The IRAM 30m Telescope on Pico Veleta

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IRAM 30m telescope

- Properties
- Thermal control & de-icing
- Aperture efficiencies, gain-elevation curves
- Planned upgrade of the telescope
- Frontends & history
- Science Highlights
The IRAM 30m telescope

- Instituto Radioastronomia Milimetrica, IRAM, a French-German-Spanish collaboration.
- Two observatories:
  + Northern Exended Millimeter Array, NOEMA at Plateau de Bure / France
  + the 30m telescope at the Pico Veleta / Sierra Nevada / Spain.
  - 2850m altitude, 37° latitude
  - Seasonal variation of the amount of precipitable water vapour:
    - Winter months October - March: 50% < 4.2mm, 25% < 3mm
    - Summer months April - September: 50% < 6mm, 25% < 4.2mm
  - In operation since 1985, day and night, 365 days per year.
  - Surface accuracy ~ 60µm rms. No active surface.
  - Thermally controlled back structure and yoke. Panel de-icing system.
  - Wobbling subreflector ±2'
  - Observing up to 18-20 m/s wind speed
  - Sun avoidance radius = 1°
  - More than four generations of new instrumentation.
  - Planned upgrade of the telescope in coming years.
Today's and Future role of the IRAM 30m telescope

- Large bandwidth multi band spectroscopy in range 70 to 370 GHz
- Large high sensitivity maps in line and continuum with resolutions 7” to 35”.
  - Mapping-out structure of gas and dust in clouds of the Milky Way and in nearby galaxies
  - Detailed chemical studies of individual sources and regions (3D mapping)
  - Low Surface Brightness Science: Sunyaev-Zel’dovich Effect, diffuse molecular gas
- Essential short spacing tool for NOEMA and ALMA
- Polarimetry of Galactic Structures
- Essential high sensitivity mm VLBI station
Thermal control at the 30m

- Thermal drifts can affect pointing, focus, reflector surface.
- Passive control: paint, insulation, closed back structure
- Active control: ventilated and climatized backup structure. Since 2000, ventilation and heating of yoke.
- Temperature uniformity between the yoke, the backup structure, and the quadripod less than ±1°C
- Temperature uniformity of the backup structure \(\text{rms}(T_{\text{BUS}})\) of less than 0.5°C.
- The present system (after 2000) has 150 temperature sensors in the backup structure and in the yoke.

Pedestal-yoke supported reflector. 1: yoke, 2: backup structure, 3: central tower on azimuth bearing, 4: quadripod. Solid square: reference temperature of the yoke to which the temperature of the backup structure and quadripod are actively controlled. Baars et al. (1988)
De-icing

- Heating is installed at panel rear side, the reflector rear cladding, yoke surfaces, quadripod, and subreflector, to avoid icing when it is raining at freezing temperatures.
- This keeps the panel front surfaces free of ice, but some ice and icicles may still form at cold edges.
- After the storm and switching-off de-icing the telescope needs about 6 hours to recover a thermally stable state.
The current aperture efficiency drops with frequency from 66% to 46% at 230GHz.
At 230 GHz, the beam is broadened by error beams containing 25% of the power. And the point source sensitivity drops by ~25% at low and high elevations. This behaviour is expected and understood!
The pre-study by industry done in 2018 indicates that the surface rms and the gain-elevation curve can be improved with two actions:

1/ Re-aligning all 420 panels on their 210 sub-frames. After dis-mouting the frames and panels, the panel plaint will also be replaced.

2/ Installing about 50-60 actuators, to use lookup-tables, to flatten the gain-elevation curve.
Why upgrading the 30m?

- **Improved surface accuracy** will
  - improve the beam efficiencies, **sensitivities**, calibration accuracy, and also
  - **imaging quality** in particular, beyond 200 GHz, and for low declination sources.
- Its first **surface paint layer** will be replaced, leading to improved thermal behaviour and improved ability to observe under day-time conditions, and near the sun.
- **New servo and control system** will improve
  - **Slewing and tracking speeds** to:
    - allow for more efficient observations of Galactic GMCs, and to better overcome atmospheric fluctuations for NIKA2 observations,
    - and to raise the **elevation limit** beyond 83°.
  - **Reaction to wind** will be improved, improving tracking performance, and losses of observing time due to high wind.
  - Implementation of **new scanning patterns** will be easier.
Instrumentation: Status and Future Evolution

- EMIR for 3mm, 2mm, 1mm, 0.8mm with high resolution backends for up to 32 GHz total bandwidth

- HERA, an heterodyne 3x3 dual-polarisation array at 1.3mm

- NIKA2, continuum imager for simultaneous observations at 1 and 2mm with 6’ Field-of-View and polarization capability at 1mm.

- The future 5x5 pixel 3mm and 7x7 pixel 1.3mm heterodyne arrays
Lessons learned: EMIR

- Go in small steps for hardware, but also for software! Teamwork!

<table>
<thead>
<tr>
<th>Contents</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <strong>EMIR Users Guide</strong></td>
</tr>
<tr>
<td>1. [News](last update: 25-Apr-2017, CM)</td>
</tr>
<tr>
<td>2. <strong>Upgrades</strong></td>
</tr>
<tr>
<td>1. <a href="#">Sep-2016: New dichroic for E0/E2 dual-band operation</a></td>
</tr>
<tr>
<td>2. <a href="#">Dec-2015: New 2SB mixers for E0 and E1</a></td>
</tr>
<tr>
<td>3. <a href="#">Sep-2013: 2SB mixers for E1</a></td>
</tr>
<tr>
<td>4. <a href="#">Nov-2011: 2SB mixers for E2 and E3</a></td>
</tr>
<tr>
<td>5. <a href="#">Jul-2011: 32GHz IF-system, FTS backends</a></td>
</tr>
</tbody>
</table>

- GILDAS software package:
  - observers interface: PAKO — specific to all observations with the 30m
  - spectral line calibration package: MIRA / MRTCAL — specific to the 30m
  - spectral line data reduction package: CLASS — used at a variety of observatories
Lessons learned: NIKA2

- NIKA Pathfinder
  - 10/2009: 1st light with 69 KIDs at 150 GHz
  - 10/2010: Technical run with dual-band camera
  - 2011-2014: 7 technical campaigns
  - 2014-2015: NIKA opened to the community
- NIKA2 commissioning
  - 10/2015: Installation and first light
  - 1/2016: complete readout electronics
  - 1/2016 - 4/2017: 10 commissioning campaigns
  - 9/2017: IRAM end-of-commissioning review. Adam et al. 2018: The NIKA2 camera for the 30m telescope
  - Since 10/2017, NIKA2 is available to the community
  Ruppin et al. 2018: First SZ mapping with NIKA2

- 2nd Phase of Commissioning:
  - 11/2017 - 11/2018: 1mm polarimetry
  - In-situ measurements of bandpasses using Martin-Puplett Interferometer
  - 8/2018: Installation of new dichroic built in Cardiff
  - 9/2018: Commissioning of new data acquisition software
  - Ongoing: Data processing software: quick view and offline data reduction
IRC+10216

\[ T_{\text{MB}}(^{12}\text{CO } J=2-1) \text{ in IRC+10216 with the IRAM 30m Telescope} \]

- Mass loss of AGB stars via stellar ejecta enrich the ISM and largely control the chemical evolution of galaxies
- Here, CO emission of the shells of carbon-rich AGB star IRC+10216 at 120pc distance
- Envelope is nearly spherical, expanding at 14.5 km/s.
- The resolution of 11" corresponds to an expansion time of 500 yr. The map shows the mass loss history of the last 8000 yr. The typical shell separation is 800-1000 yr.
- A companion star with a period of 800 yr would explain all key features.
- Cernicharo et al. 2015, A&A, 575, A91
- IRC+10216 exhibits a very rich chemistry. Nearly 50% of the known interstellar species have been found here.
Detection of methyl silane CH$_3$SiH$_3$ in IRC+10216

- The detection of organo-silicon molecule CH$_3$SiH$_3$ may help in understanding of silicon-carbon chemistries in the inner envelope of AGB stars, and the formation of SiC grains from gas-phase Si$_n$C$_m$.
- Ten rotational transitions detected with the IRAM 30m telescope between 80 and 350 GHz: J=4-3 to J=16-15
- Blue: Observed spectrum
  Green: Modelled CH$_3$SiH$_3$ spectrum
  Red arrows indicate K-ladder.
IRC+10216

Periodic time variability of C₄H, C₂H, CN in IRC+10216

Period = 635 days

NIKA2 maps of a $2^\circ \times 1^\circ$ region of the Galactic plane

Sites of high and low mass star formation, and infrared dark clouds towards the Galactic plane at 24° longitude. Thermal dust emission, but also radio free-free and synchrotron emission. Aiming to study dust emissivity variations and the evolution of cold dust properties.

NIKA2 continuum camera at the 30m telescope: 3000 pixels at 2mm and 1mm, using superconducting KID detectors at 150mK. Fast scanning 60″-70″/s and fast sampling with 24 Hz to overcome atmospheric fluctuations and to detect the extended emission.

Ancillary data available from Planck, Herschel, APEX. A large 30m program by Peretto, Rigby et al. 2018, EWASS.
Sunyaev-Zel’dovich map of a galaxy cluster

- Sunyaev-Zeldovich map of the galaxy cluster PSZ2G144.83+25.11 at z=0.58
- 11 hours observation time in April 2017 under average summer conditions
- Thermal pressure profile from NIKA2/30m
- combined with electron density profile from XMM-Newton

thermal SZ-effect: Inverse Compton scattering of Cosmic Background photons on electrons of the hot intra-cluster medium, leads to distortion of CMB spectrum.
Pulsar with strong B-field, $>10^{13}$ G, discovered 2013 at only 2.4as distance to Sgr A* in X-rays and at radio wavelengths. Period = 3.76s.

Follow-up observations with the 30m telescope reveal strong, variable, polarised emission at 3.45 to 1mm wavelengths. $\langle \alpha \rangle = +0.4$

Torne et al. 2015, 2017

Many more pulsars are predicted to exist in the vicinity of the Galactic Center super-massive black hole Sgr A*.

VLBI observations at 1mm aim at imaging the Event Horizon of the Galactic Center black hole with 26 micro-as resolution using simultaneous observations with 9 observatories, including the 30m.
Event Horizon Telescope (EHT)

- The EHT is made-up of 9 radio telescopes spread around the globe, to create an Earth-sized mm interferometer. It is VLBI at 1.3mm wavelength.

- Main goals are to image the silhouette of the super-massive black holes against the bright surrounding matter, in the Galactic Center and in M87 with unsurpassed angular resolution of ~20µas.

- 1st and 2nd EHT runs in April 2017 and 2018. The IRAM 30m telescope successfully participated for both runs. In April 2019, NOEMA plans to join the EHT project.