IRAM NOEMA interferometer

Observing Capabilities and Current Status

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This document is updated twice a year to reflect the 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`. The full links are also given on the last page of this document.

Table 1: Configuration Schedule

Conf	Scheduling Priority Winter 2018/2019
C	November – December
D	December – January
A	January – February
C	February – March
D	March – May

1 Progress of NOEMA

1.1 NOEMA's 10th antenna

The commissioning of antenna 10 is scheduled for the end of summer 2018. We plan to operate with all 10 antennas during the winter period 2018/2019.

2 Conditions for the next winter session

During the course of the winter semester, we plan to schedule three configurations. The number of antennas is dependent on the availability of antenna 10. A preliminary configuration schedule for the winter period is outlined in Table 1. Adjustments to this provisional configuration planning will be made according to commissioning requirements in the frame of NOEMA, proposal pressure, weather conditions, and other contingencies. The configuration schedule given in Table 1 should be taken as a rough guideline, in particular for astronomical targets that cannot be observed during parts of the winter period because of sun avoidance constraints.

The winter semester is preferred for high frequency (1 mm) and high angular resolution observations. Nevertheless, we encourage the submission of proposals that ask for observations at lower frequencies (2 mm & 3 mm) and lower angular resolution for which a significant amount of time can be invested. Observations in band 4 will not be offered this semester.

Unfinished A-rated programs from the current summer semester 2018 will be carried over into the upcoming winter semester. However, B-rated projects (or their sub-parts) from the summer semester 2018 that have not been started by the end of November 2018 will not be carried over and should be re-submitted. Investigators who wish to check the status of their project may consult the `interferometer schedule` on the IRAM website. This page is updated daily.

2.1 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, especially in light of its new capabilities. In particular, your proposal should not only justify the scientific interest, but also the need for NOEMA. Proposers should 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 to explain 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

Table 2: Configurations of the nine- and ten-antenna arrays

Name	Stations									
9D	W12	W09	W05	E10	E04	N13	N09	N05	N02	—
9C	W20	W12	W09	E16	E10	E03	N29	N20	N11	—
9A	W27	W10	E68	E24	E12	E04	N46	N29	N20	—
10D	W12	W08	W05	E10	E04	N17	N13	N09	N05	N02
10C	W23	W20	W09	E23	E18	E10	E03	N20	N17	N11
10A	W27	W23	W08	E68	E24	E16	E03	N46	N29	N20

questions related to the preparation of a proposal.

2.2 Proposal category

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

STANDARD: Proposals that ask for a total of less than 100 h of observing time and for the standard capabilities of NOEMA's current status (see the following sections).

TIME FILLER: Proposals that can be considered as backup 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 are 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, special needs with respect to calibration and more generally all non-standard observations (e.g., very large-field mosaics). These proposals will be carried out on a "best effort" basis. PIs interested in special programs should contact the science operation group (sog@iram.fr) well before the deadline to discuss feasibility and observing strategies.

LARGE PROGRAM: Under the current Call for Proposals, certain restrictions still apply (see the `Large Program Policy` on the IRAM web site for general details). In the frame of NOEMA's construction, additional antennas and more capabilities of the correlator are expected to become available during the "lifetime" of a Large Program, usually spanning over several observing semesters. For the current Call for Proposals, the observing time request should be based on the availability and performance of **the nine-element array**. We might adjust it and/or review the observing strategy in response to PI needs and enhanced array's capabilities. In addition, less than the standard 50% of the total scheduled observing time will be reserved for *Large Programs* using NOEMA at this point. This restriction is necessary to account for the significant investment of technical time still needed to bring the NOEMA project to its full completion in the upcoming years.

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

Within each of these categories, observations in Band 1, 2 and 3 can be requested which are described in more detail in Section 2.4 and in Table 3.

Short spacing observations on the 30-meter telescope should be directly requested on the interferometer proposal web form through `PMS`. A separate proposal for the 30-meter telescope is not required. The interferometer proposal form contains a box, labeled "Request for 30-meter short spacings" which should then be checked. The user will automatically be prompted to fill in an additional paragraph in which the need for short spacing data 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. The following documents may help to prepare your short spacing observations: `this Presentation` (especially page 23 for a brief summary) given at the 9th Interferometry School and `this Technical Report`. For further assistance, please contact the Science Operations Group (sog@iram.fr).

Table 3: Receiver characteristics

	Band 1	Band 2	Band 3
F_{LO1} range/[GHz]*	82.0–108.256	138.616–171.256	207.744–264.384
F_{sky} range/[GHz]*	70.4–119.872	127.000–182.872	196.128–276.000
T_{rec}/[K]**	25–45	35–55	40–70
G_{im}/[dB]	-15-...-10	-15...-10	-15 ... -10

* Guaranteed LO1 frequency ranges per offered band. The LO1 frequency is the center frequency between the USB and LSB that can both be simultaneously observed in one tuning (see Fig 1). The center frequency of the USB (LSB) is separated by +(−)7.744 GHz from the LO1 frequency. With an effective width of 7.744 GHz per sideband the lowest and highest sky frequencies that can be covered per tuning are hence F_{sky}=F_{LO1}±11.616 GHz. The lowest and highest LO1 frequencies per band define the F_{sky} ranges that are guaranteed for this call.
** for LSB and USB.

2.3 Array Configurations

Three main configurations (A, C and D) will be scheduled providing optimum coverage of the uv-plane. Their composition, however, will depend on the number of antennas. The nine- and ten-antenna arrays are hence both specified in Table 2.

The general properties of these configurations (numbers refer to a source at 20° declination and are valid for both the nine- and ten-antenna arrays) are:

- `A` alone is well suited for mapping or size measurements of compact, strong sources. It provides a resolution of ∼ 1.0″ at 100 GHz, ∼0.4″ at 230 GHz.
- `C` provides a fairly complete coverage of the uv-plane and is well adapted to combine with D for low angular resolution studies (∼2.6″ at 100 GHz, ∼1.1″ at 230 GHz) and with A for higher resolution (∼1.4″ at 100 GHz, ∼0.6″ at 230 GHz). C alone (∼2″ at 100 GHz, ∼0.9″ at 230 GHz) is also well suited for snapshot and size measurements, and for detection experiments at low source declination.
- `D` alone is best suited for deep integration and coarse mapping experiments (resolution ∼ 3.9″ at 100 GHz and ∼ 1.7″ at 230 GHz). This configuration provides both the highest sensitivity to extended structures and the lowest atmospheric phase noise.

The three configurations can be used in different combinations to achieve complementary sampling of the uv-plane, and to improve on angular resolution and sensitivity. Mosaicing is usually done with D or CD, but the combination ACD can also be requested (e.g. for high resolution mosaics). Check the ANY bullet in the proposal form if the scientific goals can be reached with any of the three configurations or their subsets. There is a possibility on the PMS web form to restrict the choice of configurations, e.g., to C or D, if your project qualifies for ANY of the more compact configurations.

2.4 Receivers

All NOEMA antennas are equipped with 2SB receivers, providing low noise performance and excellent long-term stability. The receivers provide two orthogonal linear polarizations in all three bands. Each of the two polarizations delivers a bandwidth of 7.744 GHz in the lower sideband (LSB) and upper sideband (USB). The sky frequency ranges that can be covered in each band and further characteristics are given in Table 3.

Receiver tuning will preferentially be done on a fixed LO frequency grid of 500 MHz step width on which the receiver performance is optimized. Tunings that deviate from this tuning grid (see also Section 2.7.1), are still allowed but an explanatory statement should be added to the "technical justification" in the proposal.

2.5 Sensitivity

Investigators will be asked in `PMS` to specify the requested telescope time for each Technical Sheet. Based on the NOEMA performance at the time of publication of this document[1], `PMS` then calculates

[1] RMS noise levels and corresponding telescope times will be calculated in PMS based on a nine-antenna array for this Call for Proposals. As soon as antenna 10 becomes available, adjustments to requested telescope times will be made automatically by conserving requirements concerning RMS noise levels and uv-coverage.

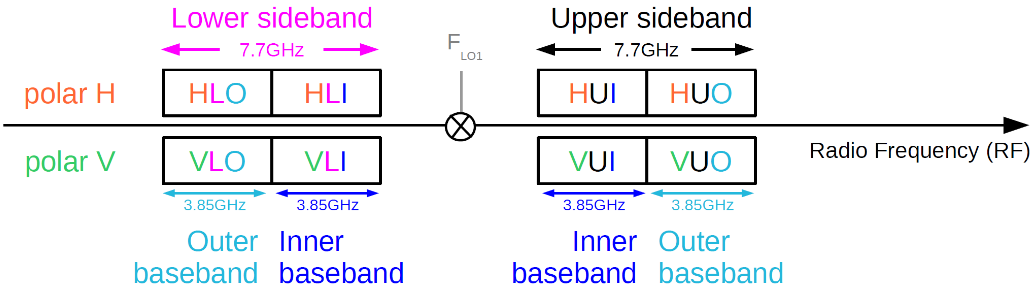

Figure 1: Basebands fed to the correlator

the corresponding 1 sigma point-source sensitivity *for one representative frequency*. The representative frequency has to be within the frequency range and for high spectral resolution projects within one of the spectral chunks that are selected in the respective technical sheet. The representative frequency does not have to be identical to the actual tuning frequency. Please note, that due to the large bandwidth and the dual-sideband mode, the noise can vary significantly with frequency in the available frequency range. Especially, if one of the sidebands is close to a receiver band edge, significant differences in the noise can occur within and between the sidebands. This should be taken into consideration when setting the representative frequency for each tuning. Please note that the newest version of PMS and ASTRO take into account variations of the noise across the entire 15.488 GHz bandwidth band to calculate the *continuum* sensitivity.

The same sensitivity calculation as done in `PMS` is also available in ASTRO through the *NOEMA Proposal Sensitivity estimator* (please use GILDAS version `aug18` or later). Both tools also account for the declination of the source to estimate the rms noise levels. Longer telescope times are needed for sources at low declinations ($\delta < -10^\circ$) than for those at high declinations to achieve the same point-source sensitivity.

Investigators should specify and justify the telescope times and corresponding point-source sensitivities in the "technical justification" of their proposal. **Please verify that your numbers match throughout the proposal**.

2.6 Track-Sharing Mode

Each technical sheet, i.e. frequency tuning, can be connected to several sources in `PMS`. In case the sources, sharing the same tuning, are reasonably close to each other and need rather short integrations times, `PMS` allows to the PI to specify a track-sharing mode (please check the track-sharing box in the technical sheet in `PMS`) which will result in a lower overall telescope time due to reduced overheads. Please note that `PMS` will issue a warning should the maximum distance between the track-shared sources exceeds a recommended 15 degrees and/or should the number of track-shared sources be larger than 15. These limitations have been chosen, among other reasons, to allow for gain calibrators that can still be reasonably close to all sources and to reduce observing overheads due to slewing and calibration needs. However, the feasibility of track-sharing is not guaranteed even if no warning is given by `PMS`. In particular, Doppler tracking will be done by default on the mean LSR velocity of the targets (requests for other tracking modes should be justified). Users should check that the spectral lines of the two targets with the highest velocity difference to the mean velocity will not move out of the selected frequency range, which is especially important wiht respect to the frequency coverage of selected high spectral resolution chunks. Therefore, special care has to be applied when configuring the spectral setup.

2.7 PolyFiX

PolyFiX can process a total, instantaneous bandwidth of 31 GHz for up to twelve antennas that is split up into two polarisations in each of the two available sidebands (the *upper* and *lower* sideband). The centers of the two 7.744 GHz wide sidebands are separated by 15.488 GHz. Each sideband is composed of two adjacent *basebands* of ∼3.9 GHz width that are called *inner* and *outer* basebands (see Fig. 1). In total, there are thus eight basebands which are fed into the correlator. The spectral resolution will be 2 MHz throughout the 15.488 GHz effective bandwidth per polarization. Additionally, up to sixteen high-resolution *chunks* can be selected in each of the eight basebands (i.e. up to 128 chunks in total). Each of these has a width of 64 MHz and, in this first implementation step of *PolyFiX*, a fixed spectral resolution of 62.5 kHz. A number of contiguous chunks defines one *spectral window (SPW)*.

Please note that there is a "non-exploitable, 20 MHz wide frequency area" (≡ LO2 zone) around the center of each sideband, i.e., in between the inner and outer basebands. Due to the filter response of the correlator, the noise level is also increased by up to a factor of two within a width of ±50 MHz around the center in each sideband. Thus, important lines should not be placed there (see also pages 19 and 20 in `this PolyFiX tutorial`).

2.7.1 ASTRO

The software ASTRO should be used to set up the receiver and correlator configuration. A description of the *PolyFiX* correlator and of the commands provided in ASTRO to prepare the correlator configuration can be found in `this PolyFiX tutorial`. Please use the `aug18` version (or later) of GILDAS.

The essential ASTRO commands are:

- `TUNING`: receiver tuning
- `BASEBAND`: selection of baseband(s)
- `SPW`: selection of chunks to define high resolution spectral windows
- `PROPOSAL`: exports a script that needs to be uploaded to `PMS`

Receiver tuning is done on a fixed grid of LO frequencies, spaced by 500 MHz throughout each receiver band, on which the receiver performance is optimized. For a correct receiver tuning, either the source LSR velocity or the redshift is needed or the (red)shifted frequencies should be used directly. In the latter case, the LSR velocity (or redshift) has to be set to zero in the source command. Also, the frequencies of molecular lines from the standard line catalogue in ASTRO that can be plotted over the spectrum (by setting `set lines on` in ASTRO) have to be redshifted by hand, i.e., a revised molecular catalogue needs to be uploaded in ASTRO (with `catalogue myfile.lin /LINE`). For more details see the internal help for the different ASTRO commands and `this PolyFiX tutorial`.

A typical session in ASTRO would be:

```
! Define a source with LSR velocity
SOURCE TOTO EQ 2000 09:11:39.786 -
                     30:53:29.257 LSR 7.0

! choice of receiver tuning
TUNING 232.686 LSB 7500
! ASTRO will shift the IF centering by
! 180.6MHz to match the tuning grid

TUNING 232.686 LSB 7319.4 /ZOOM
! Plots the selected receiver band only

BASEBAND
! select all 8 basebands

! define and display high resolution
! spectral windows (central frequency
! and width specified)
SPW /FREQUENCY 244.9 0.2
SPW /FREQUENCY 245.6 0.2
SPW /FREQUENCY 232.686 0.03
SPW /FREQUENCY 230.538 0.08
SPW /FREQUENCY 231.15 0.3
...
PROPOSAL /FILE MyFile.astro
! write the series of commands
! to set up the instrument;
! THE MyFile.astro NEEDS TO BE
! UPLOADED TO PMS
```

The `TUNING` command produces a plot showing the full 15.488 GHz bandwidth covered in both sidebands. The TUNING command checks that the LO frequency is located on the 500 MHz-spaced tuning grid. If this is not the case, the command moves the tuned frequency to a neighboring IF center frequency that matches the grid. The option /FIXED_FREQ can be used to ignore the tuning grid (e.g., if using the tuning grid does not cover all desired lines with the proposed tuning or a contiguous spectral scan is requested).

PMS will only accept to load ASTRO scripts created with the NOEMA OFFLINE syntax, i.e., with the PROPOSAL command. This will allow PMS to show spectral coverages in a consistent way for any kind of projects (including line markers at the correct rest frequency for redshifted sources for instance).

Old NOEMA ONLINE language scripts, i.e. created by the SETUP command (e.g., from the W17 semester) can be converted by typing in ASTRO:

```
OBSERVATORY NOEMA ONLINE
@ MyOnLineScript.astro
PROPOSAL /FILE MyOfflineScript.astro
```

Note that the scripts uploaded to PMS during the W17 session have been automatically converted into OFFLINE syntax in PMS. They can thus be directly cut and paste within PMS.

2.8 Source coordinates and Velocities

The interferometer operates in the equatorial J2000.0 coordinate system. Please do not forget to specify the exact coordinates and 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. Source coordinates and velocities must be correct: wrong or incomplete source coordinates are a potential cause for proposal rejection.

A later swap of targets is not foreseen for regular projects.

Please note that targets below a declination of -30 degrees are not observable from the NOEMA site as their elevations hardly exceeds $\geq$10 deg during a reasonably long LST range. Very low-declination sources between declinations of -30 and -25 degrees are extremely complicated to observe as well as they do not rise much above 10 degrees in elevation; if you are considering to observe such a very low-declination source please contact the science operation group well before the deadline (at sog@iram.fr) to discuss feasibility and observing strategies. For all other sources (i.e. mostly those between -25 and -10 degree declinations), please take into account the comments given in previous sections.

2.9 Sun Avoidance

For safety reasons, a sun avoidance circle is enforced at 32 degrees from the sun.

2.10 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.

2.10.1 Duplication Check

In order to ensure the most efficient use of the NOEMA interferometer, proposals will be checked for duplication during the technical pre-screening. Unless scientifically justified, proposals that aim to reach the same goals as programs observed in previous semesters with similar or equivalent observing configurations with respect to target selection, observing frequency, angular resolution and sensitivity will not be accepted. Header information of PdBI/NOEMA observations later than 1991 but before October 2016 (for this Call) can be found in the CDS VizieR catalogue (*Centre de Données astronomiques de Strasbourg*). In the future, PIs will be able to perform a duplication check of their proposals also against programs observed in more recent semesters. However, for this deadline we kindly ask the PIs to contact the NOEMA science operations group at sog@iram.fr in case of doubts concerning duplication of observing programs from the last two years.

2.11 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 and possible observing strategies. Non-standard observations are very large-field mosaics, projects that need special calibration (e.g., the detection of very weak lines over a very strong continuum), or projects that target frequencies that may fall (slightly) out of the guaranteed tuning ranges (see Table 3), to give a few examples.

2.12 Documentation

Documentation for the IRAM Interferometer can be retrieved from the following link: `NOEMA Documentation web pages`. Detailed up-to-date information is currently only available in the description of the `Current NOEMA capabilities` (i.e., this document).

2.13 Local Contact

A local contact will be assigned to every A and B rated proposal which does not already 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.

2.14 Data reduction

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

- We strongly recommend that proposers reduce their data in Grenoble. Remote data reduction can currently only be offered in exceptional cases. 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 two 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 backward compatible with the previous releases.

Links to online documentation mentioned in the text:

IRAM Web Pages:
http://iram-institute.org/EN/content-page-56-7-56-0-0-0.html

The Proposal Management System PMS:
http://pms.iram.fr

GILDAS Version aug18:
http://www.iram.fr/~gildas/dist/index.html

Interferometer Schedule:
http://www.iram.fr/IRAMFR/PDB/ongoing-last.html

Large Program Policy:
http://www.iram-institute.org/EN/content-page-243-7-158-243-0-0.html

Interferometry School Presentation on Short-Spacings:
http://www.iram.fr/IRAMFR/IS/IS2016/presentations/pety-mosaicking.pdf

Technical Report on Short-Spacings:
http://www.iram-institute.org/medias/uploads/IRAM_memo_2008-2-short-spacings.pd

PolyFiX tutorial:
http://www.iram.fr/~gildas/demos/astro/demo-astro-noema.pdf

The CDS VizieR catalogue:
http://vizier.u-strasbg.fr/viz-bin/VizieR-3?-source=B/iram/pdbi

NOEMA Documentation web pages:
http://www.iram-institute.org/EN/content-page-96-7-56-96-0-0.html

Current NOEMA capabilities:
http://www.iram.fr/IRAMFR/GENERAL/calls/w18/NOEMACapabilities.pdf