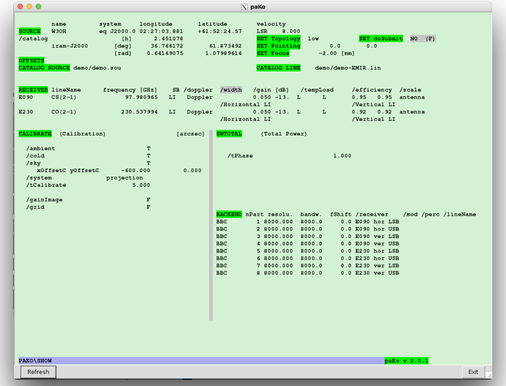
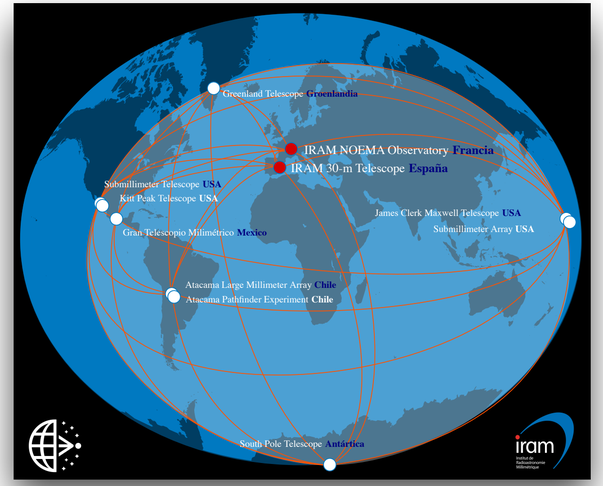
Red de Infraestructuras de Astronomía (RIA)

Promoviendo sinergias entre grandes observatorios españoles I

23-26 Octubre 2023, La Palma, Canarias

Observar con el Telescopio IRAM 30m





Pablo Torne

torne@iram.es

Instituto de Radio Astronomía Milimétrica

iram
Institut de Radioastronomie Millimétrique

```
* Loaded modules
   sic (J.Pety, S.Bardeau, S.Guilloteau, E.Reynier)
   greg (J.Pety, S.Bardeau, S.Guilloteau, E.Reynier)
   pako (Hans Ungerechts)

* In charge of paKo v1.2.3: Hans Ungerechts:
  This vers. of paKo 2.0.1: Albrecht Sievers sievers@iram.es
* Questions? Comments? Bug reports? Mail to: ungerechts@iram.es

PAKO> @setup
W-SOURCE,  please review OFFSETS (not cleared by SOURCE!)
W-OFFSETS,  /SYSTEM Nasmyth are cleared: will use automatic values
W-OFFSETS,  /SYSTEM Nasmyth are cleared: will use automatic values
W-SWBEAM,  After Switching Mode, please specify (again) Observing Mode, e.g., CALIBRATE
I-SHOW,  ....................................
I-SHOW,  paKo Revision ..................... v 2.0.1 2018-07-11
I-SHOW,  paKo subVersion ................... s 2.0.1.1 2018-07-11
I-SHOW,  Level ............. for standard output 3 for file 3
I-SHOW,  doSubmit Queue .................... F
I-SHOW,  PlotStyle ......................... simple
I-SHOW,  Project ........................... E06-22
I-SHOW,  PI ................................ P. Torne
I-SHOW,  Observer .......................... P. Torne
I-SHOW,  Operator .......................... Operator
I-SHOW,  Topology .......................... LOW
I-SHOW,  Pointing .......... azimuthCorrection 0.00 [arc sec]
I-SHOW,  Pointing ......... elevationCorrection 0.00 [arc sec]
I-SHOW,  Focus ............. focusCorrection Z -2.00 [mm]
I-SHOW,  ....................................
PAKO>
```

Contenido

- Visión General de una observación con el IRAM 30m
- Modos de Observación Disponibles
- Herramientas Disponibles (Propuestas, Observación, Datos)
- Conclusiones y Posibles Mejoras

Visión General de Observación con IRAM 30m*

* Válido para muchos observatorios

Idea de experimento científico

Escribir Propuesta de Observación

Preparar los scripts (lenguaje específico)

Realizar Observaciones

Procesar los datos (Calibración + Reducción)

Science-ready data

Publicar resultados!

M. Castillo

nature

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Article | Open access | Published: 26 April 2023

A ring-like accretion structure in M87 connecting its black hole and jet

Ru-Sen Lu, Keiichi Asada, Thomas P. Krichbaum, Jongho Park, Fumie Tazaki, Hung-Yi Pu, Masanori Nakamura, Andrei Lobanov, Kazuhiro Hada, Kazunori Akiyama, Jae-Young Kim, Ivan Marti-Vidal, José L. Gómez, Tomohisa Kawashima, Feng Yuan, Eduardo Ros, Walter Alef, Silke Britzen, Michael Bremer, Avery E. Broderick, Akihiro Doi, Gabriele Giovannini, Marcello Giroletti, Paul T. P. Ho, ... Chen-Yu Yu + Show authors

Nature **616**, 686–690 (2023) | Cite this article

42k Accesses | **6** Citations | **1516** Altmetric | Metrics

Abstract

The nearby radio galaxy M87 is a prime target for studying black hole accretion and jet formation[1,2]. Event Horizon Telescope observations of M87 in 2017, at a wavelength of 1.3 mm, revealed a ring-like structure, which was interpreted as gravitationally lensed emission around a central black hole[3]. Here we report images of M87 obtained in 2018, at a wavelength of 3.5 mm, showing that the compact radio core is spatially resolved. High-resolution imaging shows a ring-like structure of $8.4^{+0.5}_{-1.1}$ Schwarzschild radii in diameter, approximately 50% larger than that seen at 1.3 mm. The outer edge at 3.5 mm is also larger than that at 1.3 mm. This larger and thicker ring indicates a substantial contribution from the accretion flow with absorption effects, in addition to the gravitationally lensed ring-like emission. The images show that the edge-brightened jet connects to the accretion flow of the black hole. Close to the black hole, the emission profile of the jet-launching region is wider than the expected profile of a black-hole-driven jet, suggesting the possible presence of a wind associated with the accretion flow.

Metodología

- Metodología de **observación** se **ajusta al objeto y objetivo científico**
- Siempre:
  - Incluir medidas de **calibración**: en (sub)milimétrico = instrumentos y atmósfera
  - Ajustes de **puntería y foco**
- Dependiendo de fuente y objetivo:
  - **ON + OFF**
  - **Mapping**
  - **Continuous tracking**
  - **VLBI**

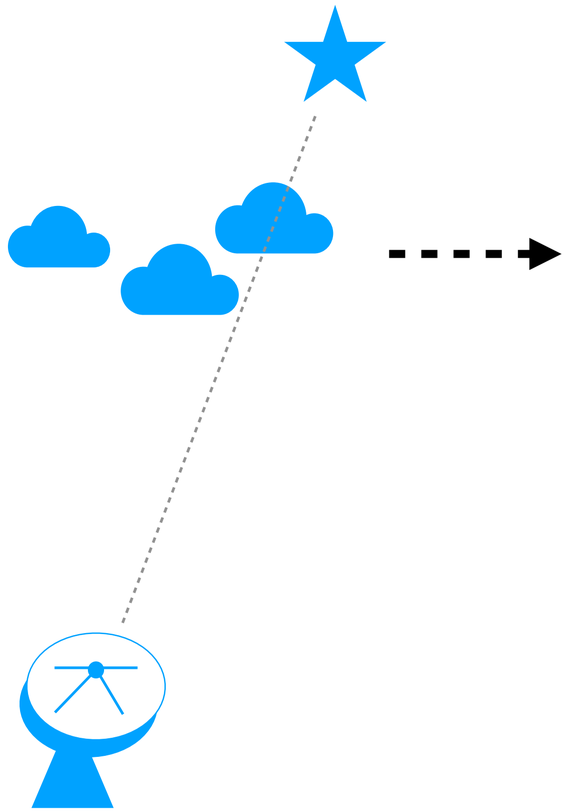
Opciones de Observación con IRAM 30m

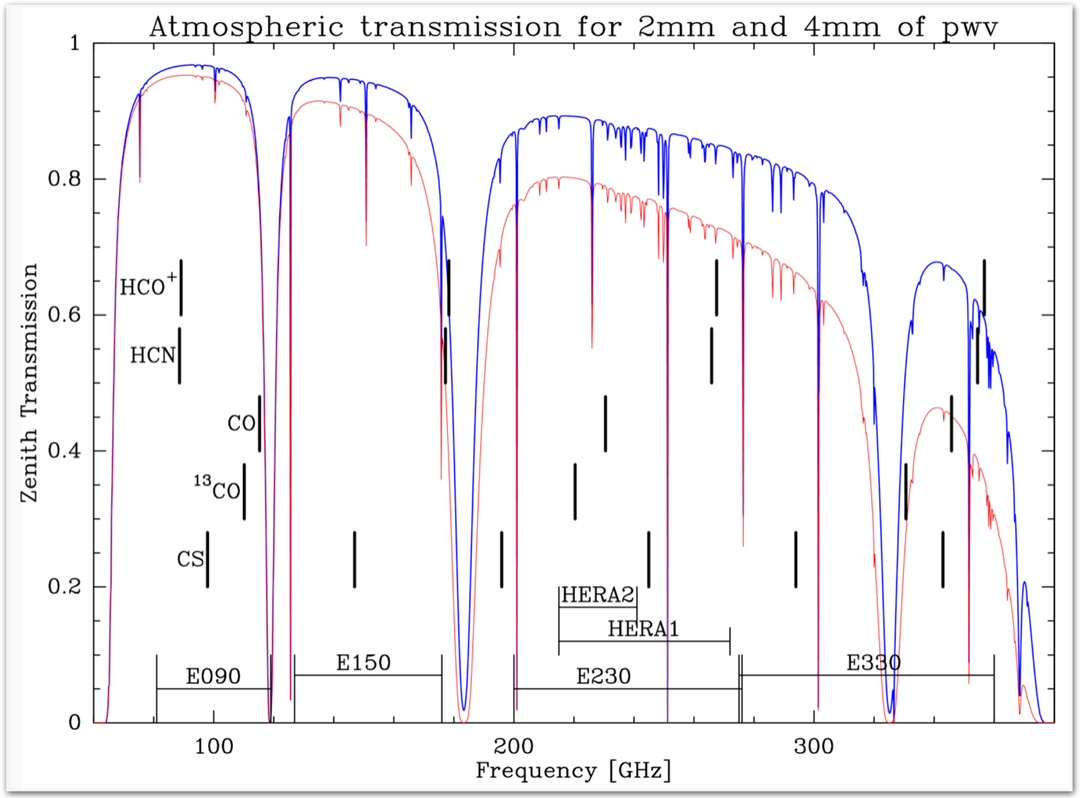
Observing mode	swTotal	swBeam	swWobbler	swFrequency
Calibrate (Heterodyne)	X			
Pointing	X	X	X	
Focus	X	X	X	
Tip (Skydip)	X			
Track				fsw
ONOFF	psw		wsw	
OTFMAP (Heterodyne)	otf/psw			otf/fsw
Raster				
OTFMAP (MAMBO Bolometer)			X	
VLBI	X			

https://iram-institute.org/science-portal/30-meter-telescope/observatory-system-status-monitor/

Puntería, Foco, y Calibración

- Puntería y foco es para **“centrar" la fuente en el punto focal**
- Calibración: **calcular y restar la contribución de los instrumentos y atmósfera**





Atmosphere

Receivers / Cameras

Target

Tant = Gain x (Trec + Tatm + Tsou)

Measure Gain, Trec, Tsky …

(Tant / Gain) - (Trec + Tatm) = Tsou

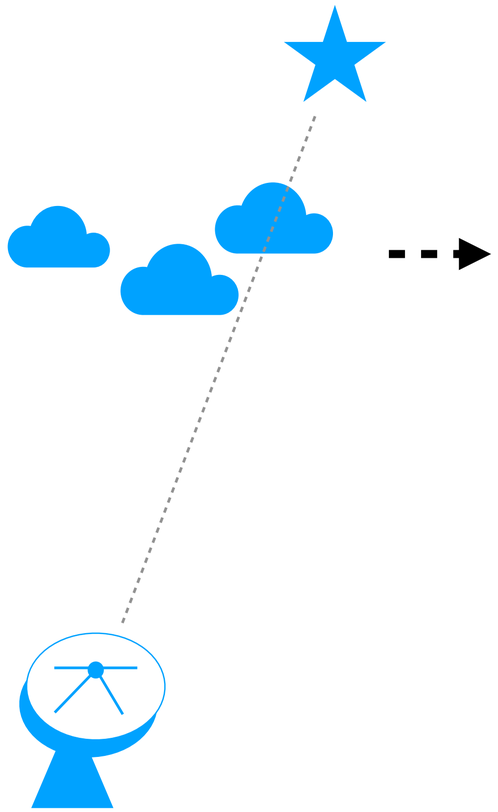
Simplificación

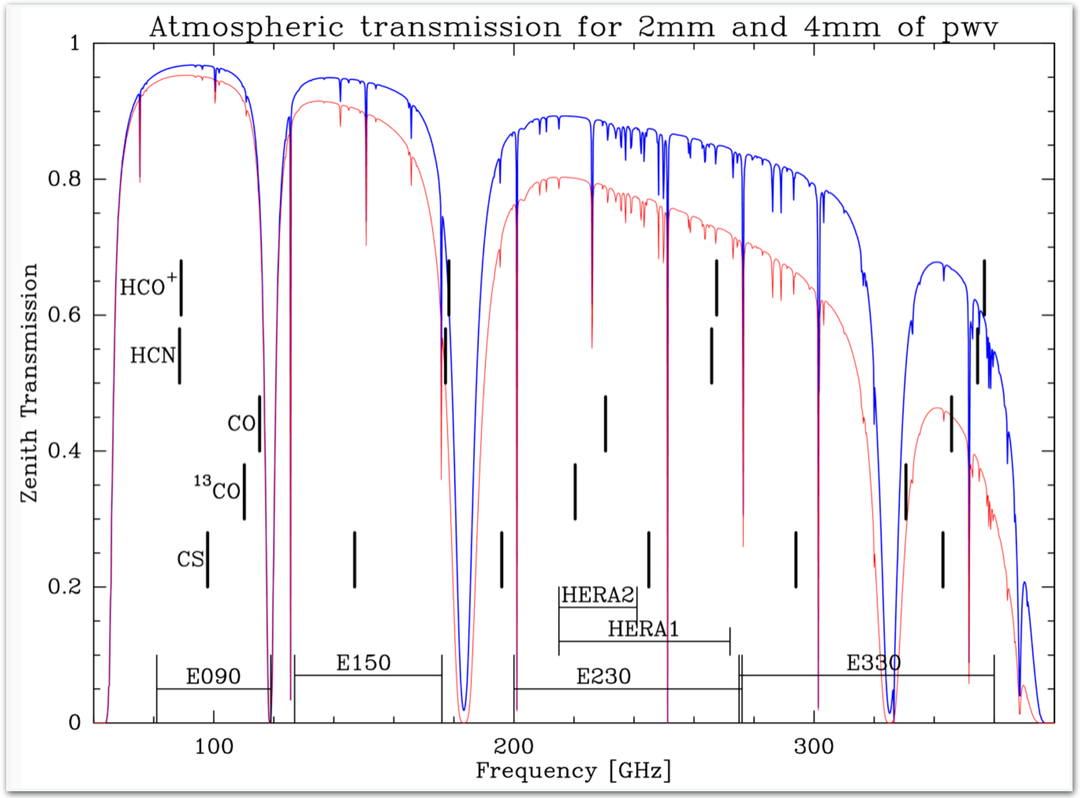
+Info: https://publicwiki.iram.es/CalibrationPapers

Puntería, Foco, y Calibración

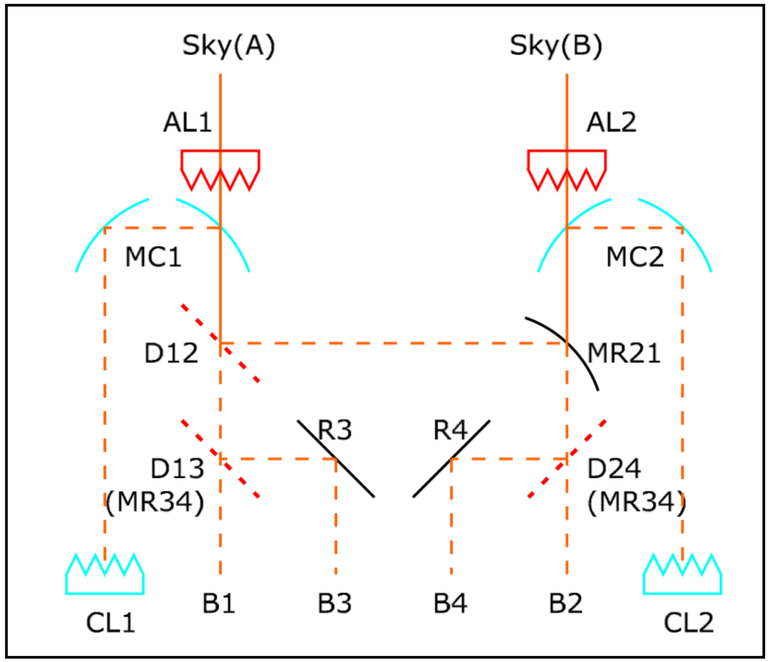
- Medidas de contribución de instrumentación: **"Hot-Cold Method" (or Y-factor)**
- Atmósfera: **medida de emisión del cielo** + estación meteo + modelo teórico (ATM)
- ATM = Atmospheric Transmission at Microwaves = Radiative Transfer Calculations

Juan Ramón Pardo,
José Cernicharo, *et al.*





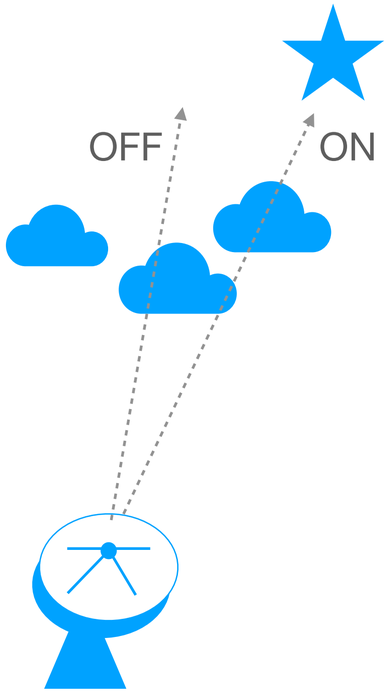
Esquema sistema calibración EMIR

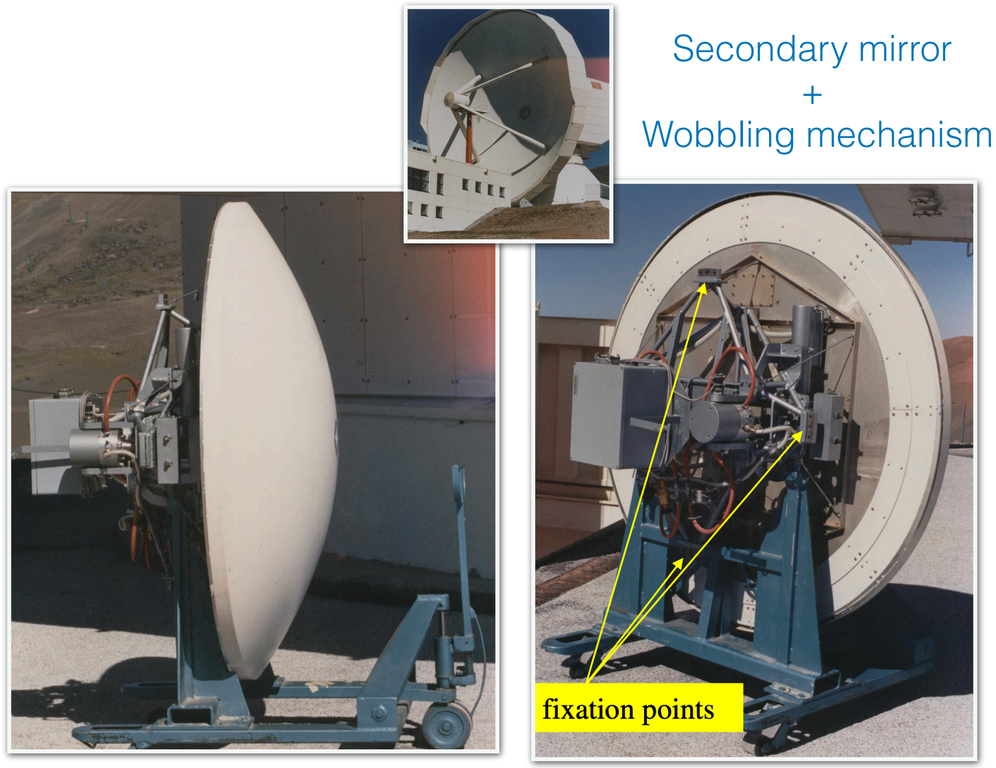


ON-OFF

- **Alternar entre posiciones ON** (sobre la fuente objetivo) **y OFF** (sólo atmósfera), y restar
- La alternancia: mover toda la antena (position) o mover el espejo secundario (wobbling)

ON-OFF
Switch: Position, Wobbler

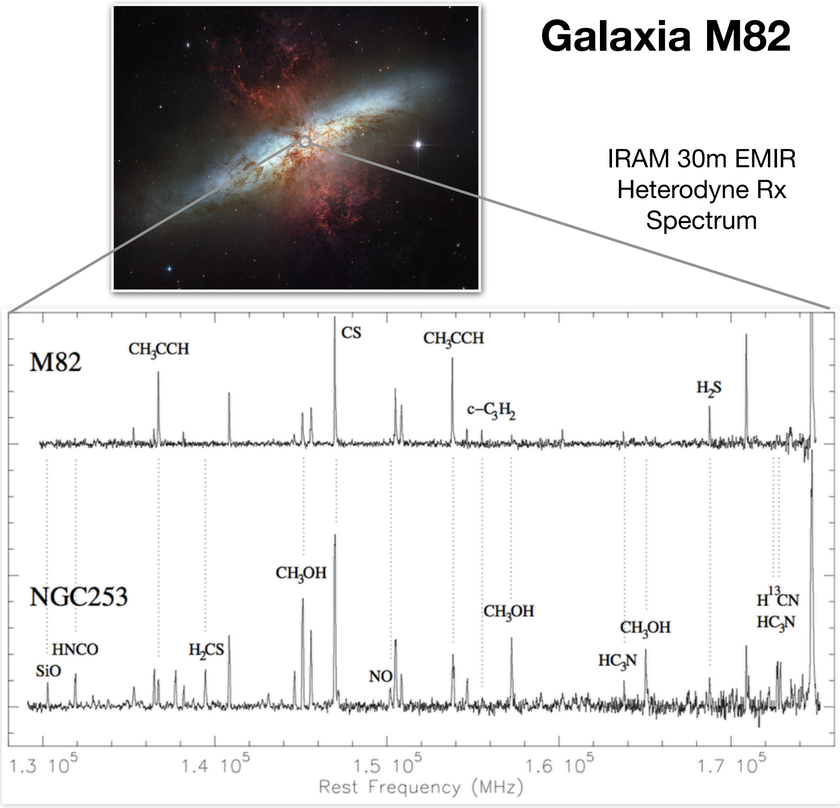




Secondary mirror
+
Wobbling mechanism

Galaxia M82

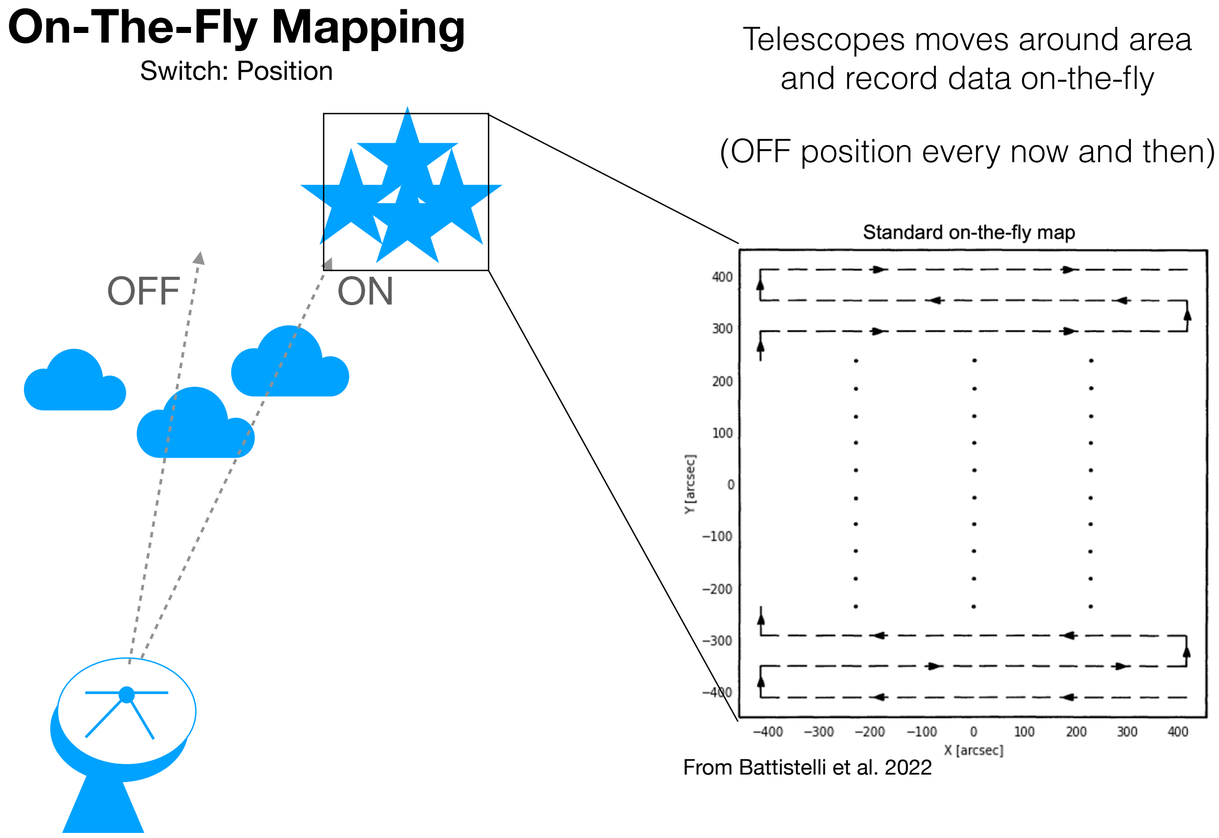
IRAM 30m EMIR
Heterodyne Rx
Spectrum



K. Menten's MPIfR blog

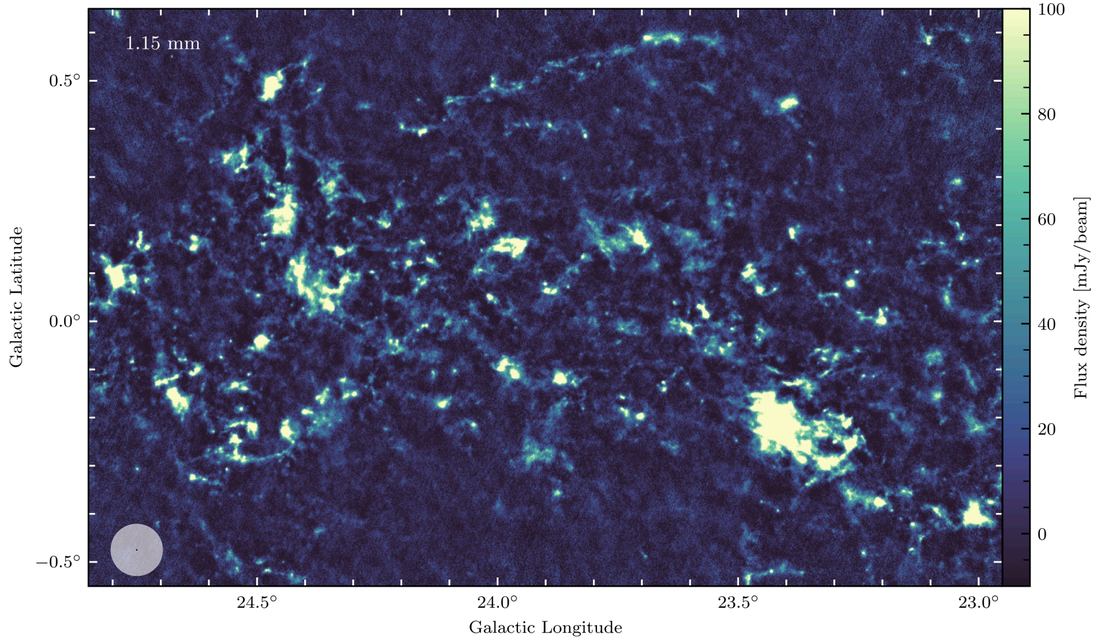
On-The-Fly Mapping

- **Mover** la antena en un patrón predefinido **grabando datos continuamente**
- Cubre **áreas grandes** de forma eficiente
- Peores sustracciones de atmósfera que ON-OFF



From Battistelli et al. 2022

Posición OFF



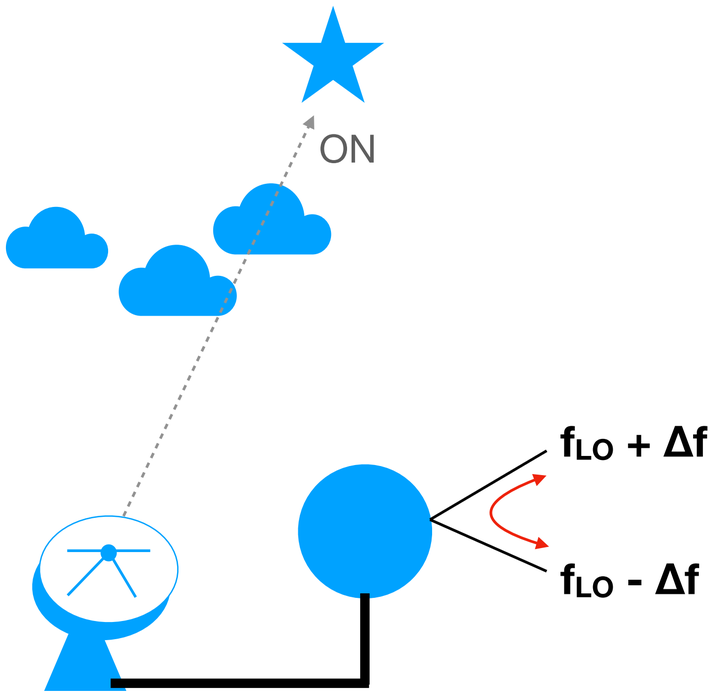
IRAM 30m NIKA2 KID Camera Map - GASTON Project Rigby et al. (2021)

Tracking

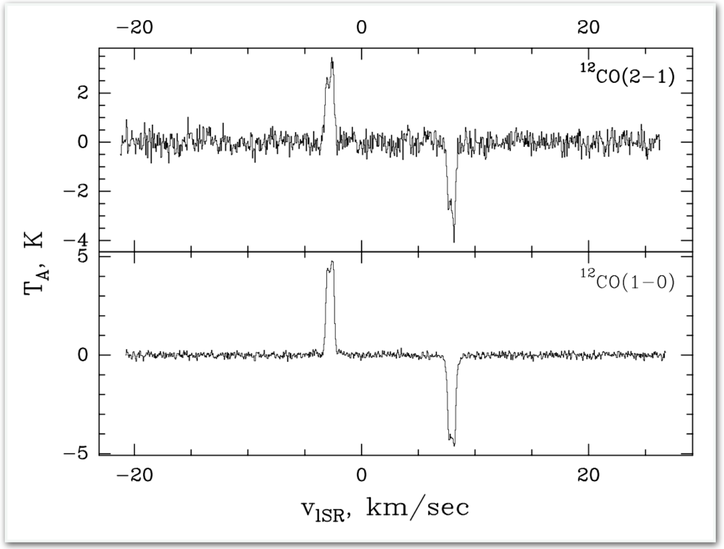
- **Apuntar continuamente** a una fuente (→ **¡doble de tiempo on-source!**)
- Atmósfera se mide **cambiando rápidamente entre dos frecuencias cercanas**
- Sin sustracción atmosférica directa: Very Long Baseline Interferometry, Púlsares

Tracking

Switch: Frequency, Ninguno

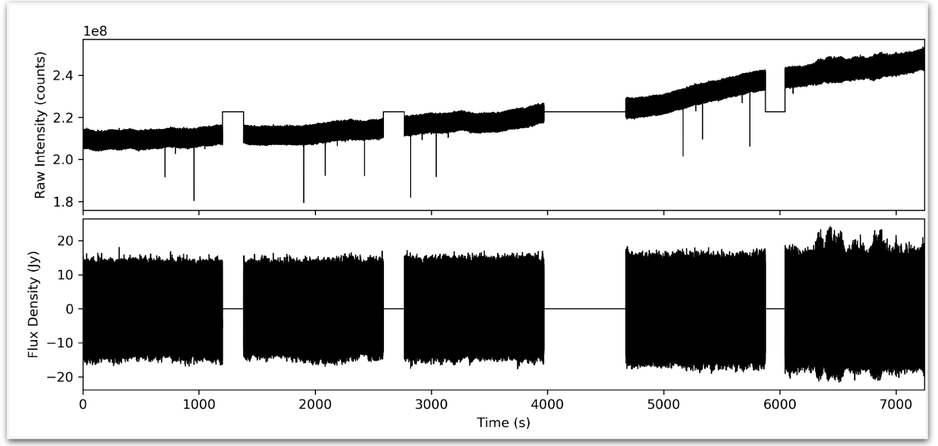


Thum et al. (1995)



IRAM 30m EMIR
Heterodyne Rx Spectrum
with Frequency Switching

Torne et al. (2021)



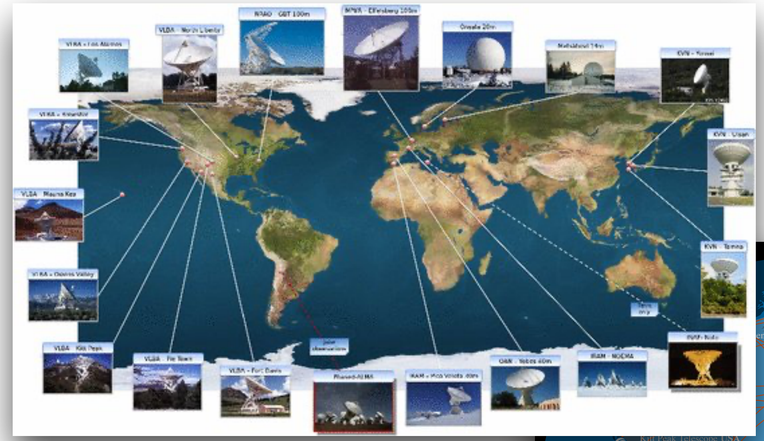
IRAM 30m EMIR
Heterodyne Rx Continuum
High-time-resolution Time Series
for Pulsar Observations

Observaciones Especiales

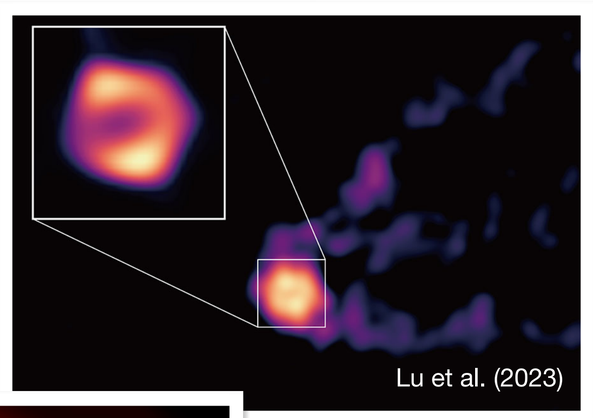
- **Tiempos técnicos (Medidas eficiencia, Holografía, Modelo puntería, Tests Hardware/Software)**
- **Very Long Baseline Interferometry (VLBI)**

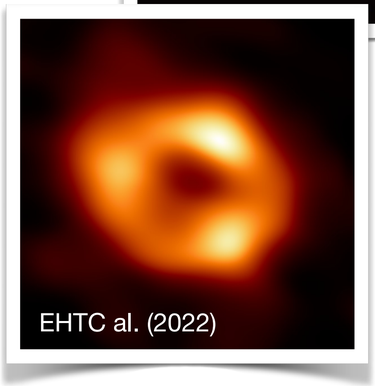
→ Global mm-VLBI Array (GMVA, λ=3 mm), Event Horizon Telescope (EHT, 1.3<λ<0.8 mm)

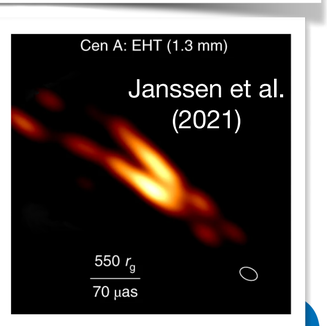
→ Campañas dedicadas. Requiere buena coordinación entre instituciones y observatorios.



H. Rottmann







Herramientas de Observación I: Propuestas

Ejemplo de propuesta en el PMS

Proposal 159-16 (pdf)

Title: Monitoring of the Galactic Centre Magnetar SGR J1745-2900 at millimetre wavelengths
PIs: Pablo Torne
CoIs: Gabriel Paubert, Gregory Desvignes, Kuo Liu, Ralph Eatough, Olaf Wucknitz, Michael Kramer
Total requested time: 21.0 (Emir)
Abstract:
We propose the monitoring of the Galactic Centre (GC) magnetar SGR J1745-2900 with a 2-week cadence. The main objective is to quantitatively study the characteristics of its variable emission, including flux density, integrated profile shape, single pulses, spectrum, and polarization. These observations will provide valuable information about the radio emission process of magnetars, and potentially also about the dynamic interstellar medium between the Earth and the pulsar (i.e. to the GC). Since the observations of SGR J1745-2900 include the GC inside the beam with minimal impact in sensitivity, we will also search the data for pulsars, combining the different epochs together to maximize our sensitivity. The monitoring at mm-wavelengths would be complemented at certain epochs (scheduling permitting) by simultaneous observations from the Effelsberg 100-m and/or Nancay telescopes, which are currently undergoing similar monitoring programmes of this source. We remark that the radio emission from magnetars is unstable and can disappear any time, which makes the period of activity of SGR J1745-2900 a rare opportunity to monitor the source at mm-wavelengths.

Sources and setups
Sources: Download sources

Id [?]	Epoch	RA	DEC	Vlsr (km/s)
J1745-2900	J2000	17:45:40.166	-29:00:29.896	0.0

Technical sheets:

Emir	Rec. time	Grade	
Time: 21.00 hours **Frontend/Backend setups:**	21.0	A	view

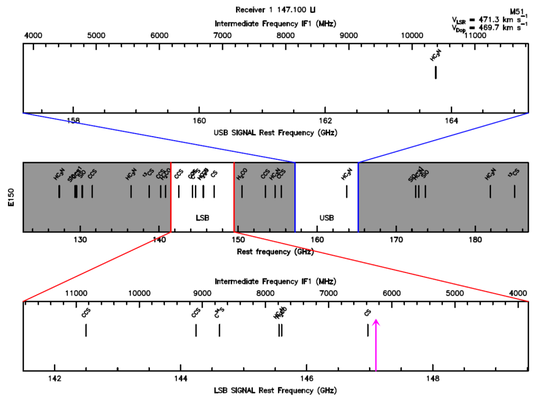
Setup	Band [?]	Species/Transition	Frequency [?] GHz	Receiver band [?]	T_A^* [?] mK	Rms [?] mK	ΔV [?] km/s	Backends [?]
1	E0 (3mm)	Continuum	88.0	LI	1.0 - 20.0	0.5	25000.0	BBC, VESPA
1	E1 (2mm)	Continuum	140.0	LI	1.0 -	0.5	17000.0	BBC, VESPA

- **Desarrollo interno** IRAM. Sistema **integrado en web**: https://oms.iram.fr/oms/?pms=frontpage
- **2x "Calls for Proposals" al año**, en Septiembre y Marzo (Winter semester / Summer semester)
- Propuestas: Parte técnica (Rx, Backends, Tunings, etc.) y Justificación Científica (4 páginas max.)
- Cada nuevo "Call" se publica un **PDF con el estado y capacidades del 30m** ese semestre
- Program Committee después de cada Call for Proposals para evaluarlas. **Rates A, B o C.**

Herramientas de Observación II: Observaciones

- **paKo**: The Observers' User Interface
- Lenguaje específico
- Usuario debe construir los scripts de observación
- Scripting sencillo en general (- ~On-The-Fly Mapping)
- **ASTRO**: Ayuda a preparar las observaciones (valida setups)

EMIR Frequency coverage: Receiver Tuning

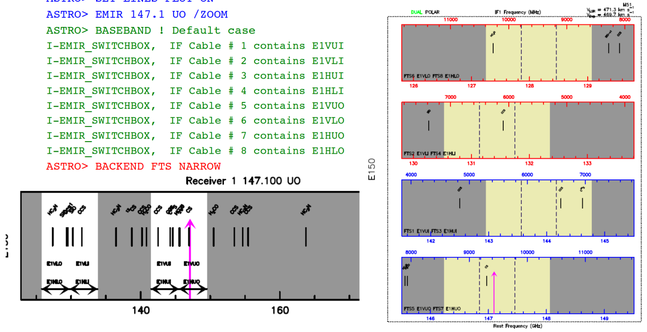


ASTRO Tutorial, J. Boissier

EMIR Frequency coverage: Backend

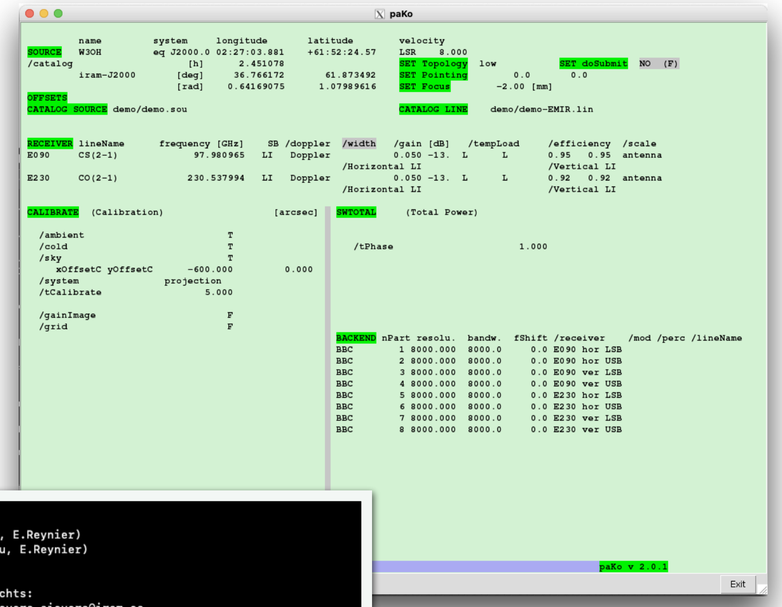
- **Example 1: Single Band observations**

```
ASTRO> OBSERVATORY 30m
ASTRO> TIME 0:0:0 15-AUG-2016
ASTRO> SOURCE M51 EQ 2000 13:29:52.698 47:11:42.93 LSR 471.26
ASTRO> SET LINES PLOT ON
ASTRO> EMIR 147.1 UO /ZOOM
ASTRO> BASEBAND ! Default case
I-EMIR_SWITCHBOX,  IF Cable # 1 contains E1VUI
I-EMIR_SWITCHBOX,  IF Cable # 2 contains E1VLI
I-EMIR_SWITCHBOX,  IF Cable # 3 contains E1HUI
I-EMIR_SWITCHBOX,  IF Cable # 4 contains E1HLI
I-EMIR_SWITCHBOX,  IF Cable # 5 contains E1VUO
I-EMIR_SWITCHBOX,  IF Cable # 6 contains E1VLO
I-EMIR_SWITCHBOX,  IF Cable # 7 contains E1HUO
I-EMIR_SWITCHBOX,  IF Cable # 8 contains E1HLO
ASTRO> BACKEND FTS NARROW
```



ASTRO Tutorial, J. Boissier

Ejemplos de preparación de setup de EMIR con ASTRO




```
* Loaded modules
   sic (J.Pety, S.Bardeau, S.Guilloteau, E.Reynier)
   greg (J.Pety, S.Bardeau, S.Guilloteau, E.Reynier)
   pako (Hans Ungerechts)

* In charge of paKo v1.2.3: Hans Ungerechts:
  This vers. of paKo 2.0.1: Albrecht Sievers sievers@iram.es
* Questions? Comments? Bug reports? Mail to: ungerechts@iram.es

PAKO> @setup
W-SOURCE,  please review OFFSETS (not cleared by SOURCE!)
W-OFFSETS,  /SYSTEM Nasmyth are cleared: will use automatic values
W-OFFSETS,  /SYSTEM Nasmyth are cleared: will use automatic values
W-SWBEAM,  After Switching Mode, please specify (again) Observing Mode, e.g., CALIBRATE
I-SHOW,  .....................................
I-SHOW,  paKo Revision ....................... v 2.0.1 2018-07-11
I-SHOW,  paKo subVersion ..................... s 2.0.1.1 2018-07-11
I-SHOW,  Level ............. for standard output 3 for file 3
I-SHOW,  doSubmit Queue ...................... F
I-SHOW,  PlotStyle ........................... simple
I-SHOW,  Project ............................. E06-22
I-SHOW,  PI .................................. P. Torne
I-SHOW,  Observer ............................ P. Torne
I-SHOW,  Operator ............................ Operator
I-SHOW,  Topology ............................ LOW
I-SHOW,  Pointing ........... azimuthCorrection 0.00 [arc sec]
I-SHOW,  Pointing ......... elevationCorrection 0.00 [arc sec]
I-SHOW,  Focus ............... focusCorrection Z -2.00 [mm]
I-SHOW,  .....................................
PAKO>
```

paKo muestra en una ventana gráfica la configuración de la observación antes de ser enviada

El telescopio se controla desde un terminal con paKo, via comandos o scripts

Herramientas de Observación III: Calibración

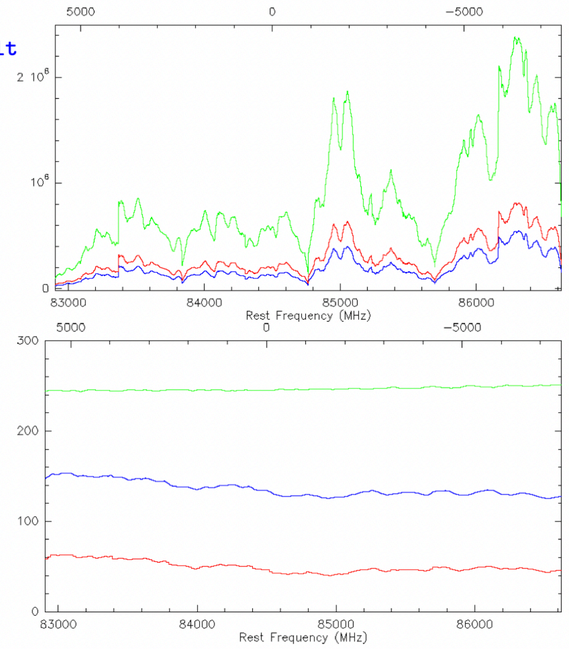
- Atualmente 3 softwares: **MIRA, MRTCAL, PIIC**
- Heterodino: Calibración automáticamente en quasi tiempo real
- Para KIDs: Ficheros de calibración, después se puede aplicar la conversión a unidades de flujo

https://www.iram.fr/IRAMFR/GILDAS/
https://publicwiki.iram.es/PIIC/

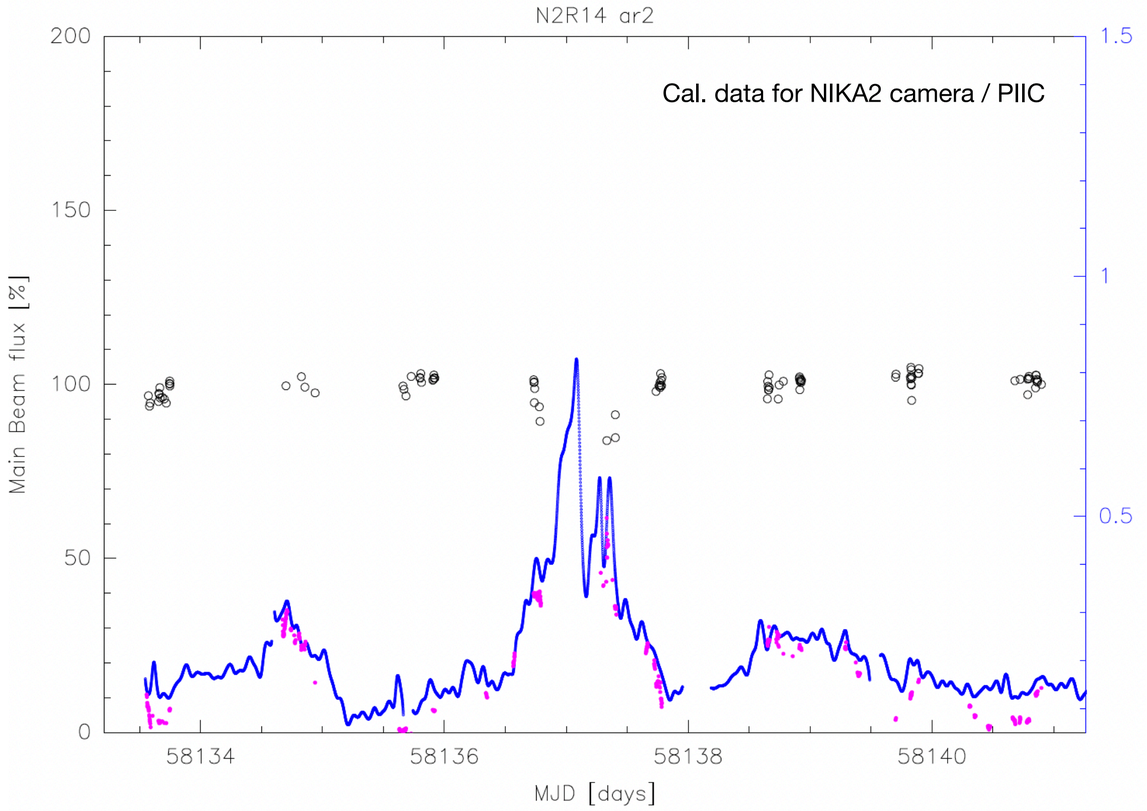
Default is to save calibration products under source calSky + Associated arrays:

```
MRTCAL> mset output calibration associated  ! Default
  (calibration)
MRTCAL> file in controld-wilma.30m  ! CLASS command
MRTCAL> find                        ! CLASS command
I-FIND,  8 observations found
MRTCAL> list /toc source            ! CLASS command
Current index contains:
Number of sources......   2
  CALSKY                4 ( 50.0%)
  CONTROLD              4 ( 50.0%)

MRTCAL> find /source CALSKY
MRTCAL> get f
MRTCAL> dump
  [...]
  ASSOCIATED ARRAYS ---------------------
  Number of associated arrays: 7
  Associated array #1: CALAMBIENT
  Associated array #2: CALCOLD
  Associated array #3: TREC
  Associated array #4: TCAL
  Associated array #5: TSYS
  Associated array #6: TAUZEN
  Associated array #7: FLAG
```

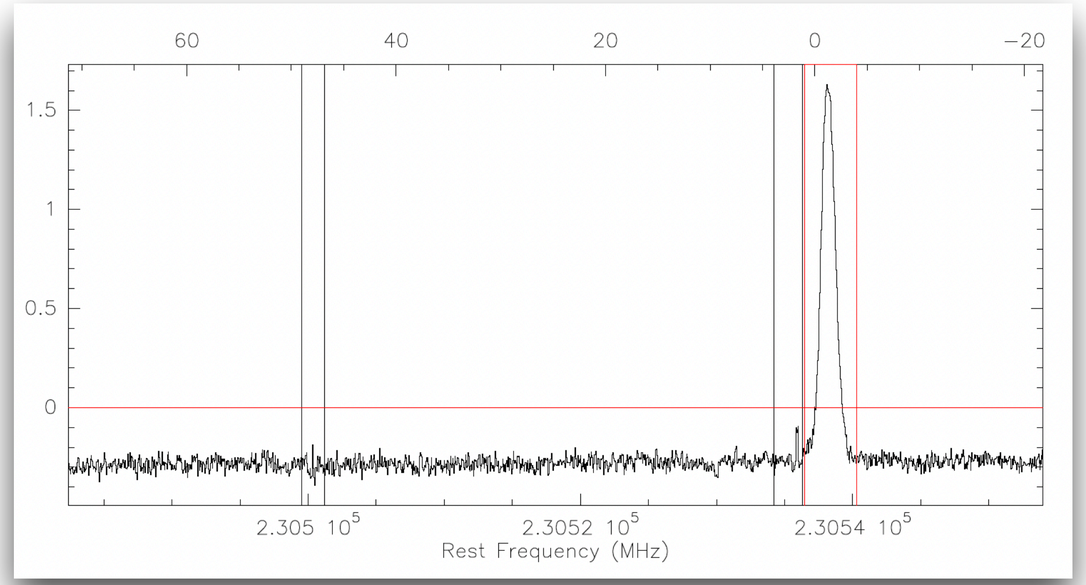


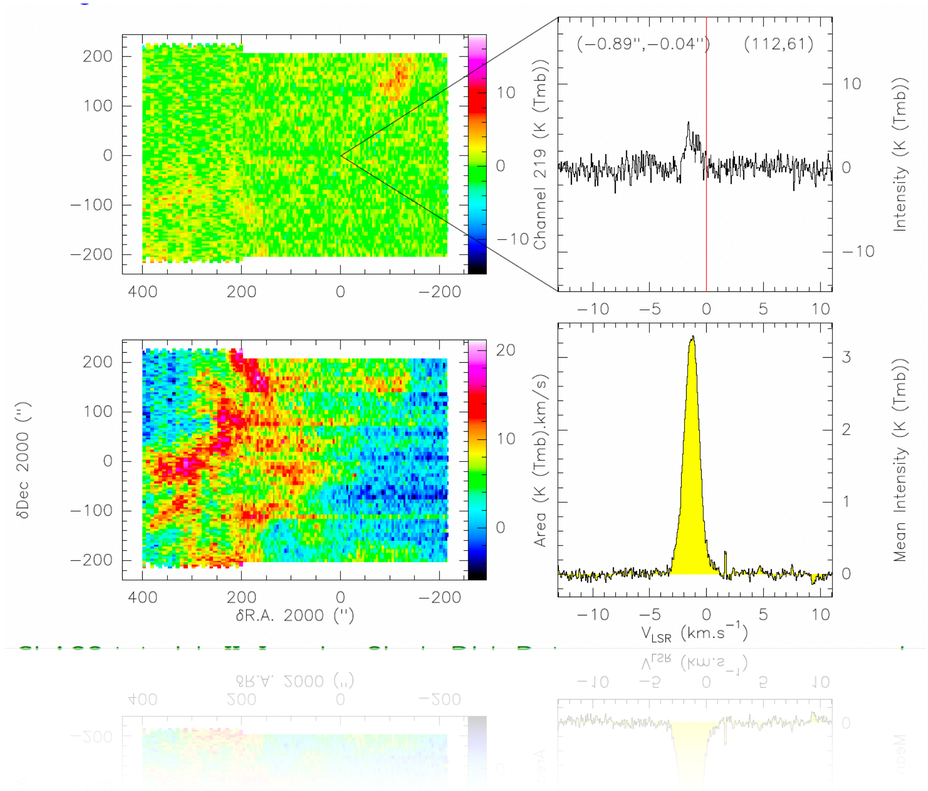
Example from MRTCAL

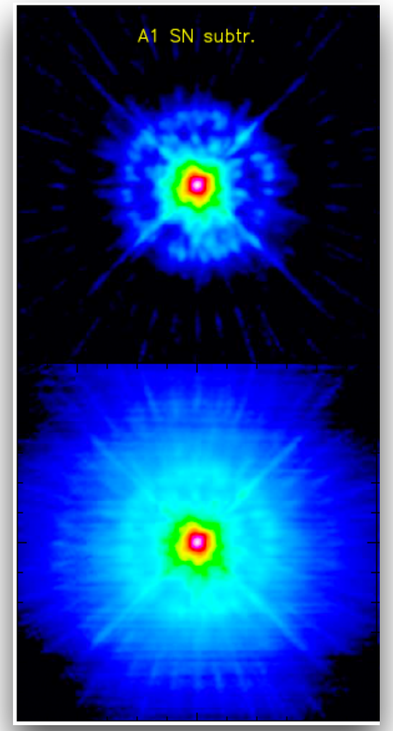


Herramientas de Observación IV: Reducción Datos

- Software de IRAM: ***GILDAS suite***. → https://www.iram.fr/IRAMFR/GILDAS/ (Check "Tutorials")
- Para 30m, 3 paquetes principales: **CLASS, (CUBE), PIIC** (NOEMA: **CLIC, IMAGING**)
- Muy eficiente, rápido
- Lenguaje SIC / Sintaxis poco intuitiva
- Mantenimiento y Nuevos desarrollos difíciles







Conclusion y Posibles Mejoras

- *IRAM30m: Metodología y herramientas maduras, ratio on-sky alto, comunidad activa ⇒ Productividad ↑*

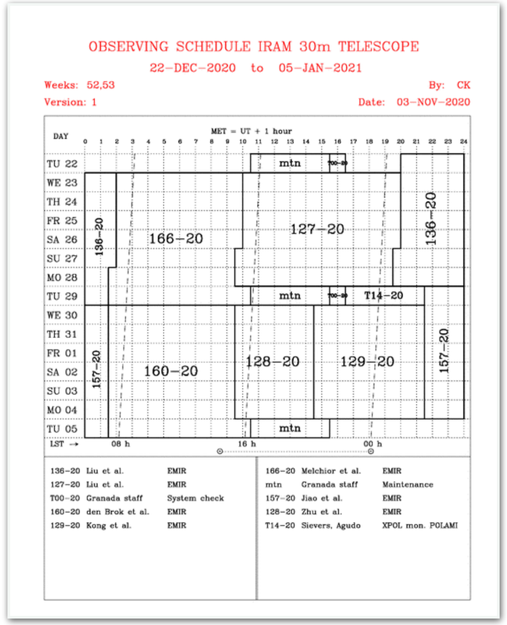
- **Documentación**: Actualizaciones, más variedad de tutoriales, webminars, …
- **Modernización del lenguaje de programación de herramientas internas**: “Pythonización”
  - Facilidad nuevas generaciones, Herramientas extra (e.g., Librerías de Inteligencia Artificial, CARTA, …)

Gracias por la atención.

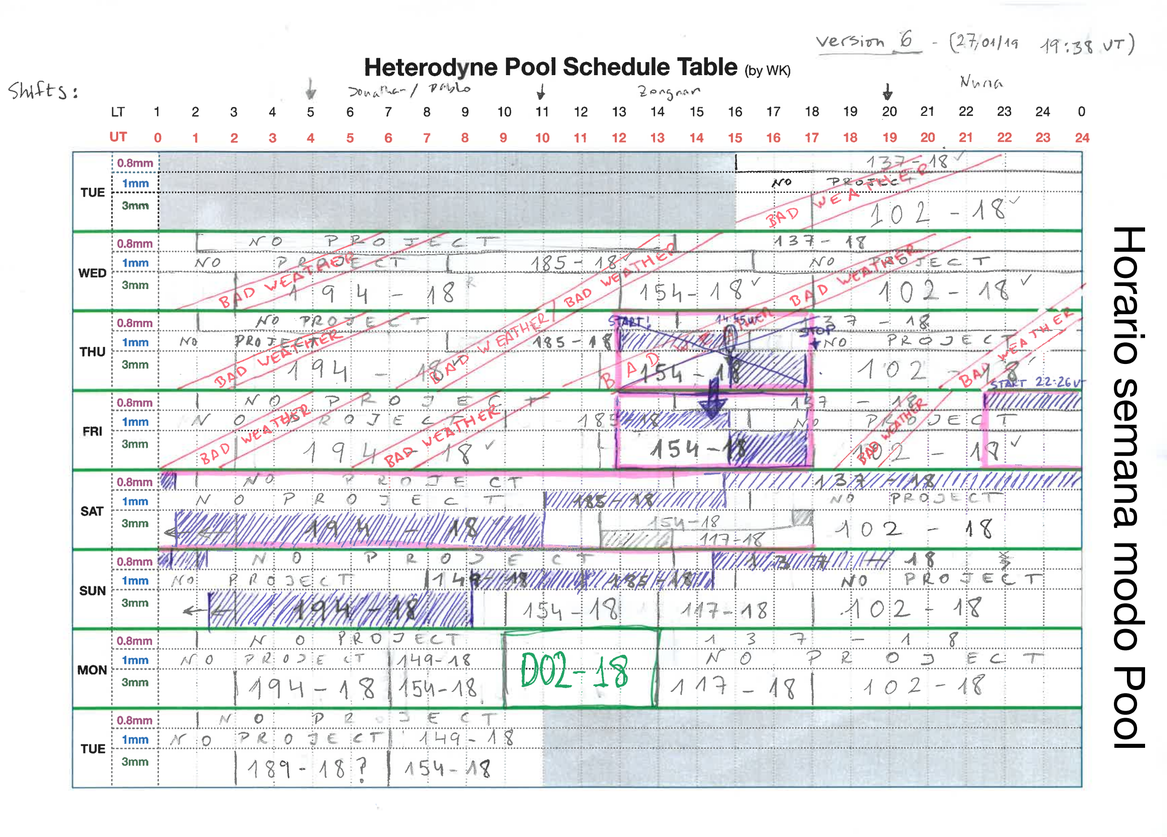
Ejecución de Observaciones

- 4 modos principales:
  - **Visitante, Remoto**
  - (Servicio)
  - **Pool (Dynamic Scheduling)**
  - *VLBI*

Astrónomo de IRAM siempre disponible para dar soporte, resolver dudas, y garantizar la utilización óptima del tiempo de telescopio. Con gran ayuda del operador.


OBSERVING SCHEDULE IRAM 30m TELESCOPE
22-DEC-2020 to 05-JAN-2021
Weeks: 52,53 By: CK
Version: 1 Date: 03-NOV-2020
MET = UT + 1 hour
DAY 0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
TU 22
WE 23
TH 24
FR 25
SA 26
SU 27
MO 28
TU 29
WE 30
TH 31
FR 01
SA 02
SU 03
MO 04
TU 05
LST → 08 h 16 h 00 h
mtn
T00-20
166-20
127-20
136-20
136-20
mtn
T00-20
T14-20
157-20
157-20
160-20
128-20
129-20
mtn
136-20 Liu et al. EMIR
127-20 Liu et al. EMIR
T00-20 Granada staff System check
160-20 den Brok et al. EMIR
129-20 Kong et al. EMIR
166-20 Melchior et al. EMIR
mtn Granada staff Maintenance
157-20 Jiao et al. EMIR
128-20 Zhu et al. EMIR
T14-20 Sievers, Agudo XPOL mon. POLAM

Horario semana modo visitantes



Horario semana modo Pool