NOEMA & 30m

IPAG 06.06.2018
IRAM is funded by CNRS (France) – Max-Planck-Gesellschaft (Germany) – IGN (Spain)

Two mm observatories: 30-m on Pico Velata (Sierra Nevada, Spain) and NOEMA interferometer on Plateau de Bure (French Alps)

Technical/software/support center in Grenoble, France
INVESTIGATOR DISTRIBUTION MAP
2010 – 2016

- 85% France, Germany, Spain
- 15% open time
- Individual investigators: 1790
- Countries: 43
Northern Extended Millimeter Array
Extension of the IRAM Plateau de Bure interferometer
<table>
<thead>
<tr>
<th>NOEMA Phase I (2018)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 new antennas (7-8-9-10)</td>
</tr>
<tr>
<td>new receivers (4 bands, 70-350 GHz)</td>
</tr>
<tr>
<td>12-antennas correlator</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>NOEMA Phase II (2020)</th>
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</thead>
<tbody>
<tr>
<td>2 new antennas (11-12)</td>
</tr>
<tr>
<td>Baseline extension (1.6 km)</td>
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</tbody>
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<table>
<thead>
<tr>
<th>NOEMA Extensions</th>
</tr>
</thead>
<tbody>
<tr>
<td>VLBI</td>
</tr>
<tr>
<td>Refurbishment antennas 1-6</td>
</tr>
<tr>
<td>Dual band observations (Rx + Corr.)</td>
</tr>
</tbody>
</table>
NOEMA external partnerships
### NOEMA factsheet

**Collecting area**

<table>
<thead>
<tr>
<th></th>
<th>Interferometry</th>
<th>Short spacings</th>
</tr>
</thead>
<tbody>
<tr>
<td>ALMA/ACA</td>
<td>5655 m²</td>
<td>914 m²</td>
</tr>
<tr>
<td>NOEMA/30m</td>
<td>2121 m²</td>
<td>707 m²</td>
</tr>
</tbody>
</table>

**Bandwidth per polarization**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>PdBI</td>
<td>4 GHz</td>
</tr>
<tr>
<td>ALMA</td>
<td>2 x 4 GHz</td>
</tr>
<tr>
<td>NOEMA/30m</td>
<td>2 x 8 GHz</td>
</tr>
</tbody>
</table>

Other parameters: Trec receivers, Tsys atmosphere, correleror efficiency, number of antennas, etc.
## NOEMA factsheet

### Sensitivity NOEMA vs ALMA

<table>
<thead>
<tr>
<th>Category</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Line observations</td>
<td>&gt; 45%</td>
</tr>
<tr>
<td>Continuum observations &amp; spectral</td>
<td>&gt; 65%</td>
</tr>
</tbody>
</table>

### Additional NOEMA gains

<table>
<thead>
<tr>
<th>Category</th>
<th>Gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larger bandwidth</td>
<td>Gain of factor 2 in observing time for spectral surveys</td>
</tr>
<tr>
<td>Dual-band observations</td>
<td>Gain of factor 2 in observing time for multi-bands projects</td>
</tr>
<tr>
<td>Correlator</td>
<td>Full continuum sensitivity for all observations</td>
</tr>
<tr>
<td>Correlator</td>
<td>High flexibility: many high-resolution lines simultaneously</td>
</tr>
</tbody>
</table>
Antenna 7 inauguration, 22 September 2014
NOEMA with 8 antennas, April 2016
NOEMA with 9 antennas, June 2017
PolyFiX correlator, September 2017
Surface rms Antenna 8 = 26 μm
2 polar x 2 sidebands x 8 GHz = 32 GHz/antenna
NOEMA receivers

16 GHz instantaneous bandwidth per polarization
• 5th generation receivers
• 4 bands covering 70-370 GHz
• 2 polar x 2 sidebands x 8 GHz IF = 32 GHz/ant.

EMIR @ 30-m has similar performances: installed in 2009 + upgrades in 2010-15
NOEMA correlator: PolyFiX

PolyFiX : FX correlator + based on FPGAs

- Simultaneous 32 GHz continuum and line capabilities
- Up to 128 spectral windows, up to 150000 spectral channels
**Mode 1: continuum + lines**  
Complete 16 GHz coverage in each polar. with 2 MHz channels

**AND**

128 windows of 64 MHz (= 8 GHz coverage) with 62.5 kHz channels, each window tunable individually in steps of 64 MHz*

**Mode 2: survey mode**  
Complete 16 GHz coverage in each polar. with 250 kHz channels

**Mode 3: continuum + high-res. lines**  
Same as mode 1, but with 64/32/16 windows of 64 MHz with 32/15/8 kHz channels

* With the constrain of having 16 windows in each of the 8 4 GHz-wide correlator units
Spectral windows:
- df = 2000.0 kHz
- df = 62.5 kHz
- 64/128 flexible chunks used

REST: 230.538 GHz (LSR: 230.538, RF: 230.538) IF1: 5000.000 MHz USB

Half the most narrow SPW is equivalent to an offset of 83.226 km/s in source LSR velocity.

Band 3

LO2 zone

24-APR-2018 00:00:00.0

V shift
V_{LSR} = 0.0 km s^{-1}
V_{Dop} = 0.0 km s^{-1}

SPW coverage for V_{LSR} = 0.000 km s^{-1}

df = 62.5 kHz  df = 2000.0 kHz
NOEMA correlator: PolyFiX

Frequency setup optimized for spectral surveys
Wide-band spectroscopy with PolyFiX

- 7.2 hr on-source with nine antennas, two frequency setups
- continuum detected with a dynamic range 200:1

HLS J091828+5414223 (z = 5.2)  
Herrera et al. in prep
The outflow driven by the protostellar object L1157 is a perfect laboratory to study shock chemistry.

Methanol (CH$_3$OH) emission is enhanced in the outflow shocks, and triggers further reactions leading to more complex organic species.

López-Sepulcre et al. in prep.
Deuteration fractionation of a borderline Class 0/I environment with multiple tracers

Deuteration Fractionation:
- seems to decrease from Class 0 protostars to disks
- but varies from one molecule to the other (low vs high temperature formation route)
1st 1mm line scan on evolved star: H$_2$O around RS Cnc

(Winters et al. in prep.)
NOEMA: next steps

- Antenna 10: summer 2018
- Antenna 11: end 2019
- Antenna 12 – TBD
- Baseline extensions: 2020
- Dual-band capabilities: 2020
  - Simultaneous observations with two bands (e.g. 3 + 1.3 mm): gain in observing time + calibration accuracy
30m telescope
• New generation continuum receiver
• 1000 pixels @ 2mm with sensitivity goal = 10 mJy.s\(^{-0.5}\)
• 2000 pixels @ 1mm (x two polars) with goal = 15 mJy.s\(^{-0.5}\)
• FOV = 6.5 arcmin (new receiver cabin optics since April 2015)
• KIDs technology

• NIKA2 consortium PI = A.Benoit/A.Monfardini Institut Neel, Grenoble
• IPAG, LPSC, IAS, CEA Saclay, Cardiff + IAP, IRAP, LAM

• Science case : large-scale mapping star formation regions, external galaxies, high-z sources, SZ, ...

• NIKA2 installed in October 2015, now offered to community
NIKA2 2mm 2°x1° map of the Galactic plane around 24° longitude — GASTON

Peretto, Rigby et al. 2018, EWASS, Liverpool
Similar to NOEMA: 2 polar x 2 sidebands x 8 GHz
Dual-band observations capabilities

<table>
<thead>
<tr>
<th>Band</th>
<th>Frequency Range</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1</td>
<td>83-116 GHz</td>
<td>70-116 GHz</td>
</tr>
<tr>
<td>Band 2</td>
<td>124-184 GHz</td>
<td></td>
</tr>
<tr>
<td>Band 3</td>
<td>202-274 GHz</td>
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<tr>
<td>Band 4</td>
<td>277-375 GHz</td>
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</tbody>
</table>
Spectral wide-field imaging @ IRAM-30m

$C^{18}O \, J=1-0, \, ^{13}CO \, J=1-0, \, ^{12}CO \, J=1-0$

Integration time 124 hours.
Field of view $0.81 \times 1.10^\circ$, i.e., 0.9 square degree.
Observing mode Position switched On-The-Fly (mostly a single coverage).
Spatial resolution From 22.5'' to 30.5'' ($\sim 50$ mpc), i.e. Nyquist sampling $\Rightarrow$ images of $315 \times 420$ pixels.
Bandwidth 32 GHz (2 tunings) from 84 to 116 GHz.
Spectral resolution 200 kHz resolution, i.e., $0.5 - 0.7 \text{ km s}^{-1}$.
Number of channels $\Rightarrow 160 000$ channels, i.e., at 24 images per seconds, it makes a movie of 1h50!
Field of view $\times$ channels $144 000$ channel $\times$ square degree (i.e., the equivalent of twice of the sky in 5 days!).
Median noise level 0.1 to 0.5 K ($T_{\text{mb}}$).
A sea of noise Clear signal detected in $\sim 800$ channels, or 0.5% of the data (a video of about 30 seconds).
Data size 900 GB of raw data.

Outstanding Radio-Imaging of OrioN-B

J. Pety 2018
Multi-beam projects

Multi-beam receivers projects for Pico Veleta

- 3 mm 5x5 pixels
- 1.3 mm 7x7 pixels
- Same pixel performances as EMIR: 2 polar, 2SB, 16 GHz IF

Common 300K optics:
- 1 focusing mirror
- 2 flat mirrors
- 1 dichroic filter?