencies for which the tuning cannot be guaranteed, non-standard configurations and more generally all non-standard observations. These proposals will be carried out on a "best effort" basis.

LARGE PROGRAM: This category is offered on both IRAM instruments, see the `Large Program Policy` on the IRAM web site. In the frame of NOEMA, additional antennas and more receiver bandwidth are expected to become available during the "lifetime" of a Large Program. For the current Call for Proposals, the observing time request should be based on the availability and performance of the current seven element array, though. We might adjust it and/or review the observing strategy in response to PI needs and enhanced array's capabilities.

The proposal category will have to be specified on the `PMS` web form and should be carefully considered by proposers.

Within each of these categories, observations in one or several of the following frequency bands can be requested:

BAND 1: Proposals that ask for 3 mm data (80 to 116 GHz).

BAND 2: Proposals that ask for 2 mm data (129 to 177 GHz). Band 1 receivers can be used for pointing and calibration purposes, but cannot provide any imaging.

BAND 3: Proposals that ask for 1.3 mm data (201 to 267 GHz). Band 1 receivers can be used for pointing and calibration purposes, but cannot provide any imaging. During the summer semester, proposals requesting the extended tuning range (256-267 GHz) will be carried out on a "best effort" basis only.

BAND 4: Proposals that request observations in the 0.8 mm window (277 to 371 GHz). Band 1 receivers can be used for pointing and calibration purposes, but cannot provide any imaging. Please note that band 4 observations can only be carried out at the end of the summer semester on a "best effort" basis.

Short spacing observations on the 30m telescope should directly be requested on the interferometer proposal web form through `PMS`. A separate proposal for the 30m telescope is not required. The interferometer proposal form contains a box, labeled "Request for 30m short spacings" which should then be checked. The user will automatically be prompted to fill in an additional paragraph in which the need for the short spacings should be justified. It is essential to give here all observational details, including size and type of map, rms noise, spectral resolution, receiver, and time requested.

3.3 Configurations

Configurations planned for the summer period are:

Name	Stations						
7D	W08	W05	E04	N11	N07	N02	E10
7D6	W08	W05	E04	N11	N07	N02	—
7C	W12	W09	E18	E12	E04	N17	N11
7C6	W12	W09	—	E12	E04	N17	N11
7A6	W27	W10	E68	E24	—	N46	N29

Part of the projects will be scheduled at the end of the summer period when the seven-element array is expected to be back to operation. Please note that high spectral resolution studies using the narrow-band correlator are restricted to six antennas. Projects that should be observed with a subset of the six-element array will be adjusted in uv-coverage and observing time.

The following configuration sets are available:

- `D` is best suited for deep integration and coarse mapping experiments (resolution ∼ 4.5″ at 100 GHz). This configuration provides both the highest sensitivity and the lowest atmospheric phase noise.
- `CD` (i.e. the combination of C **and** D configuration) is well adapted for low angular resolution studies (∼3.2″ at 100 GHz, ∼1.4″ at 230 GHz).
- `C` is appropriate for mapping, snapshot, and size measurements and for detection experiments at low declination. It provides a spatial resolution of ∼ 2.5″ at 100 GHz.
- `A` is well suited for mapping or size measurements of very compact, strong sources. It provides a resolution of 0.7″ at 100 GHz, ∼0.3″ at 230 GHz.

Finally, enter ANY in the proposal form if your project doesn't need a particular configuration.
Please consult the documentation
`An Introduction to the IRAM NOEMA interferometer`
for further details.

3.4 Receivers

All antennas are equipped with dual polarization receivers for the 3 mm, 2 mm, 1.3 mm, and 0.8 mm atmospheric windows. The frequency ranges are 80 GHz to 116 GHz for band 1, 129 GHz to 177 GHz for band 2, 201 to 267 GHz for band 3, and 277 to 371 GHz for band 4.
Each band is dual-polarization with the two RF channels, one per polarization, observing at the same frequency. The four bands are not co-aligned in the focal plane (and therefore are not aligned on the sky). Due to the pointing offsets between the four frequency bands, only one band can be observed at any time. Time-shared observations between band 1 and one of the other frequency bands (band 2, 3, or 4) are possible in well justified cases, they are however not very efficient. Please contact the NOEMA Science Operations Group (sog@iram.fr) to discuss the feasibility in case you are interested in using this mode.
The mixers for bands 1, 2, and 3 are single-sideband, backshort-tuned; they will usually be tuned LSB, except for the upper part of the frequency range in all three bands where the mixers will be tuned USB. The band 4 mixers are 2SB receivers, operated in SSB mode. They can be tuned LSB or USB throughout most of the accessible frequency range. The

	Band 1	Band 2	Band 3	Band 4
RF range*/[GHz]	80–116	129–177	201–267	277–371
T_{rec}/[K] LSB	40–55	30–50	40–60	30–50
T_{rec}/[K] USB	40–55	40–80	50–70	30–50
G_{im}/[dB]	-10	-12 ... -10	-12 ... -8	-20
RF LSB/[GHz]	80–104	129–165	201–264	277-359
RF USB/[GHz]	104–116	164–177	264–267	289-371

* center of the 4.2-7.8 GHz IF band

typical image rejection is 20 dB for band 4, 10 dB for bands 1, 2, and 3.

3.5 Signal to Noise

The rms noise can be computed from

$$\sigma = \frac{J_{\rm pK} T_{\rm sys}}{\eta \sqrt{N_{\rm a}(N_{\rm a}-1) N_{\rm c} T_{\rm ON} B}} \frac{1}{\sqrt{N_{\rm pol}}} \qquad (1)$$

where

- $J_{\rm pK}$ is the conversion factor from Kelvin to Jansky (22 Jy/K in band 1, 29 Jy/K in band 2, 35 Jy/K in band 3, and 45 Jy/K in band 4). These factors were determined for stable atmospheric conditions.
- η is an additional efficiency factor due to atmospheric phase noise ($\eta = 0.9$ in band 1, 0.8 in band 2, 0.6 in band 3, and 0.50 in band 4). These factors take into account average phase stability in typical summer conditions.
- $T_{\rm sys}$ is the system temperature ($T_{\rm sys}$ = 100 K below 110 GHz, 180 K between 110 and 116 GHz, 150 K in band 2 below 150 GHz, 200 K in band 2 above 150 GHz, 250 K in band 3, and 500 K in band 4 for sources at $\delta \geq 20°$ and for typical summer conditions).
- $N_{\rm a}$ is the number of antennas and $N_{\rm c}$ is the number of configurations: 1 for D, 2 for CD, 1 for C.
- $T_{\rm ON}$ is the on-source integration time per configuration in seconds (2 to 8 hours, depending on source declination). Because of various calibration overheads, the total observing time is typically 1.6 $T_{\rm ON}$.
- B is the spectral bandwidth in Hz (40 kHz to 2.5 MHz for spectral line observations using the narrow-band correlator, and from about 2 MHz for line projects up to 3.6 GHz for continuum projects using WideX).
- $N_{\rm pol}$ is the number of polarizations: 1 for single polarization and 2 for dual polarization (see section *Correlators* for details).

The sensitivity equation Eq. (1) is implemented in PMS and should be used to estimate the required observing time/sensitivity. Investigators have to specify in the "technical justification" and on the Technical Sheet the 1 sigma point source sensitivity which is necessary to achieve each individual goal of a proposal, and particularly for projects aiming at deep integrations. In case of mapping projects, PMS asks for the on-source time requested and calculates the resulting point-source sensitivities using Eq. (1). Please verify that your numbers match throughout the proposal.

3.6 Correlators

3.6.1 Wide-Band correlator (WideX)

At any given time, only one frequency band can be observed, but with the two orthogonal polarizations available. Each polarization delivers a 3.6 GHz bandwidth (from IF=4.2 to 7.8 GHz). The two 3.6-GHz bandwidths coincide in the sky frequency scale. The wide-band correlator WideX gives access to the two 3.6 GHz wide IF bands simultaneously. WideX provides a fixed spectral resolution of 1.95 MHz over the full bandwidth and is available in parallel to the narrow-band correlator. WideX is capable of correlating the signals of up to 8 antennas.

3.6.2 Narrow-Band Correlator

The narrow-band correlator accepts as input two signals of 1 GHz bandwidth, that must be selected within the 3.6 GHz delivered by the receiver. In practice, the IF processor splits the two input 4.2–7.8 GHz bands in four 1 GHz wide "quarters", labeled *Q1...Q4*. Two of these quarters must be selected as narrow-band correlator inputs. Up to six antennas can be processed with the narrow-band correlator. The system allows the following choices:

- first correlator entry can only be Q1 HOR, or Q2 HOR, or Q3 VER, or Q4 VER
- second correlator entry can only be Q1 VER, or Q2 VER, or Q3 HOR, or Q4 HOR

where HOR and VER refer to the two polarizations:

Quarter IF1 [GHz]	Q1 4.2-5.2	Q2 5.0-6.0	Q3 6.0-7.0	Q4 6.8-7.8
input 1	HOR	HOR	VER	VER
input 2	VER	VER	HOR	HOR

Note, that the combination VER VER is not allowed.

How to observe two polarizations with the NB correlator? To observe simultaneously two polarizations at the same sky frequency, one must select the same quarter (Q1 or Q2 or Q3 or Q4) for the two narrow-band correlator entries. This will necessarily result in each entry seeing a different polarization. The system thus gives access to 1 GHz $\times$ 2 polarizations.

How to use the full 2 GHz bandwidth? If two different quarters are selected (any combination except VER VER is possible), a bandwidth of 2 GHz can be analyzed by the narrow-band correlator. Only one polarization per quarter is available in that case; this may or may not be the same polarization for the two chunks of 1 GHz.

Is there any overlap between the four quarters? In fact, the four available quarters are 1 GHz wide each, but with a small overlap between some of them: Q1 is 4.2 to 5.2 GHz, Q2 is 5.0 to 6.0 GHz, Q3 is 6.0 to 7.0 GHz, and Q4 is 6.8 to 7.8 GHz. This results from the combination of filters and LOs used in the IF processor.

Is the 2 GHz bandwidth necessarily continuous? No: any combination (except VER VER) of two quarters can be selected. Adjacent quarters will result in a (quasi) continuous 1.8 or 2 GHz band. Non-adjacent quarters will result in two separate 1 GHz bands.

Where is the selected sky frequency in the IF band? It would be natural to tune the receivers such that the selected sky frequency corresponds to the center of the IF bandwidth, i.e. 6.0 GHz. However, this corresponds to the limit between Q2 and Q3. If your project depends on the narrow-band correlator, it is therefore highly recommended to center a line at the center of a quarter (see Section "ASTRO" below). In all bands, the receivers offer best performance in terms of receiver noise and sideband rejection in Q3 (i.e. the line will usually be centered at an IF1 frequency of 6500 MHz).

3.6.3 Spectral units of the narrow-band correlator

The narrow-band correlator has 8 independent units, which can be placed anywhere in the 100–1100 MHz band (1 GHz bandwidth). 7 different modes of configuration are available, characterized in the following by couples of total bandwidth/number of channels. In the 3 DSB modes (320MHz/128, 160MHz/256, 80MHz/512 – see Table) the two central channels may be perturbed by the Gibbs phenomenon if the observed source has a strong continuum. When using these modes, it is recommended to avoid centering the most important part of the lines in the middle of the band of the correlator unit. In the remaining SSB modes (160MHz/128, 80MHz/256, 40MHz/512, 20MHz/512) the two central channels are not affected by the Gibbs phenomenon and, therefore, these modes may be preferable for some spectroscopic studies.

Spacing (MHz)	Channels	Bandwidth (MHz)	Mode
0.039	1×512	20	SSB
0.078	1×512	40	SSB
0.156	2×256	80	DSB
0.312	1×256	80	SSB
0.625	2×128	160	DSB
1.250	1×128	160	SSB
2.500	2×64	320	DSB

Note that 5% of the passband is lost at both ends of each subband. The 8 units can be independently connected to the first or the second correlator entry, as selected by the IF processor (see above). Please note that the center frequency is expressed in the frequency range seen by the narrow-band correlator, i.e. 100 to 1100 MHz. The correspondence to the sky frequency depends on the quarters of the 3.6 GHz bandwidth which have been selected as correlator inputs and on the selected receiver side band (LSB or USB).

3.6.4 ASTRO

The software ASTRO can be used to simulate the receiver/correlator configuration.

The previous `LINE` command has been replaced by several new commands (see internal help; the following description applies to the current receiver system). The behavior of the `LINE` command can be changed by the `SELECT BURE 1995|2000|2006|2013` command, that selects the frontend/backend status of the interferometer corresponding to years 1995 (old receivers, 500 MHz bandwidth), 2000 (580 MHz bandwidth), 2006 (new receivers and new IF processor, 3.6 GHz bandwidth), 2013 (upgrade of the LO system). Default is 2013:

- `LINE`: receiver tuning
- `NARROW`: selection of the narrow-band correlator inputs
- `SPECTRAL`: spectral correlator unit tuning
- `PLOT`: control of the plot parameters.

A typical session would be:

```
! choice of receiver tuning
line xyz 93.200 lsb 6500

! choice of the correlator windows
narrow Q3 Q3

! correlator unit #1, on entry 1
spectral 1  20 600 /narrow 1

! correlator unit #2, on entry 1
spectral 2  20 735 /narrow 1

! correlator unit #3, on entry 1
spectral 3 320 300 /narrow 1

! correlator unit #4, on entry 2
spectral 4 320 666 /narrow 2
...
```

The first step above:

```
! choice of receiver tuning
line xyz 93.200 lsb 6500
```

would produce a plot showing the full 3.6 GHz bandwidth delivered by the receivers that is accessible to WideX in dual polarization.
Astronomers are advised to download the most recent version of `GILDAS` to prepare their proposals.

3.7 Source coordinates and Velocities

The interferometer operates in the equatorial J2000.0 coordinate system. Please do not forget to specify either LSR velocities or redshifts for the sources. The source list must contain all the sources (and only those sources) for which observing time is requested. The list must adhere to the standard sexagesimal notation.
Any later request for a swap of targets has to be submitted for approval to the IRAM director and to be justified by new evidence or exceptional circumstances.

3.8 Sun Avoidance

For safety reasons, a sun avoidance circle is enforced that was recently reduced to 32 degrees from the sun. In the long term we aim to further reduce this sun avoidance limit.

3.9 Mosaics

NOEMA has mosaicing capabilities, but the pointing accuracy may be a limiting factor at the highest frequencies. Please contact the Science Operations Group (sog@iram.fr) in case of doubts.

3.10 Local Contact

A local contact will be assigned to every A or B rated proposal which does not involve an in-house collaborator. He/she will assist you in the preparation of the observing procedures and provide help to reduce the data. Assistance (write to sog@iram.fr) is also provided before a deadline to help in the preparation of a proposal. Depending on the program complexity, IRAM may require an in-house collaborator instead of the normal local contact.

3.11 Data reduction

Proposers should take the following into account with respect to reduction of their data:

- We recommend that proposers reduce their data in Grenoble. For experienced users, remote data reduction can also be offered with some restrictions enforced on the VISITOR accounts. Please contact your local contact if you're interested in this possibility.
- We keep the data reduction schedule very flexible, but wish to avoid the presence of more than 2 groups at the same time in Grenoble. Data

reduction will be carried out on dedicated computers at IRAM. Please contact us in advance.

- In certain cases, proposers can be provided with updates as their observations progress. This service does not replace a careful data reduction after completion of the project. Please contact your local contact or NOEMA's Science Operations Group (sog@iram.fr) if you are interested in observational updates.

- Observers who wish to finish data reduction at their home institute should obtain the most recent version of CLIC. Because differences between CLIC versions may potentially result in errors if new data are reduced with an old package, we advise observers having a copy of CLIC to take special care in maintaining it up-to-date. The newer versions are downward compatible with the previous releases.

3.12 Technical pre-screening

All proposals will be reviewed for technical feasibility in parallel to being made available to the members of the program committee. Please help in this task by submitting technically precise proposals. Note that your proposal must be complete and exact: the source position and velocity, as well as the requested frequency setup must be correctly given.

3.13 Non-standard observations

If you plan to execute a non-standard program, please contact the Interferometer Science Operations Group (sog@iram.fr) to discuss the feasibility.

3.14 Documentation

Documentation for the IRAM Interferometer can be retrieved from the `NOEMA Documentation web pages`. Detailed information is given in the description of the `Current NOEMA capabilities` (this document), in the `Introduction to the IRAM NOEMA Interferometer`, and in the `Calibration CookBook`.