Radiotelescopio IRAM Pico Veleta

Miguel Sánchez-Portal & Manuel Castillo-Fraile

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The Institute

The "Instituto de Radioastronomía Milimétrica" (IRAM) is a French (CNRS)-German (MPG)-Spanish (IGN) institute, founded in 1979. The headquarters are located in Grenoble (France) with offices in Granada (Spain).

IRAM operates two observatories, namely NOEMA (Northern Extended Millimetre Array) and the 30-meter MRT telescope.

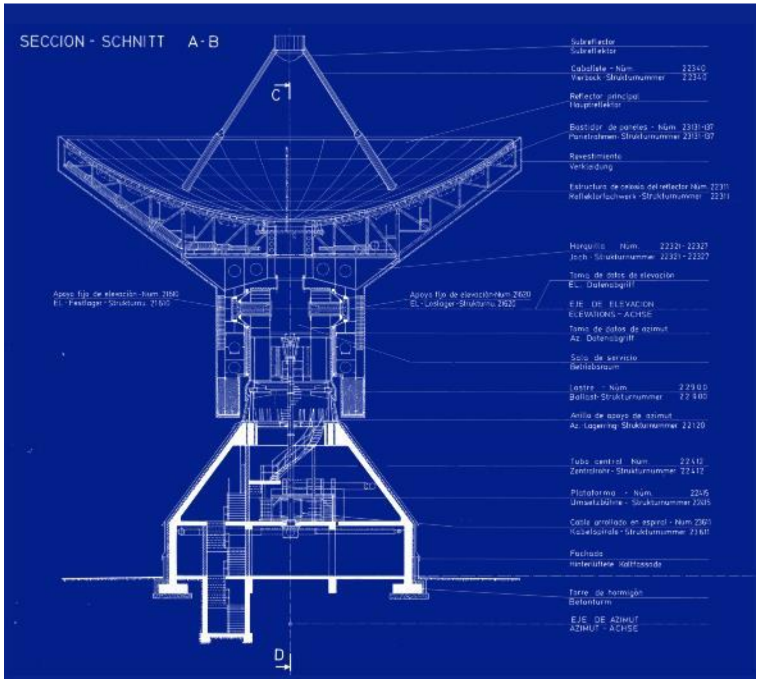
The Observatory

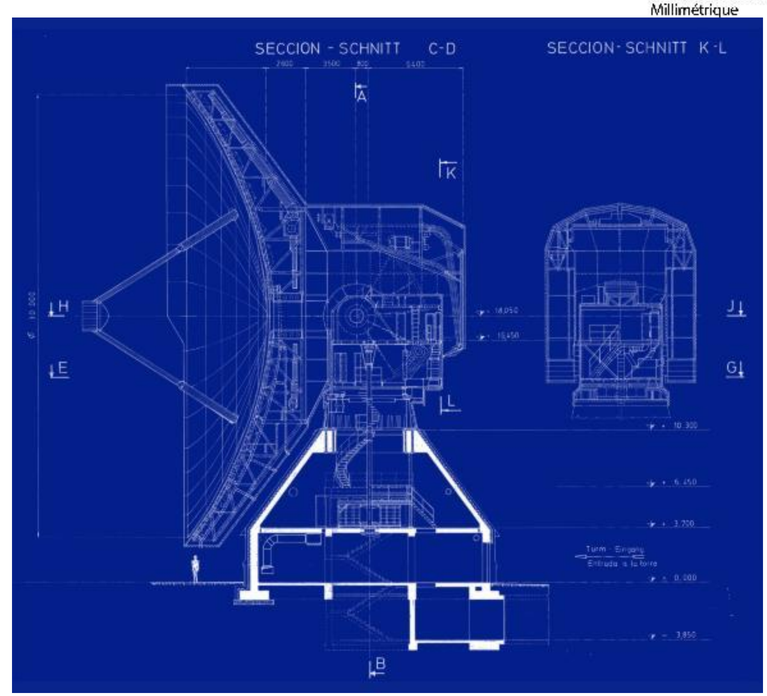
Inaugurated in 1984, the 30-meter MRT is sitting at 2850m in the *Loma de Dílar* in *Sierra Nevada*, in Granada, Southern Spain.

- **High-altitude (2850 m)** allows observing around or beyond 350 GHz (sub-mm range)
- **Low-latitude (37º N)** permits easy access to the Galactic Centre.

The 30-meter is one of the facilities within the Map of ICTS, integrated in the Spanish Network of Astronomy Infrastructures (RIA).

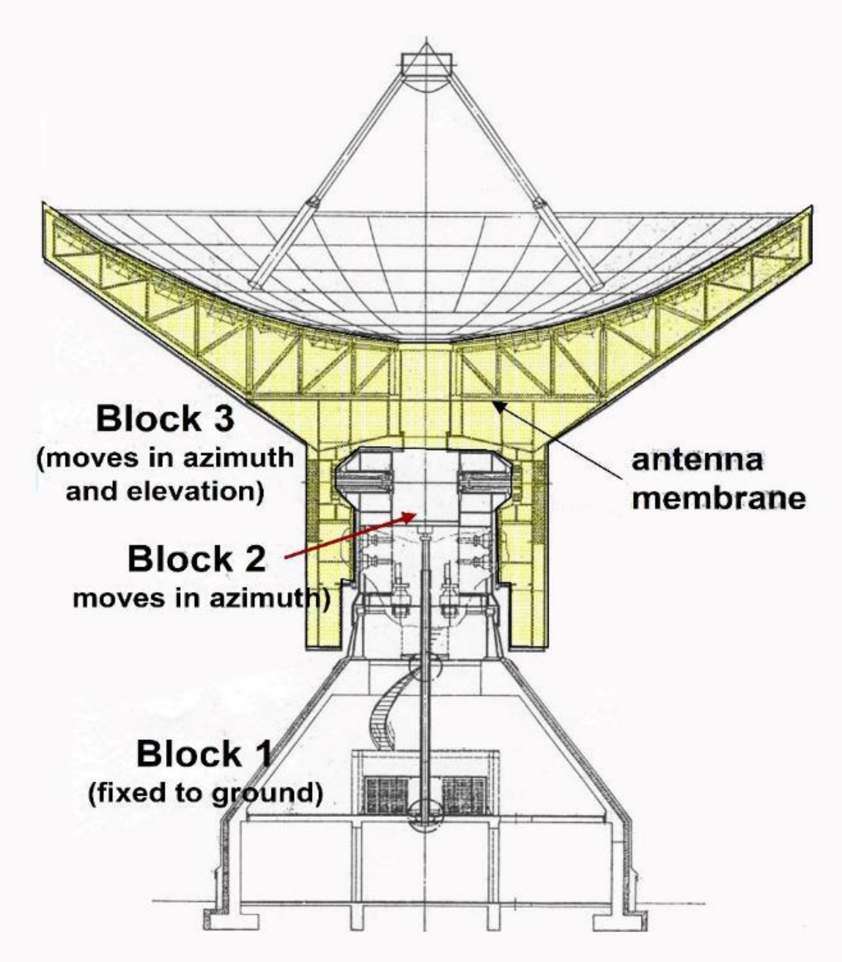
The Radio Telescope





- The 30-meter MRT telescope consists of a parabolic antenna with an altazimuth mount. Built in steel. **Total Weight** (excluding concrete pier): 800t
- **Quasi-homologous design**. **Cassegrain/Nasmyth optical configuration**.
- **Large aperture (30m)** ensuring high sensitivity and excellent resolving power (11/7.5 arcsec HPBW at 230/340 GHz). Excellent imaging quality.
- **High mirror/surface accuracy** (around 60 μm) making it very efficient

Thermal control

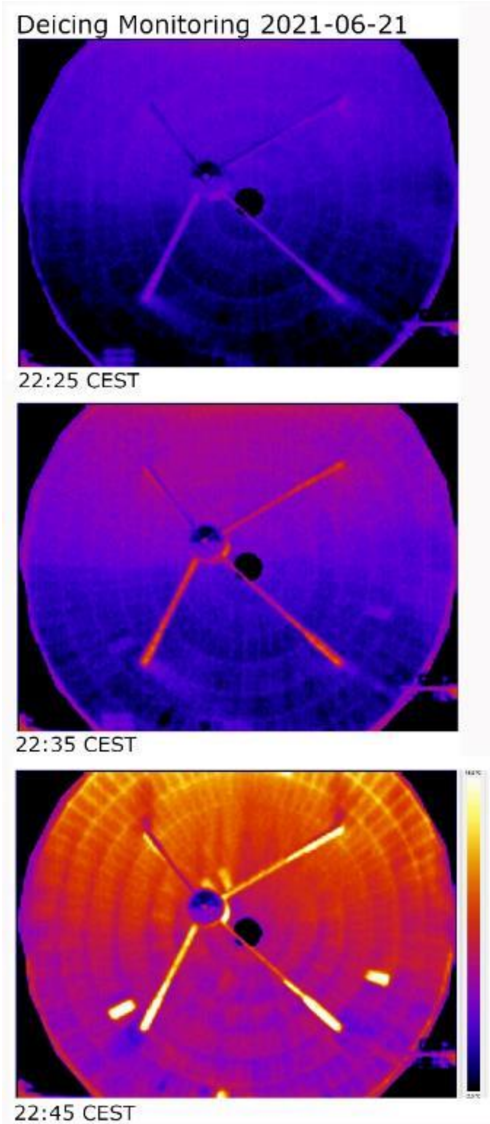


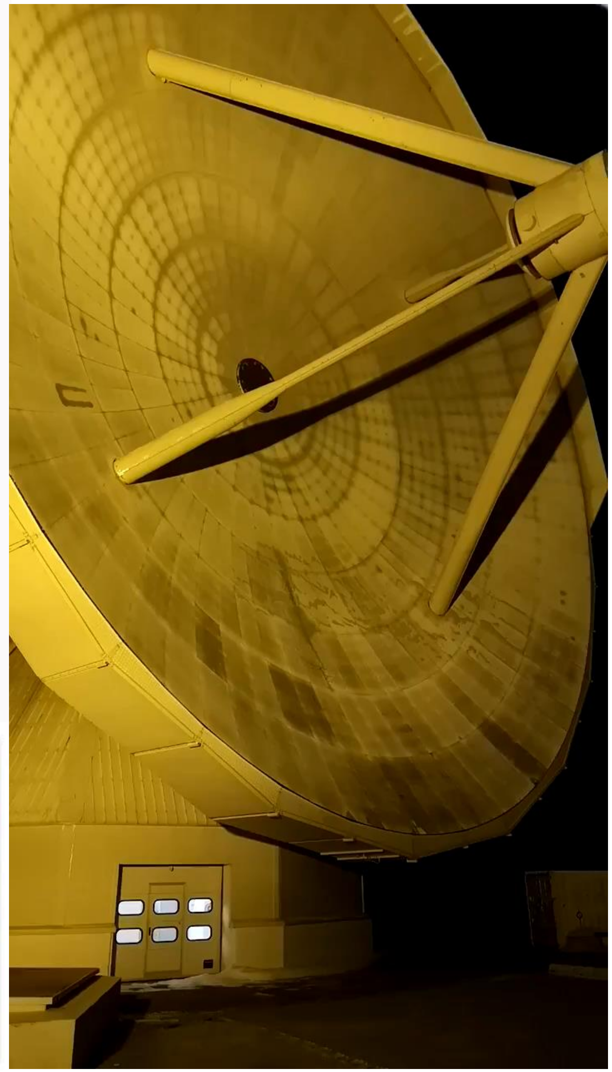
- Thermal drifts can affect pointing, focus, reflector surface.
- Passive control: paint, insulation, closed back structure
- Active control: ventilated and climatized backup structure and quadripod. Ventilation and heating of yoke, counter-weights. This greatly reduces astigmatism.
- Temperature uniformity between the yoke, the backup structure, and the quadripod less than ±1°C with respect to the reference temperature.
- Temperature uniformity of the backup structure rms (TBUS) of less than 0.5°C.

De-icing

Heating is installed at panel rear side, the reflector rear cladding, yoke surfaces, quadripod, and sub-reflector, 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 deicing the telescope needs about 6 hours to recover a thermally stable state.

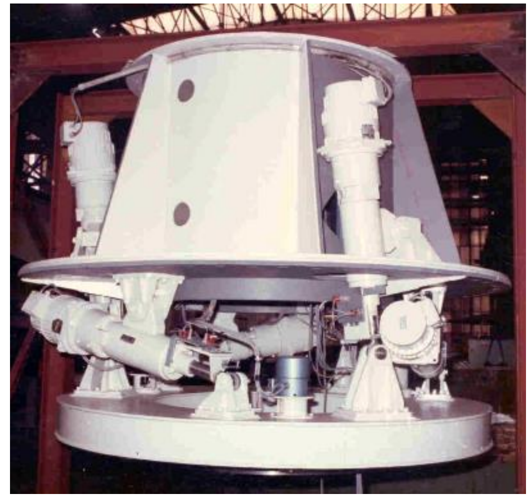
Servo Control System

The current pointing and tracking capabilities are:

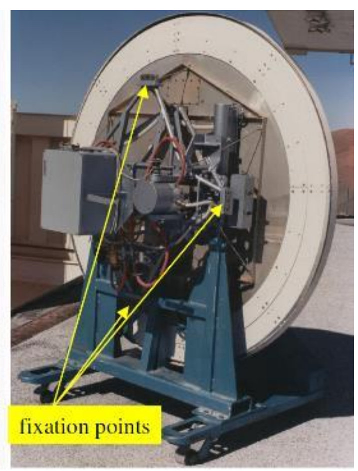
- Maximum slewing speed limited to 0.5°/sec (nominal = 1°/s)
- Maximum tracking speed limited to 150"/sec
- Elevation range limited to 83° due to tracking speed limitations
- The tracking accuracy is excellent (~ 0.2") for low wind speeds.
- However, tracking degrades for wind velocities above ~10 m/s. Currently observing up to ~ 18-20 m/s. Around 10% of the time is lost due to high wind
- The blind pointing accuracy remains excellent, 2- 3'' (pointing model with inclinometers).
- While some components (e.g. gearboxes) have been renewed, some others (e.g. servo-amplifiers, motors) remain the same since the 80's

Servo Control System

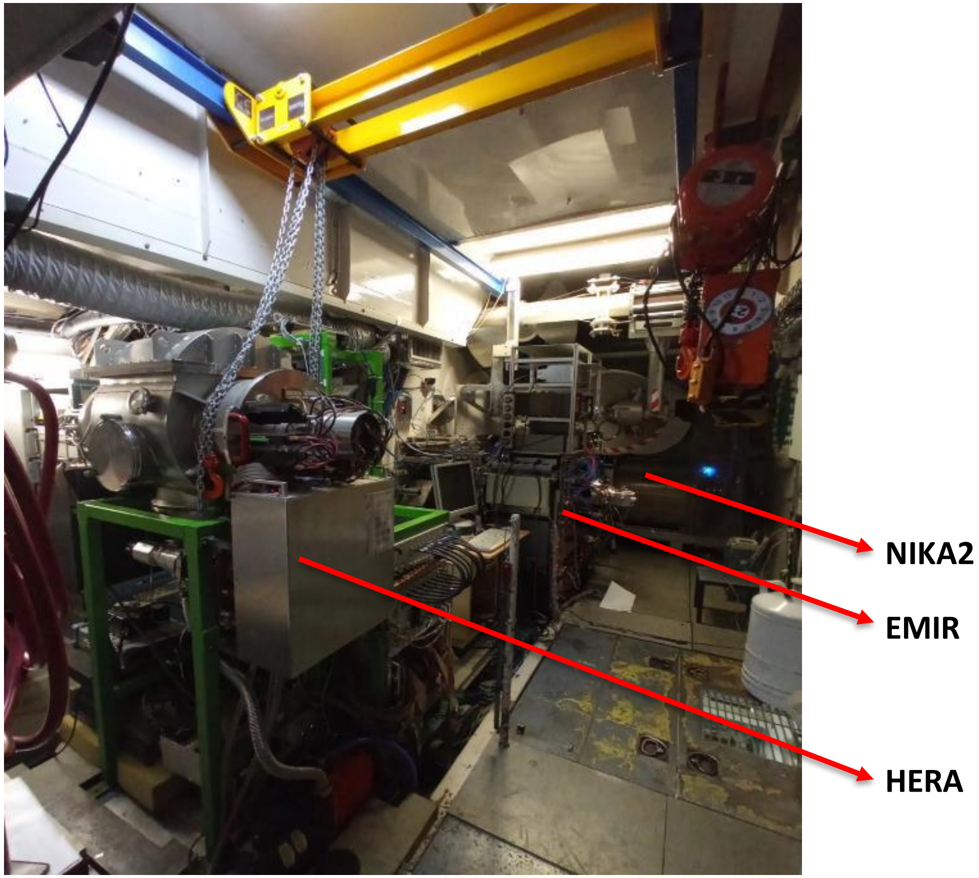
- 3 vertical and 3 horizontal spindles allow the sub-reflector to shift and tilt in X, Y, Z. On top of that, the subreflector can be also rotated. In this way, besides focusing the homology correction can be applied.



- The sub-reflector is equipped with a wobbler with up to ±120” throw and 2 Hz frequency (@±45” throw)



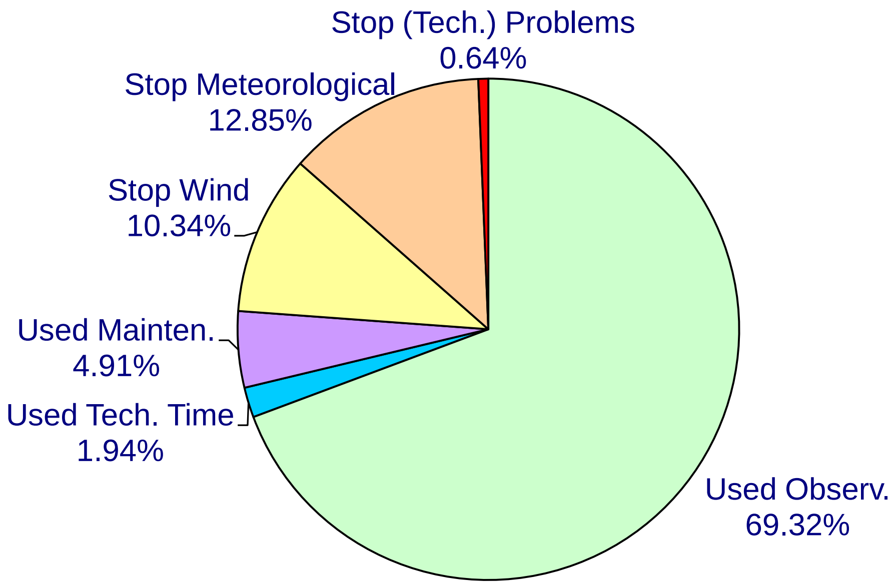
State-of-the-art instrumentation



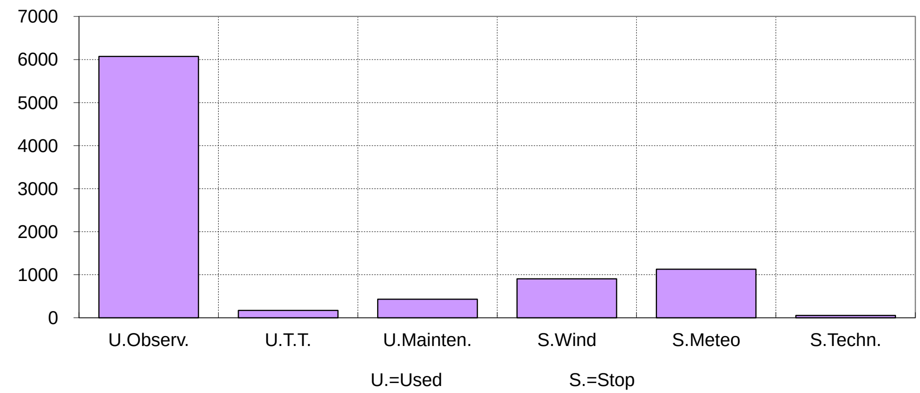
- **EMIR**, a very efficient single-pixel multi-band heterodyne receiver working at 3, 2, 1.3 and 0.8 mm cooled to 4K
- **HERA**, a 3 x 3 multi-beam 1mm receiver
- **NIKA2**, a novel, KID technology-based continuum camera with two channels at 1.2 and 2mm and polarimetry capabilities cooled to 0.15K.

Operation time distribution

30m time distribution - 2019



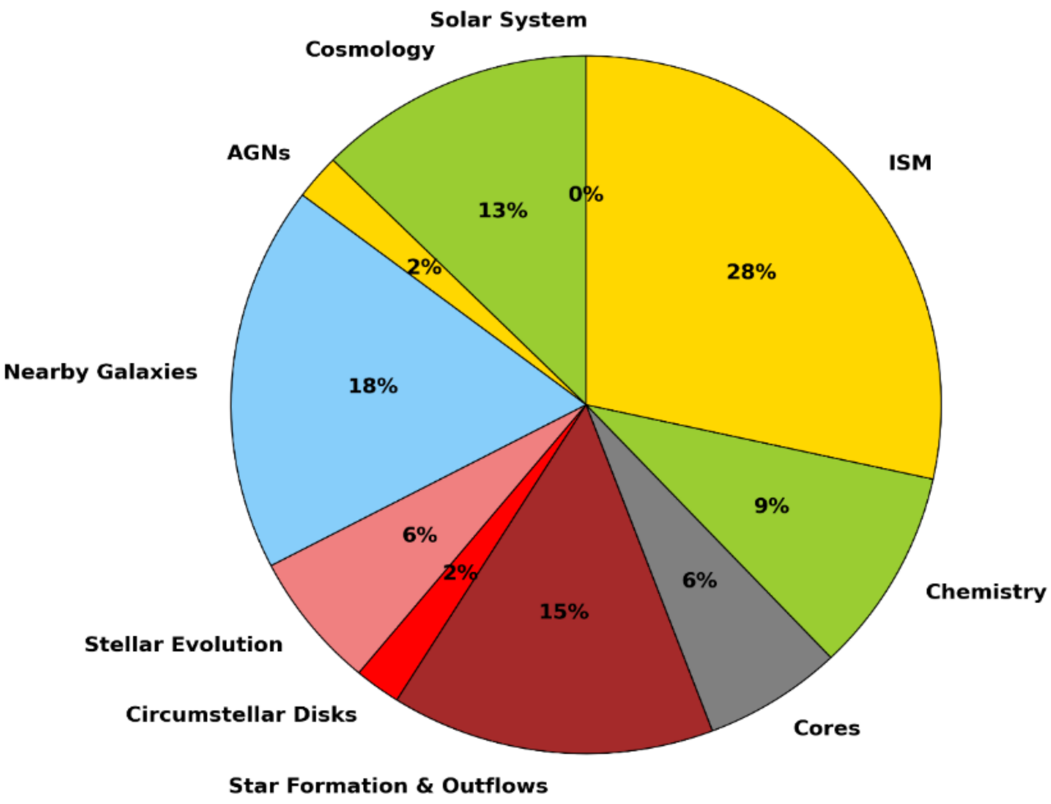
- "Used Maintenance": 6 hours each Tuesday (~3.6%)
- "Used Technical Time": 1 week heavy maintenance per year + technical projects



- In 2019, we almost reach 70% observing efficiency. The highest in the last five years
- Maintenance and technical was further reduced to less than 7%
- Loss time due to technical problems remains very low, below 1%
- The fraction of time lost due to weather was reduced to around 23%
- Along 2020 and 2021 we reached around 64% efficiency (even with COVID-19)

Time distribution by science topics

2019



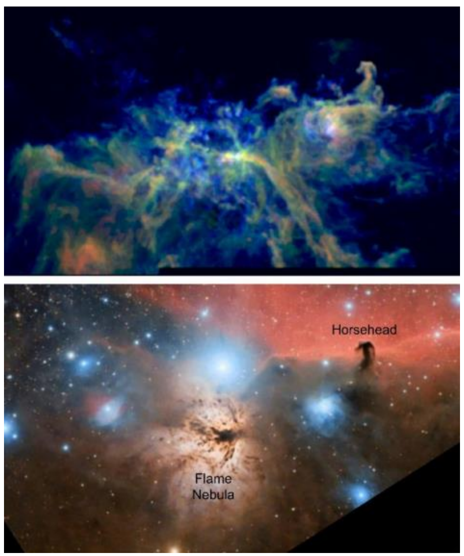
- Almost 100% of the observing time is awarded in open, competitive mode.
- Two calls per year (Summer and Winter semesters)
- Around 200 projects observed every year.
- The usual distribution is 2/3 on galactic topics, 1/3 extragalactic ones (reversed in NOEMA)
- Around 80% of the time is requested for the EMIR heterodyne instrument, 20% for the continuum NIKA2 camera.

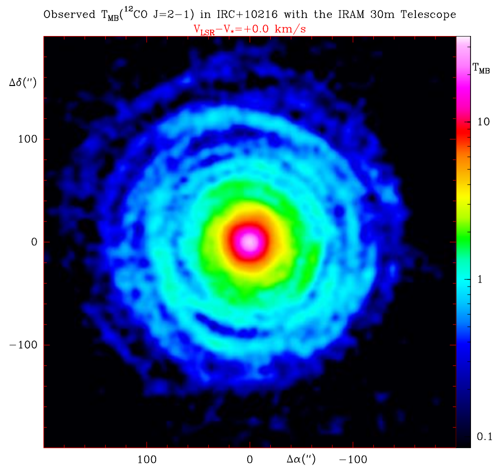
Science highlights

A SUBSTANTIAL fraction of the molecules ever discovered at the ISM and circumstellar medium were detected for the first time using the MRT telescope. Just look at http://www.astrochymist.org/astrochymist_ism.html

There are so many extraordinary discoveries made with the IRAM 30-meter MRT telescope that is difficult to choose a reduced set. Anyway handful of recent 'cool' results can be shown:

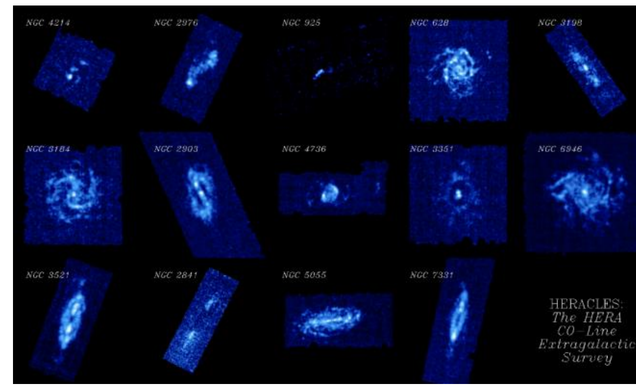
The ORION-B project (Pety & Gerin)



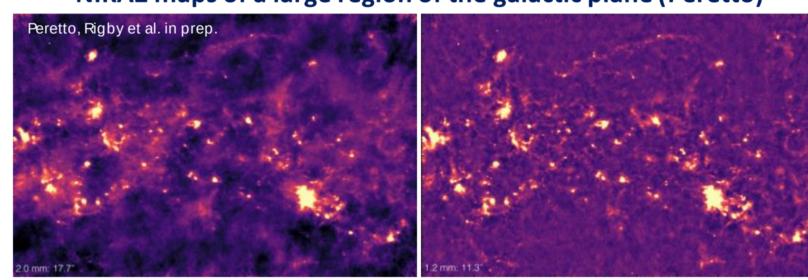


Expanding shells around the carbon-rich AGB star IRC+10216 (Cernicharo et al. 2015)

The HERA CO-line extragalactic survey of nearby galaxies



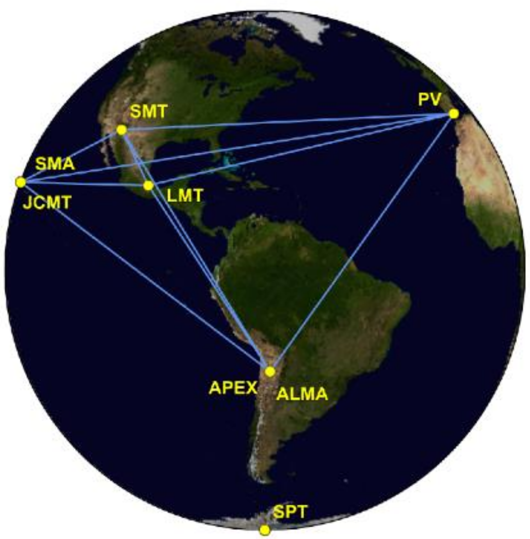
NIKA2 maps of a large region of the galactic plane (Peretto)

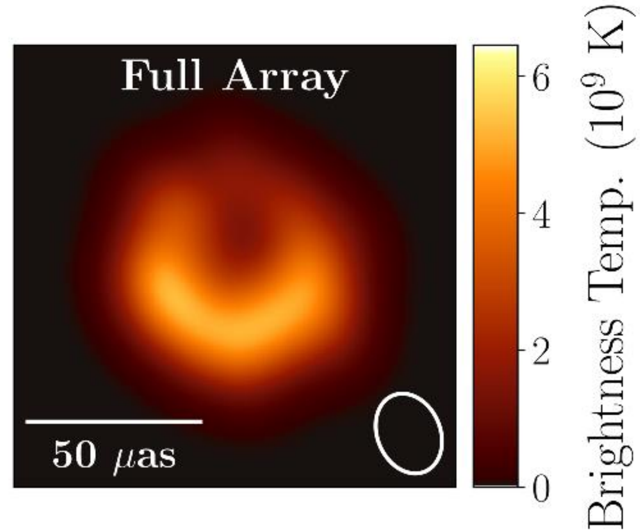


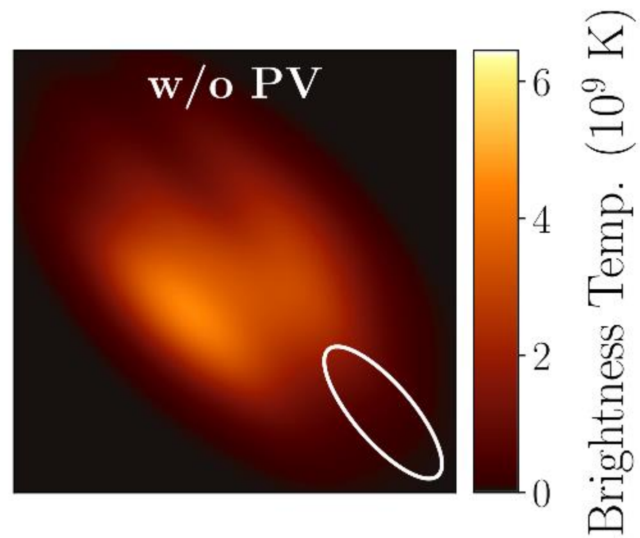
Event Horizon Telescope (EHT)

Event Horizon Telescope (EHT) imaging of M87*

- 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.
- The IRAM 30m telescope participated successfully in the 1st and 2nd EHT runs in April 2017 and April 2018.
- IRAM 30m key for resolving the shadow of M87 due to its unique location (enable E-W baselines) and sensitivity (second most sensitive telescope after ALMA).







Strategic Plan 2021-2024

The following strategic objectives have been proposed by IRAM in order to keep the IRAM 30m telescope as a state of-the art world leading facility in the 3 to 0.8 mm wavelength range in the near future.

Priority has been evaluated by CAIS (Comité Asesor de Infraestructuras Singulares).

Objective	Priority	Status
Upgrade of the telescope servo system	HIGH	Ongoing
Upgrade of the telescope main mirror surface	HIGH	Surface Study Completed Implementation planned
New sub-reflector	LOW	Planned
Laser metrology to minimize the permanent antenna surface deformations	LOW	Planned
New 3mm and 1.3mm bands multi-beam receivers	HIGH	Ongoing
Upgrade the NIKA2 continuum camera	HIGH	Planned
New backend for Multi-beam (MB) receivers	HIGH	Planned
VLBI upgrades	HIGH	Planned
Improved data-flow architecture for the IRAM 30m	HIGH	Planned
Science Archive Hardware Expansion	HIGH	Planned
Improved science archive software interface	HIGH	Planned
Upgrade of the IRAM 30m observatory to 100Gbps	MEDIUM	Planned
Sewage system	HIGH	Planned
Vehicle for Outdoor Work & Emergencies	LOW	Planned

On-going upgrade: new servo control

– Pointing and tracking goals:

1. Improve the tracking accuracy at both low and high wind speeds
2. Allow faster slews and máximum tracking speed. That will reduce observation overhead and expand the operational range.
3. Extend the operational lifetime by replacing obsolete components by state-of-art ones

– Proposed actions to to accomplish the Goals:

1. Implement a new servo system, featuring state-of-the-art electronics and control loop, running at much higher rates than now.
2. Increase the control loop bandwidth to 1 Hz will improve the tracking performance by around 30%
3. Renew also the servo-control of the sub-reflector, including the hexapod (6 spindle motors and) and wobbler control amplifiers, to ease future maintenance.
4. Renew the control software replacing the current Antenna Mount Drive (AMD).

Planned upgrade: improvement of telescope surface

– Surface improvement goals:

1. **Improve the thermal behaviour of the surface and reduce the surface r.m.s. due to optical path differences.**
2. **Improve the surface r.m.s. error to 50µm at any elevation, with a goal of 40µm**
3. **Reduce the dependency of mirror efficiency with elevation, such as the the contribution to the r.m.s. error due to gravitationally-only effects should be less than 30 µm in the whole elevation range from 20 to 80 degrees.**

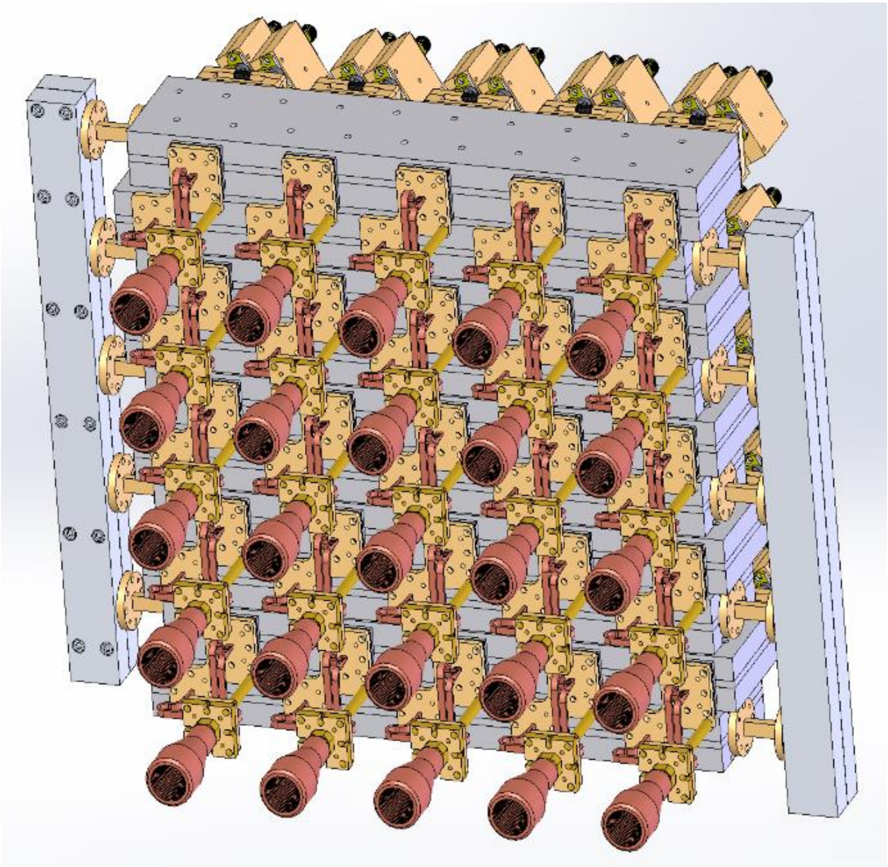
– Proposed actions to to accomplish the Goals:

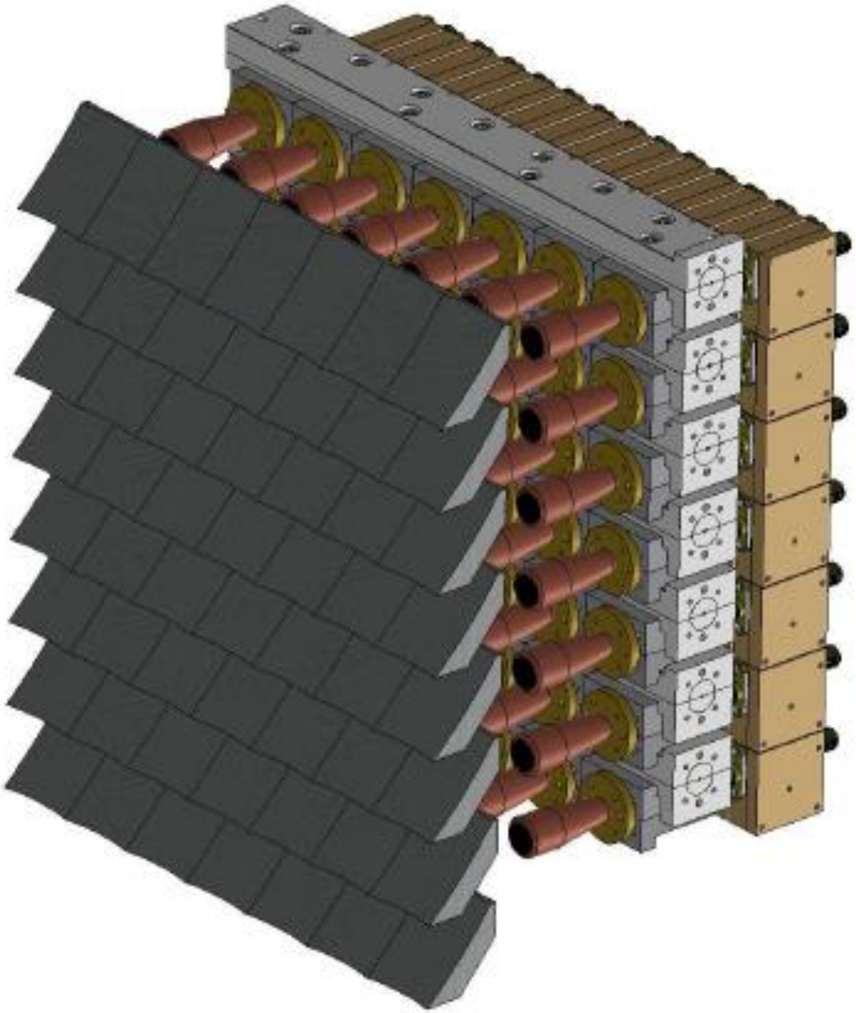
1. Re-paint the telescope surface with very stringent accuracy requirements (±5μm peak-to-peak). To be done in Summer 2023 TBC. To be done in-situ or after dismounting the panels
2. Dismounting and carefully re-aligning all 420 panels on their 210 sub-frames at a carefully chosen inclination (potential upgrade under study)
3. Install a number of actuators placed at the corners of the subframes, that, using pre-defined lookup-tables, would be used to improve the gain-elevation curve (potential upgrade under study)

Future multi-beam instruments

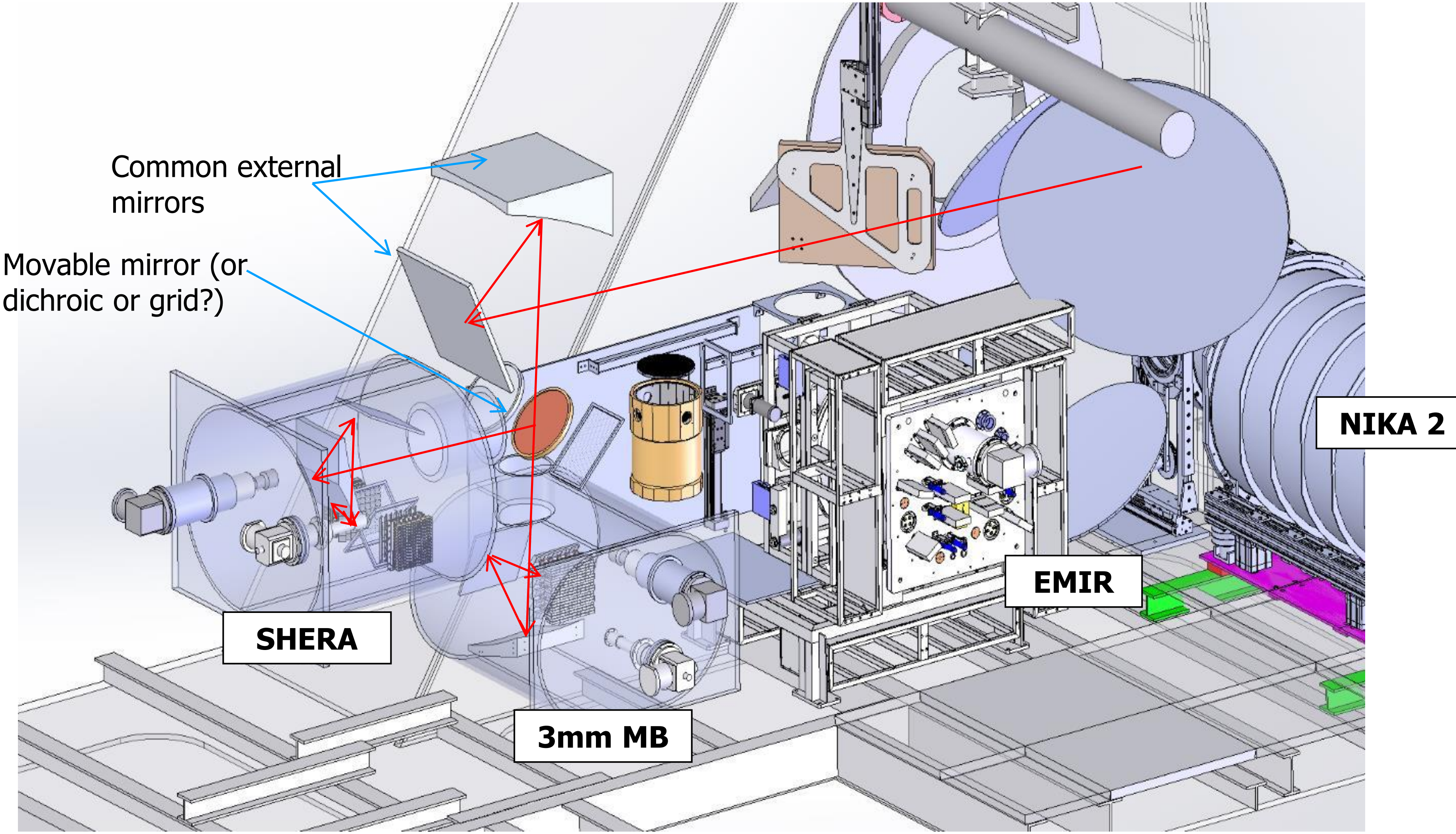
HERA	SHERA	3mm Multi-beam
3x3 pixels	7x7 pixels	5x5 pixels
dual-polarization	dual-polarization	dual-polarization
218-267 GHz	200-280 GHz	70-116 GHz
SSB mixers	2SB mixers	2SB mixers
1 GHz IF bandwidth	8 GHz IF bandwidth	8 GHz IF bandwidth
2 GHz inst. BW/pixel	32 GHz inst. BW/pixel	32 GHz inst. BW/pixel

Future multi-beam instruments

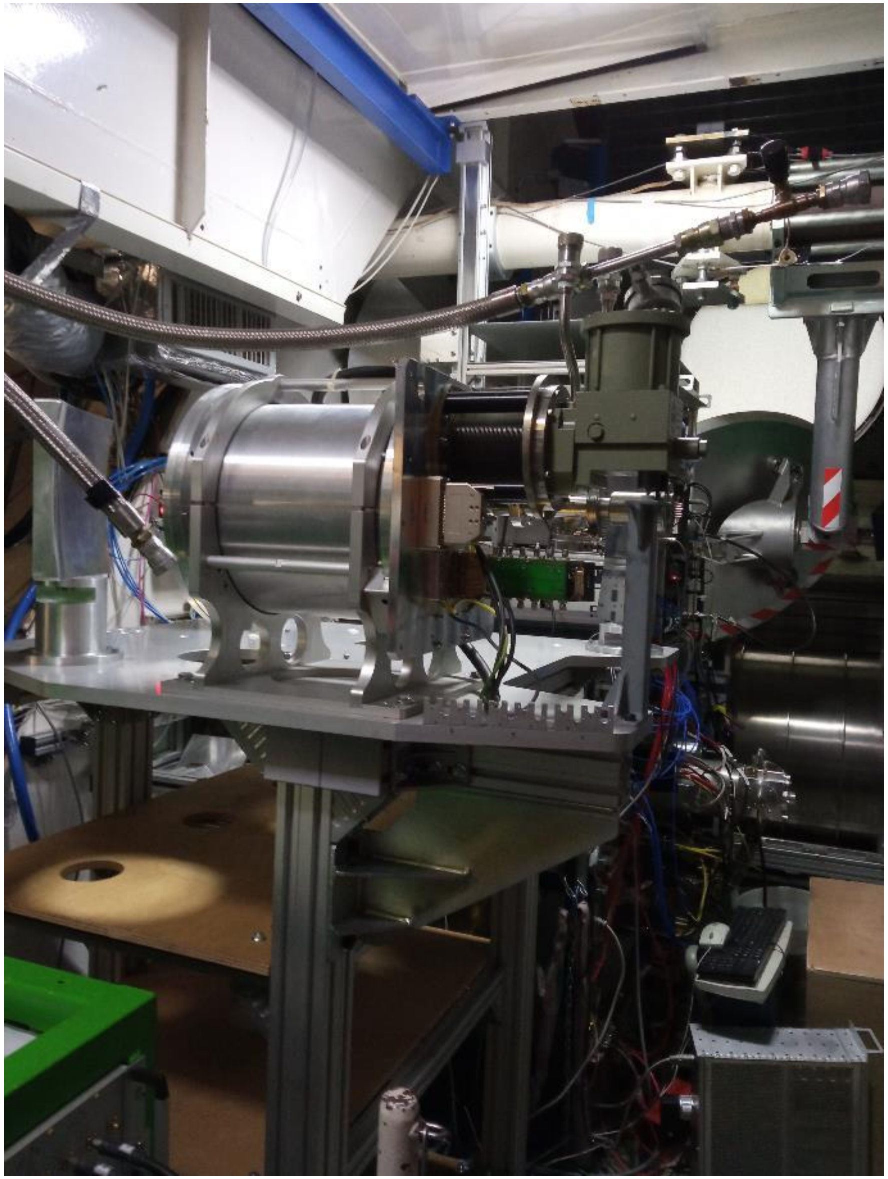




Future multi-beam instruments



Current 3-mm multi-beam prototype (AETHRA)



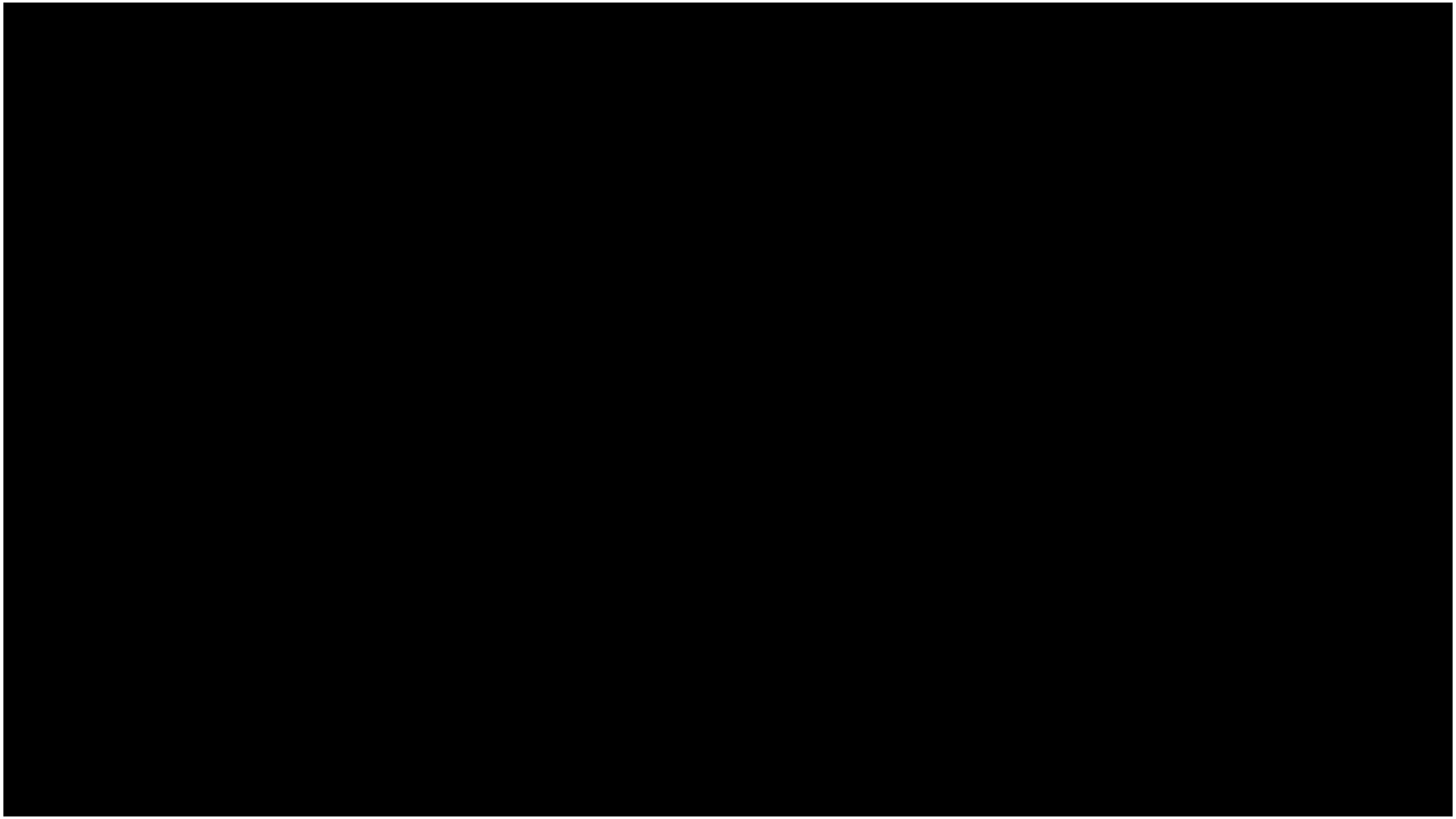
HEMT technology
Up to 3 x 3 pixel
8 GHz sideband
2 polarisations
32 GHz/pixel.

High-capacity backends to be developed

Conclusion

- The IRAM 30-meter MRT telescope has been producing top-rank science for more than 30 years.
- Has been a game-changer in millimetre astronomy.
- It is being continuously improved to keep it in the front-line. Currently running the fifth generation of instruments.
- New multi-beam instruments are currently under development
- A major upgrade of the telescope is planned for Summer 2022 and 2023. It will keep the telescope as a reference facility in the coming decades.

Conclusion



Picture credits: A. Sievers.