
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.

Todays 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

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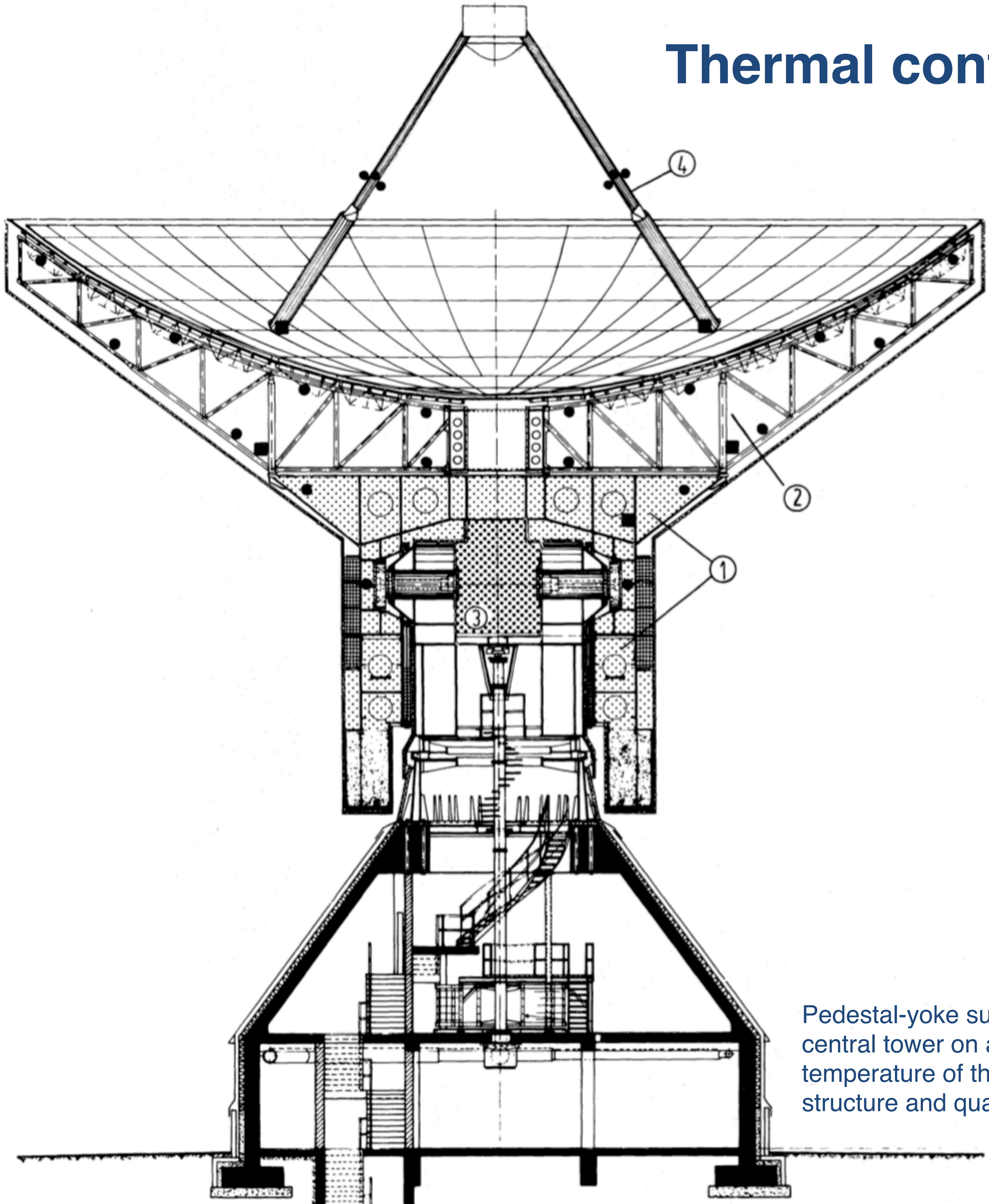


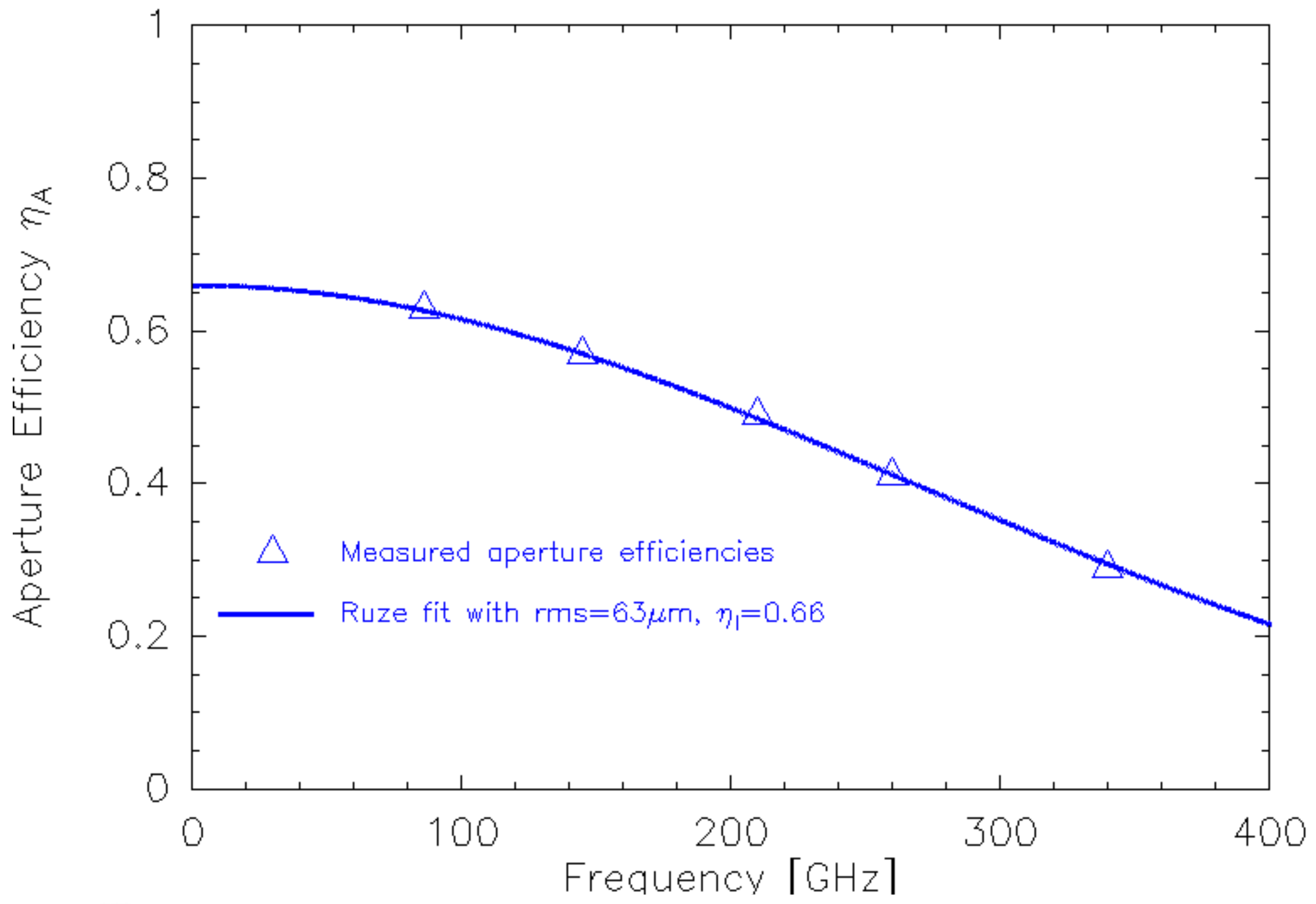
- Thermal drifts can affect pointing, focus, reflector surface.
- Passive control: paint, insulation, closed back structure
- Active control: ventilated and climatized backup structure. Since 2000, ventilation and heating of yoke.
- Temperature uniformity between the yoke, the backup structure, and the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

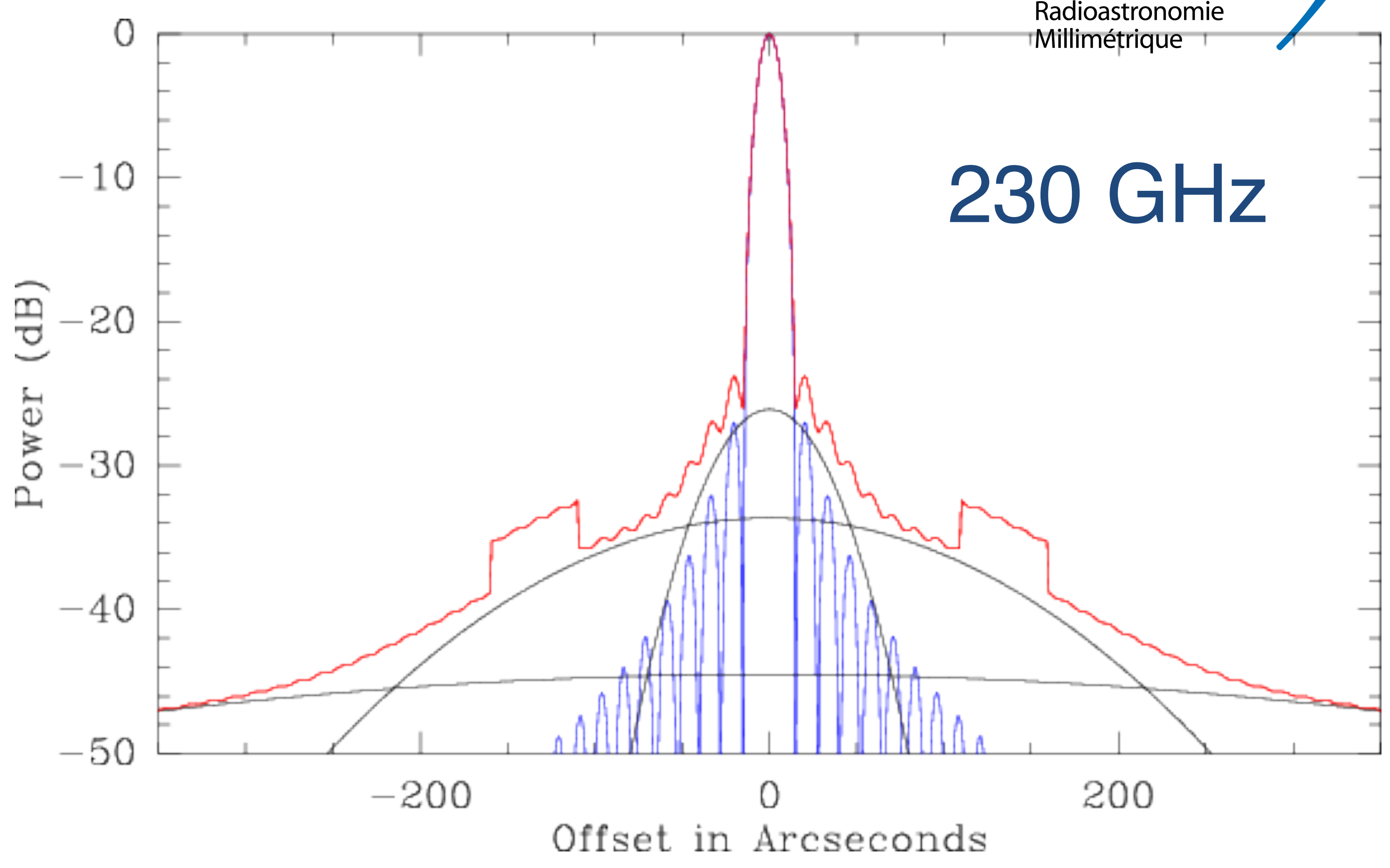
Pedestal-yoke supported reflector. 1: yoke, 2: backup structure, 3: central tower on azimuth bearing, 4: quadripod. Solid square: reference temperature of the yoke to which the temperature of the backup structure and quadripod are actively controlled. Baars et al. (1988)

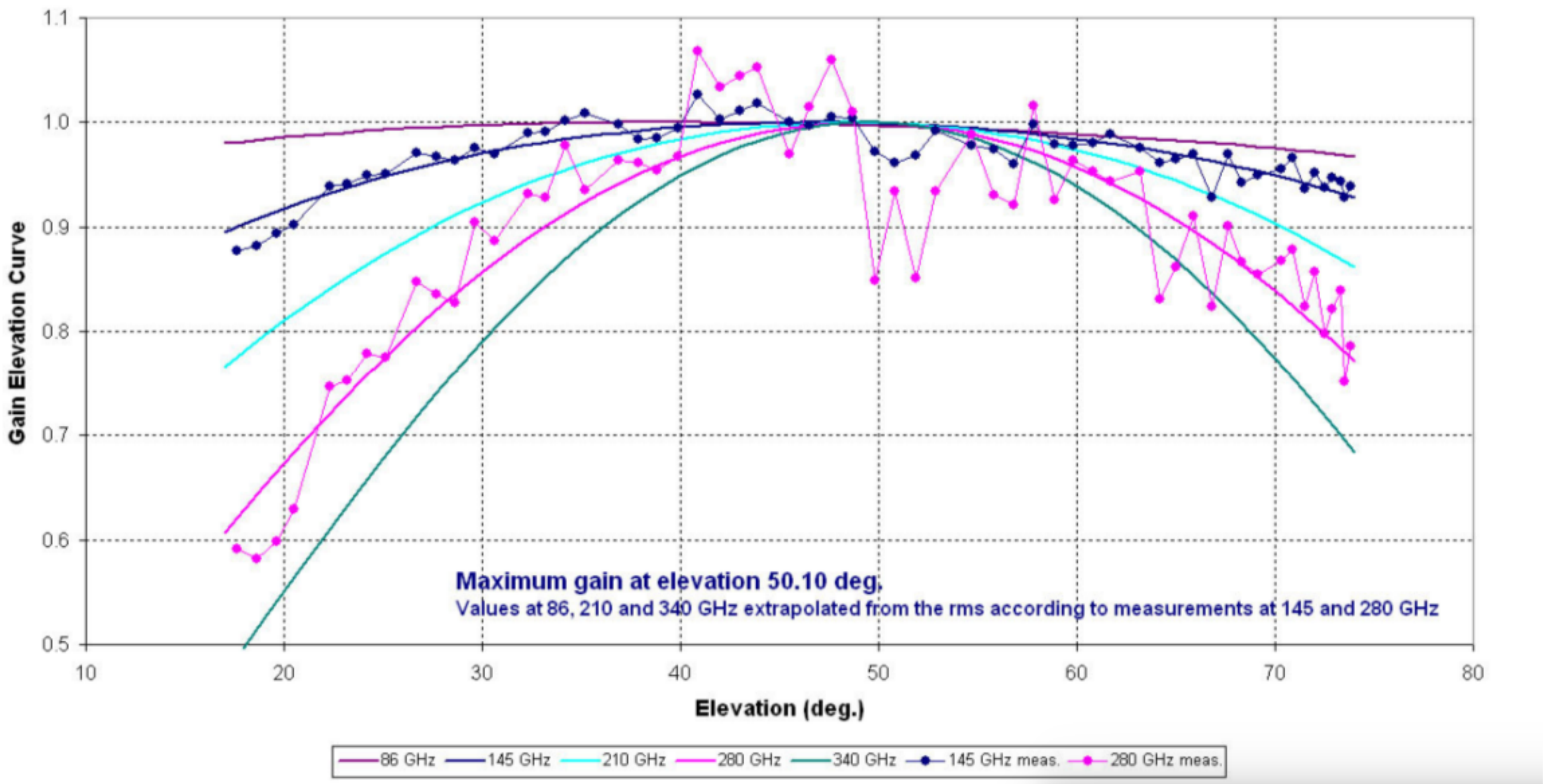
De-icing

- 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.

30m telescope: point source sensitivities, gain-elevation curve, antenna diagram, surface accuracy



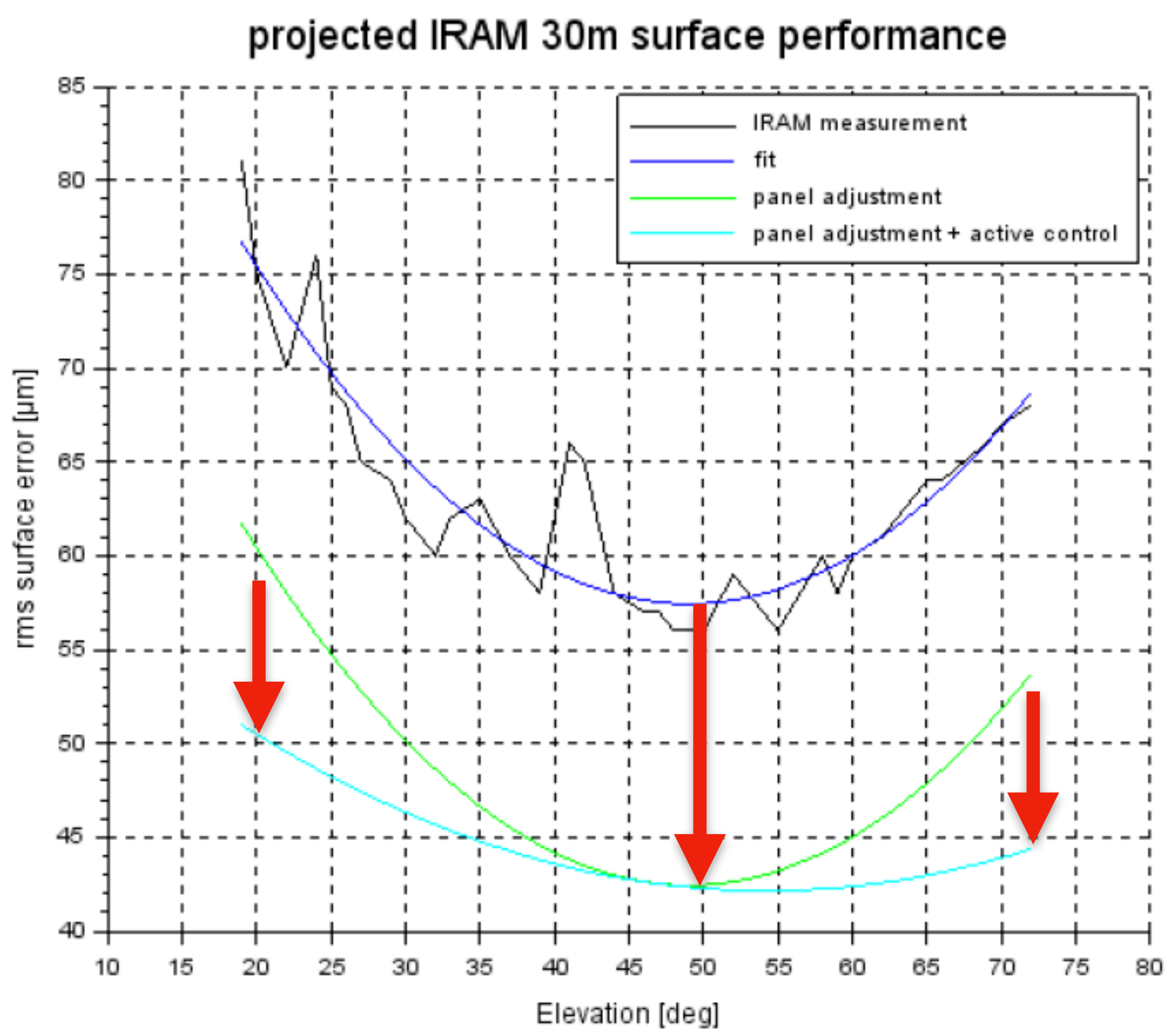




The current aperture efficiency drops with frequency from 66% to 46% at 230GHz.

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 !

Planned upgrade of the 30m telescope: Primary mirror



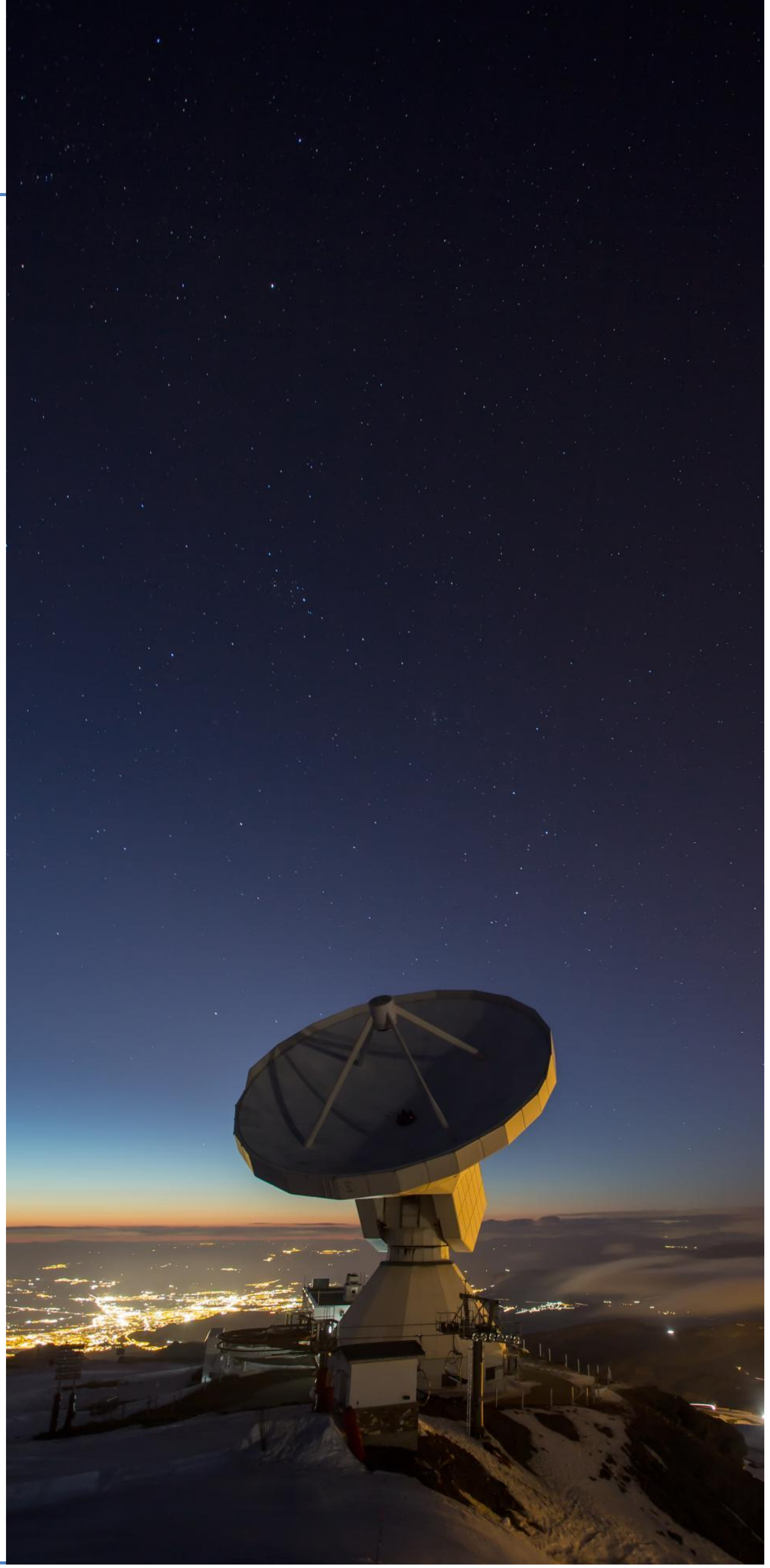
The pre-study by industry done in 2018 indicates that the surface rms and the gain-elevation curve can be improved with two actions:

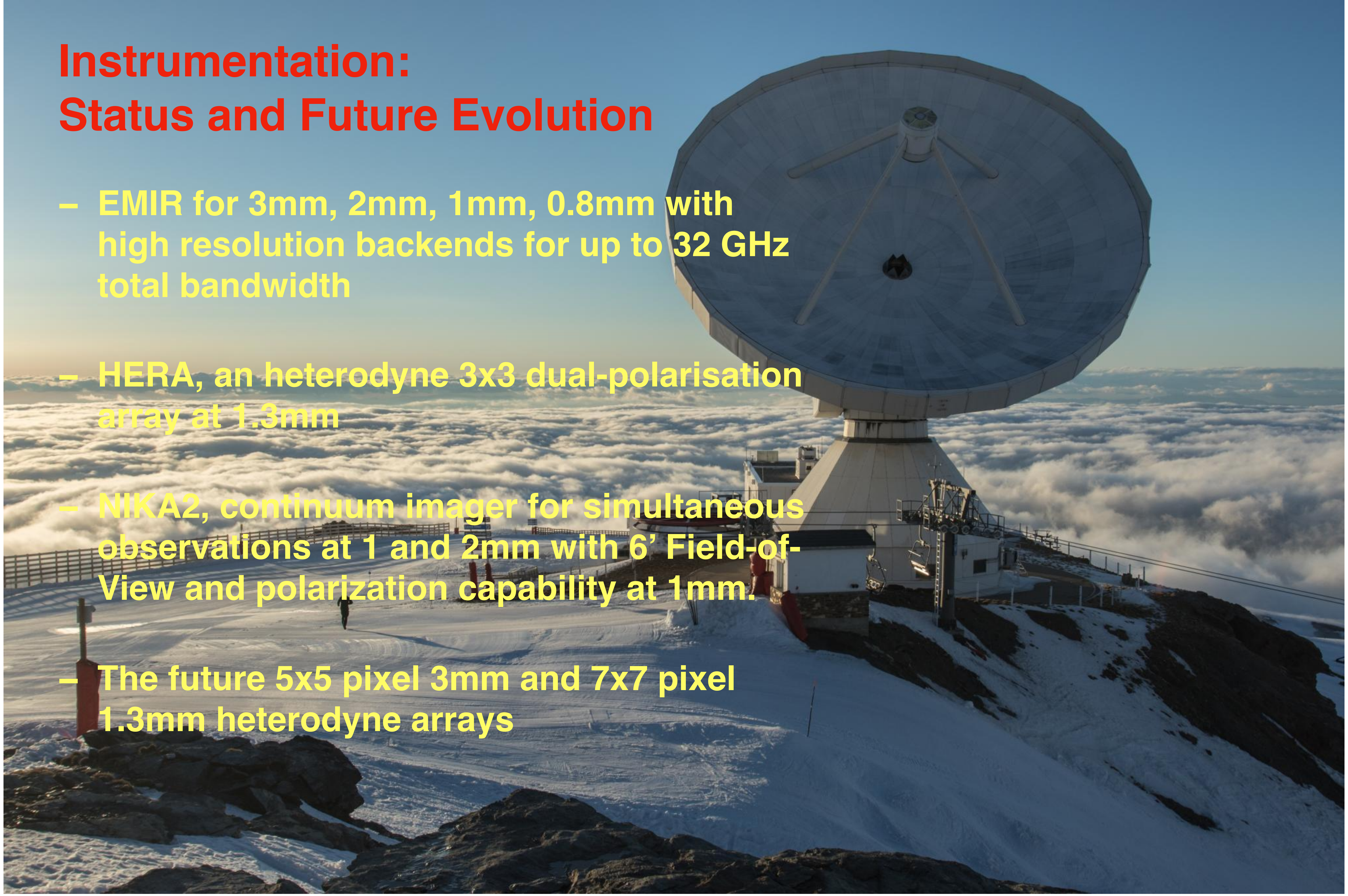
1/ Re-aligning all 420 panels on their 210 sub-frames. After dis-mouting the frames and panels, the panel plaint will also be replaced.

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

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

Contents

1. EMIR Users Guide
    1. News (last update: 25-Apr-2017, CM)
    2. Upgrades
        1. Sep-2016: New dichroic for E0/E2 dual-band operation
        2. Dec-2015: New 2SB mixers for E0 and E1
        3. Sep-2013: 2SB mixers for E1
        4. Nov-2011: 2SB mixers for E2 and E3
        5. Jul-2011: 32GHz IF-system, FTS backends

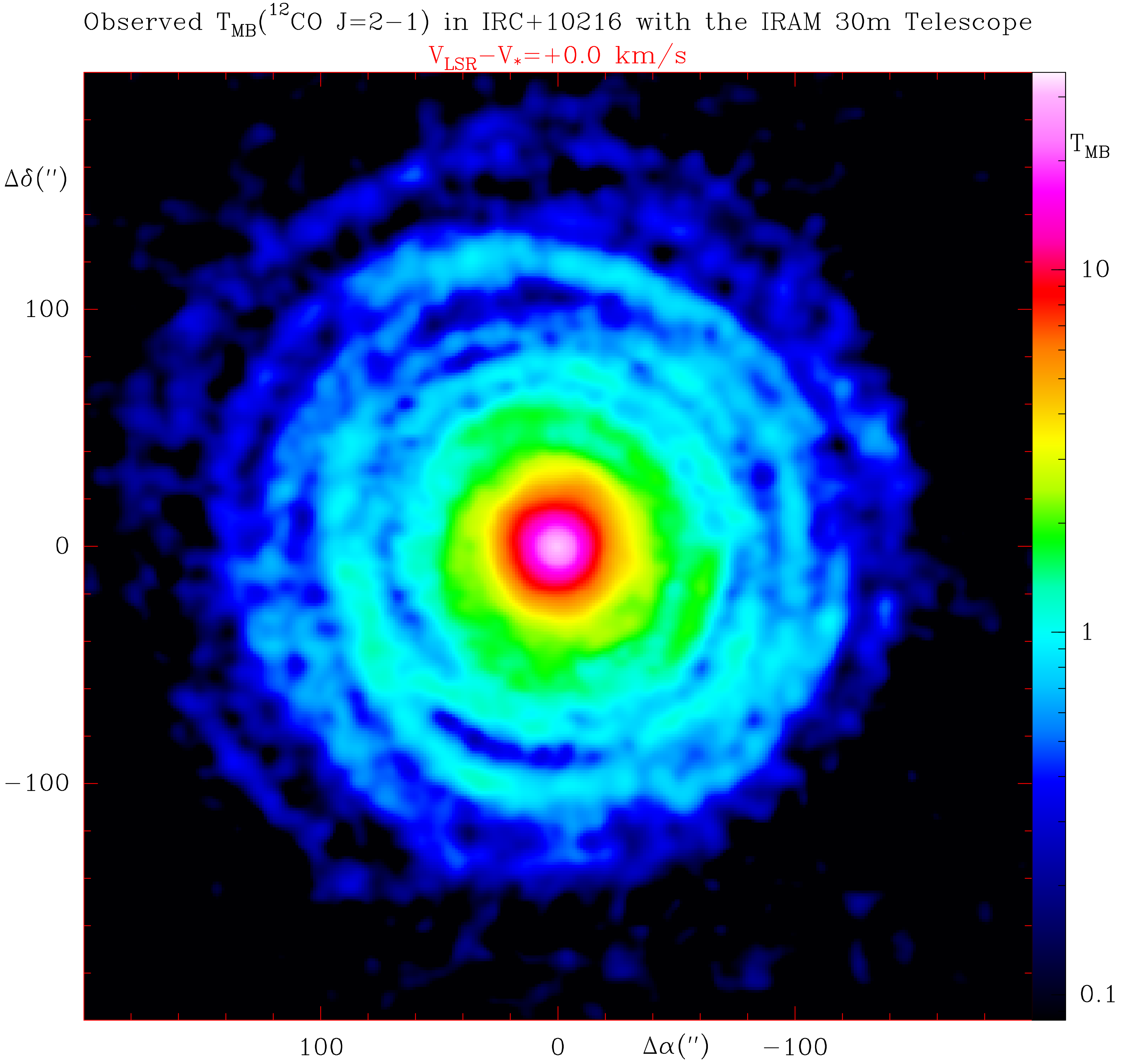
- GILDAS software package:
    - observers interface: PAKO — specific to all observations with the 30m
    - spectral line calibration package: MIRA / MRTCAL — specific to the 30m
    - spectral line data reduction package: CLASS — used at a variety of observatories

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

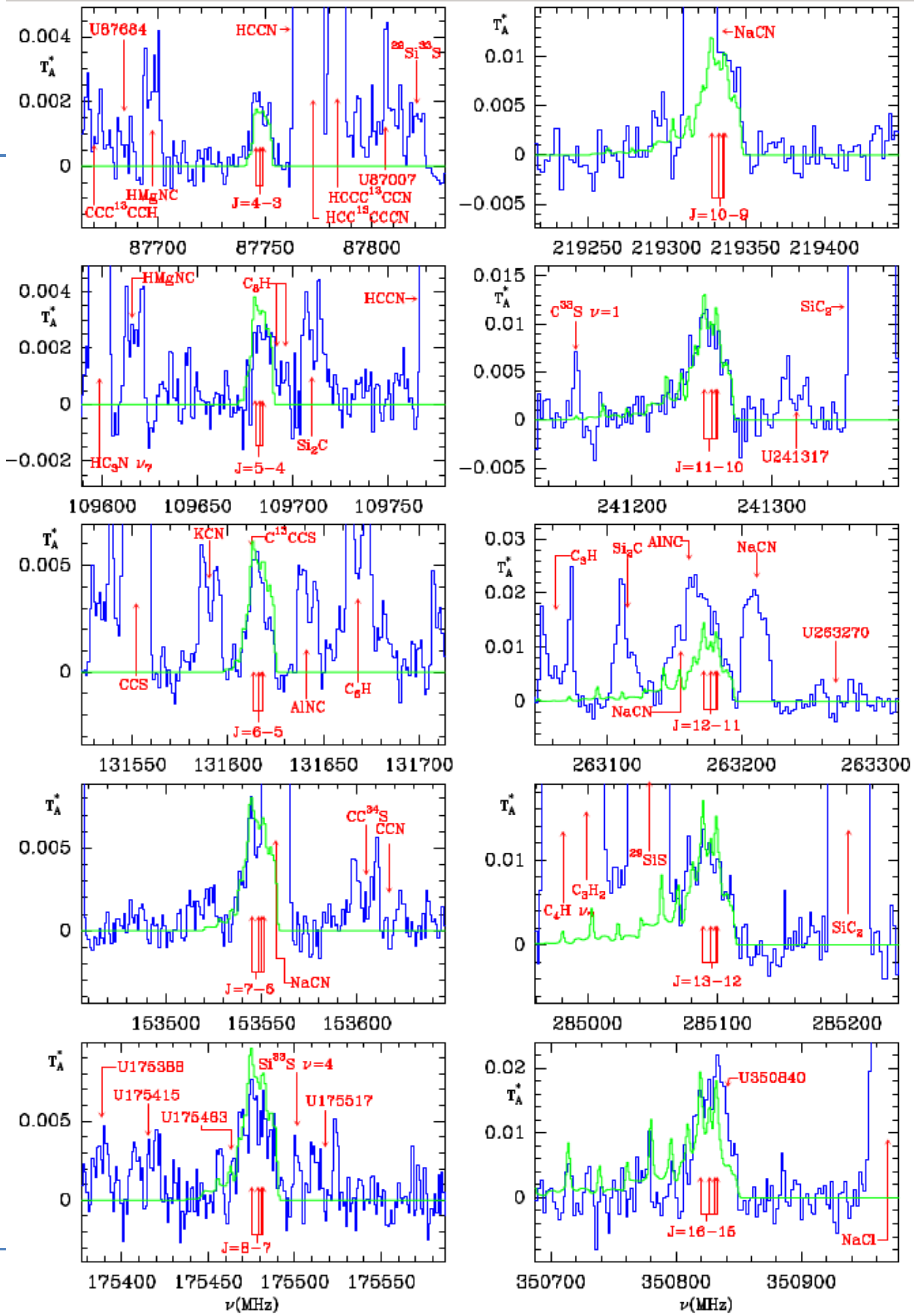


- Mass loss of AGB stars via stellar ejecta enrich the ISM and largely control the chemical evolution of galaxies
- Here, CO emission of the shells of carbon-rich AGB star IRC+10216 at 120pc distance
- Envelope is nearly spherical, expanding at 14.5 km/s.
- The resolution of 11″ corresponds to an expansion 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.

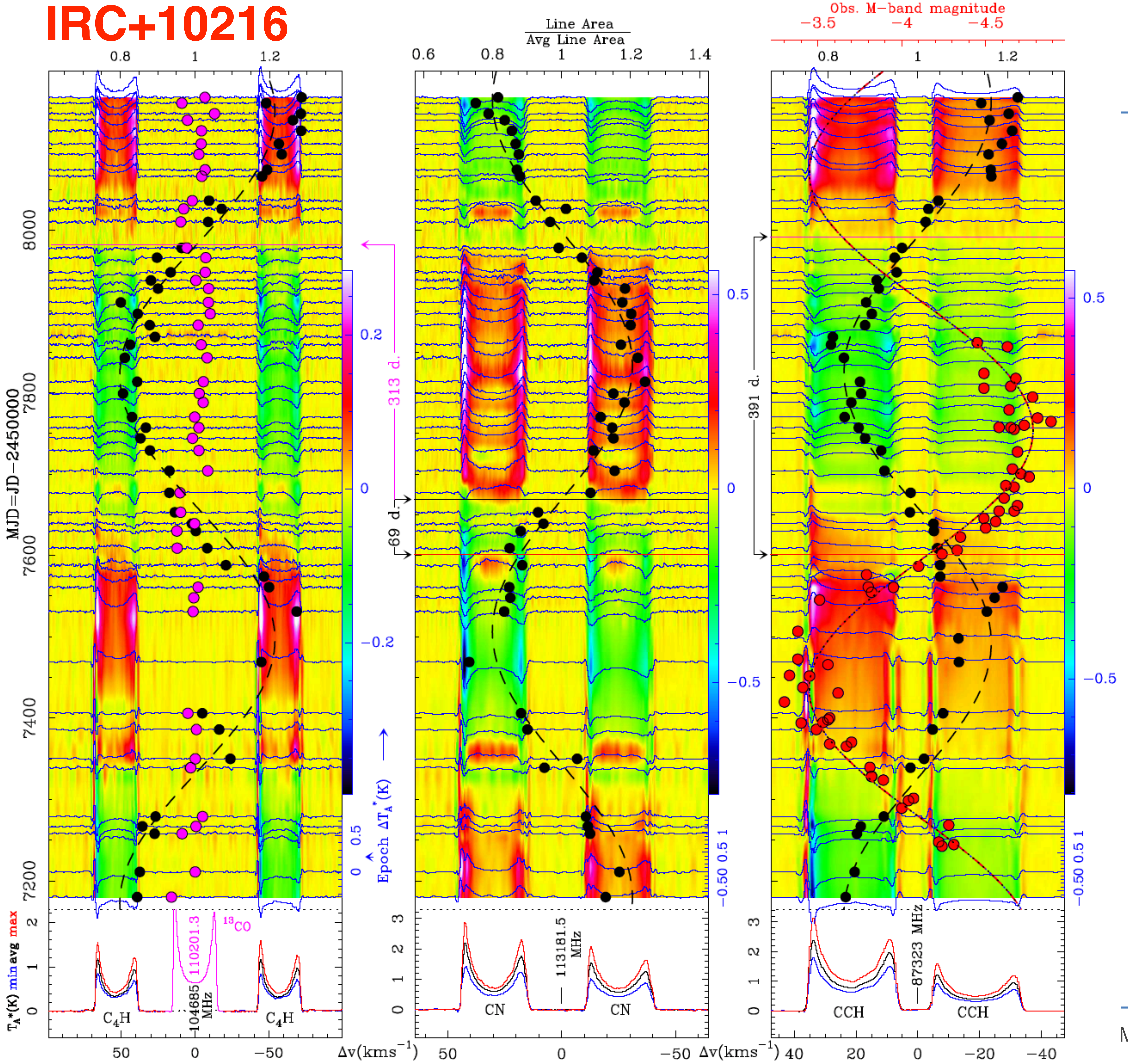
Detection of methyl silane CH_3SiH_3 in IRC+10216

- The detection of organo-silicon molecule CH_3SiH_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_nC_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_3SiH_3 spectrum
  Red arrows indicate K-ladder.
- Cernicharo, Agundez et al. 2017 (A&A, 606, 5)



IRC+10216

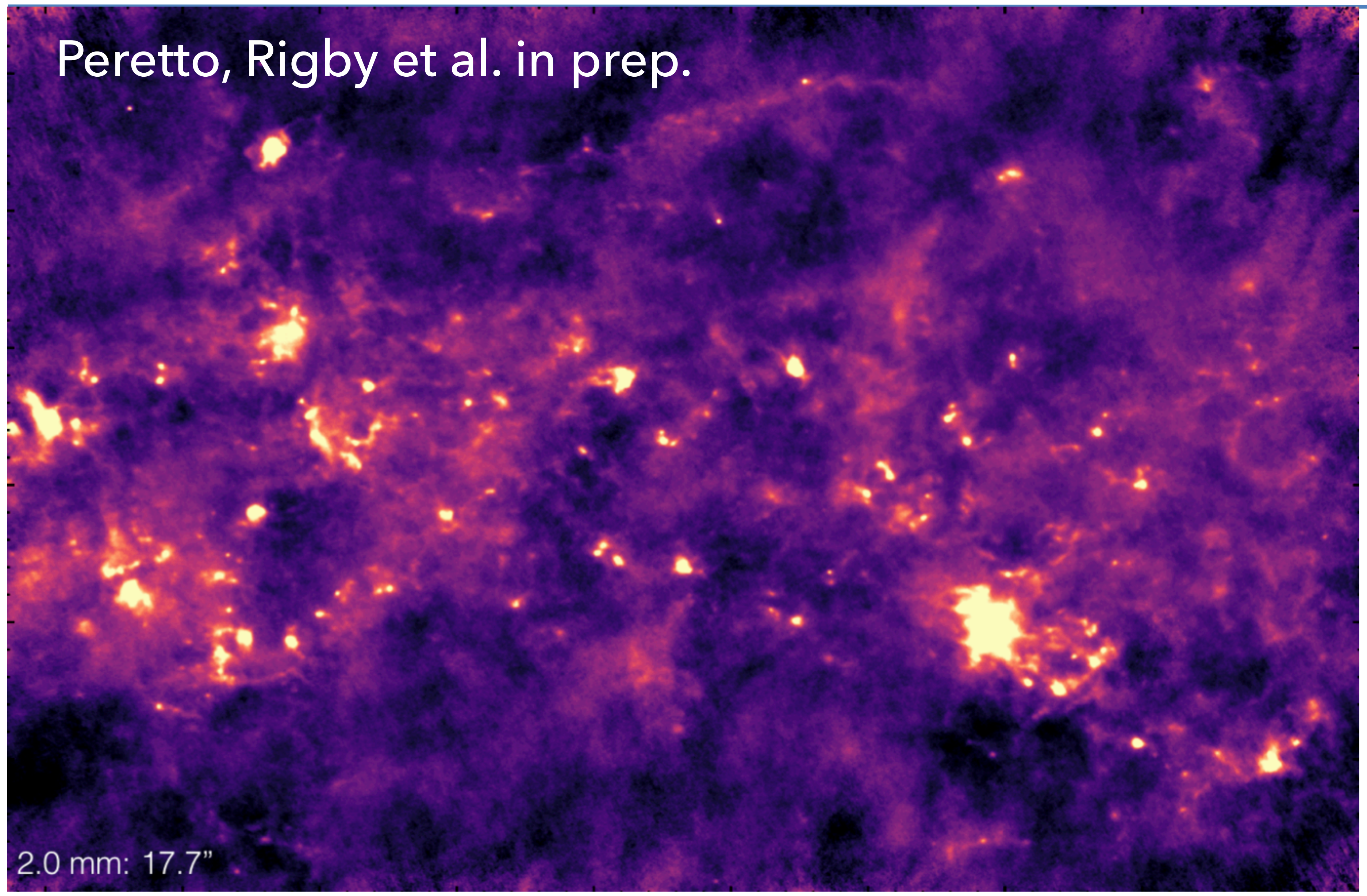


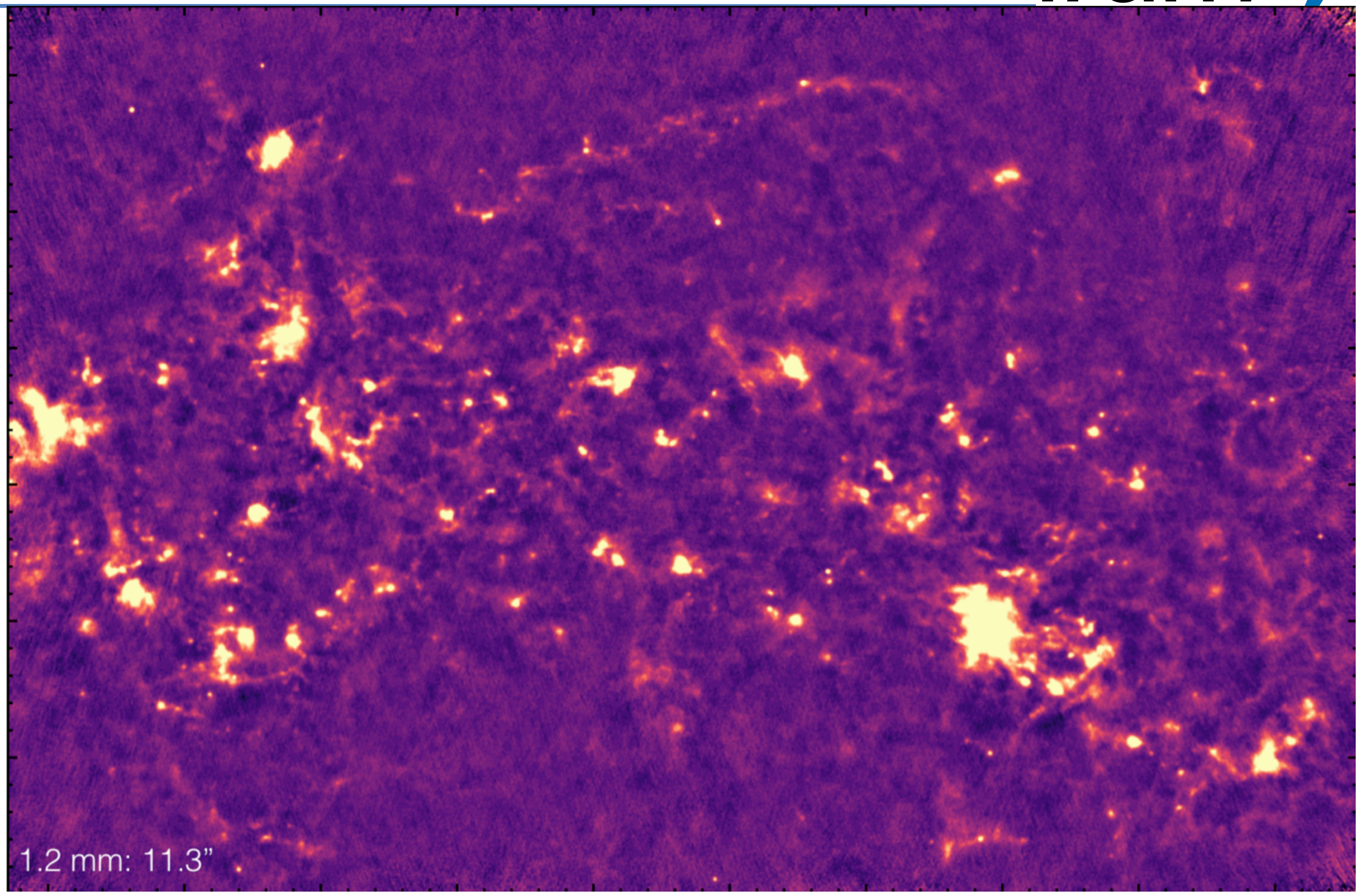
Periodic time variability of C_4H, C_2H, CN in IRC+10216

Period = 635 days

(Pardo et al. 2018, A&A, 615, 4)

NIKA2 maps of a 2°x1° region of the Galactic plane

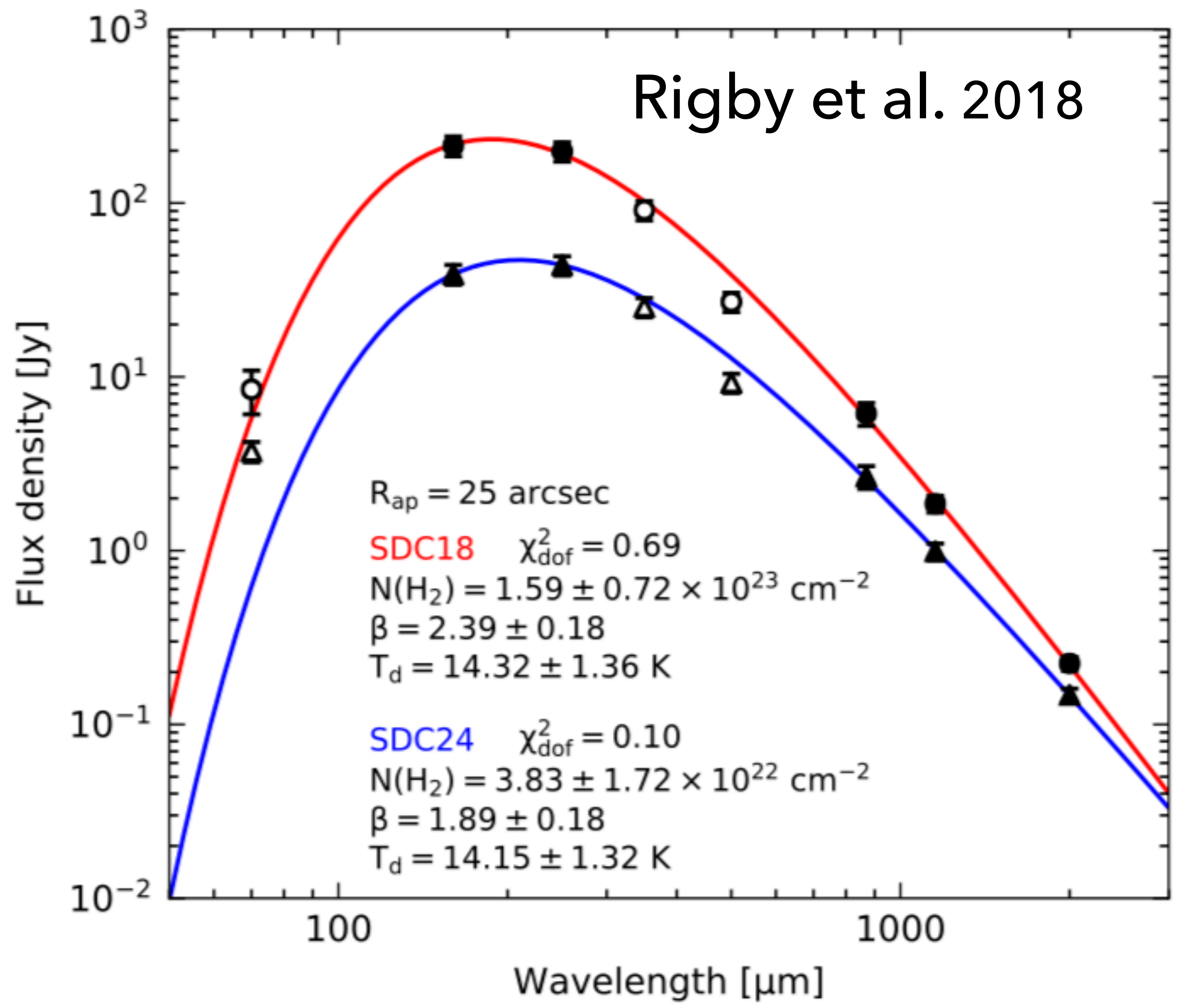




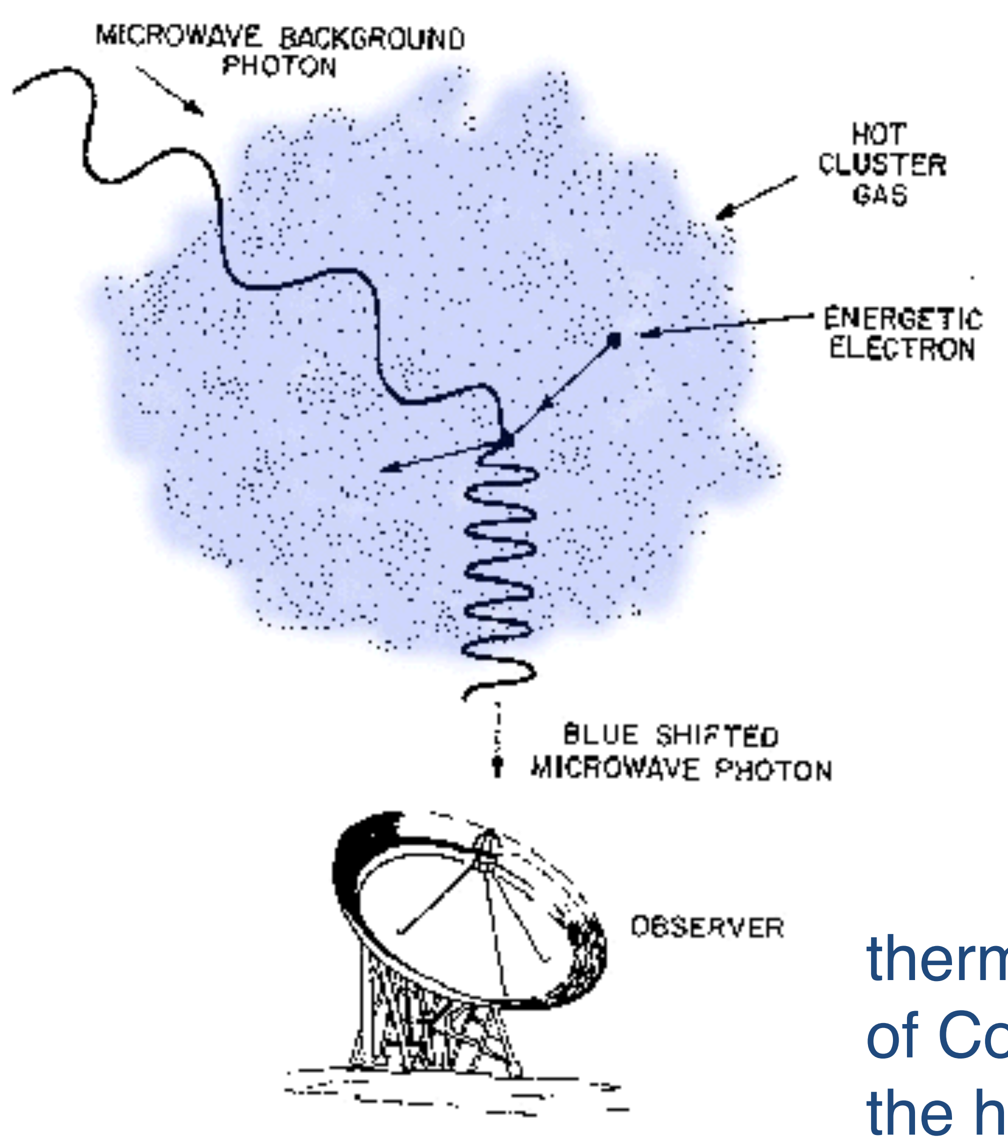
Sites of high and low mass star formation, and infrared dark clouds towards the Galactic plane at 24° longitude. Thermal dust emission, but also radio free-free and synchrotron emission. Aiming to study dust emissivity variations and the evolution of cold dust properties.

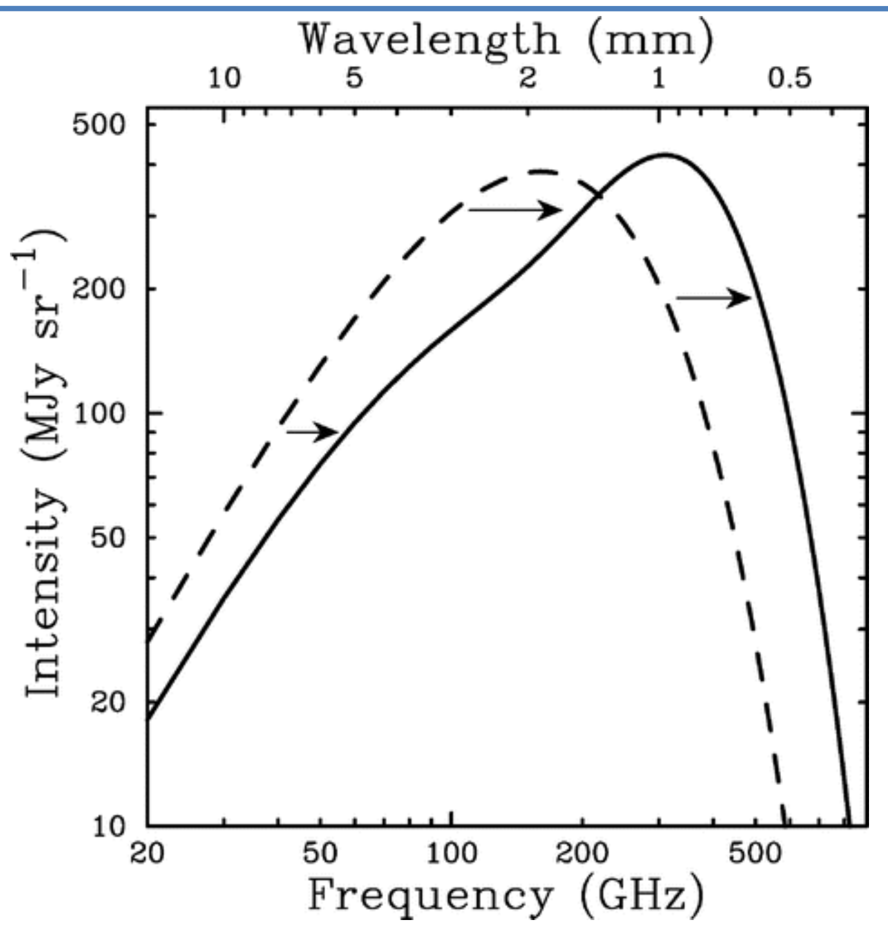
NIKA2 continuum camera at the 30m telescope: 3000 pixels at 2mm and 1mm, using superconducting KID detectors at 150mK. Fast scanning 60"-70"/s and fast sampling with 24 Hz to overcome atmospheric fluctuations and to detect the extended emission.

Ancillary data available from Planck, Herschel, APEX.
A large 30m program by Peretto, Rigby et al. 2018, EWASS.

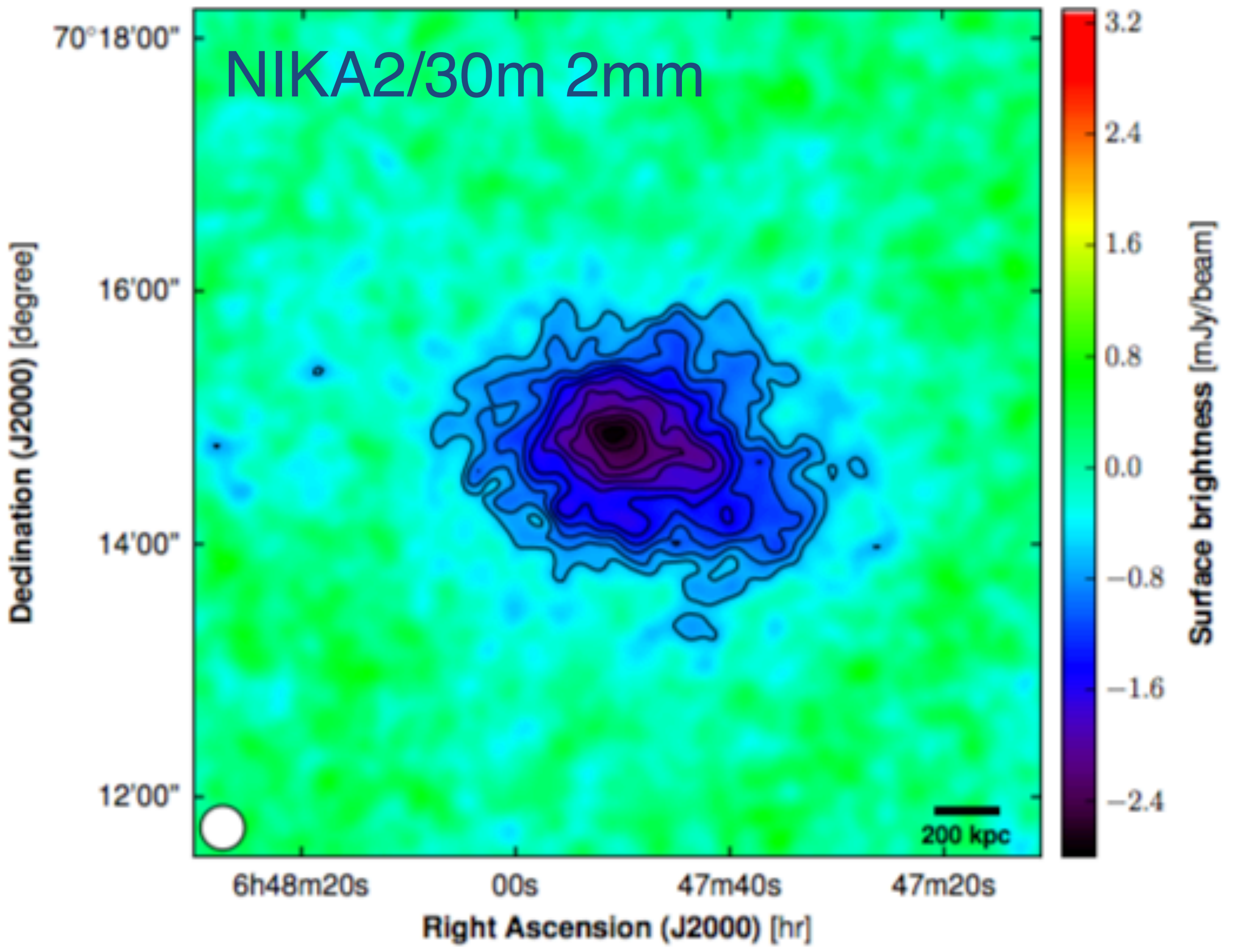


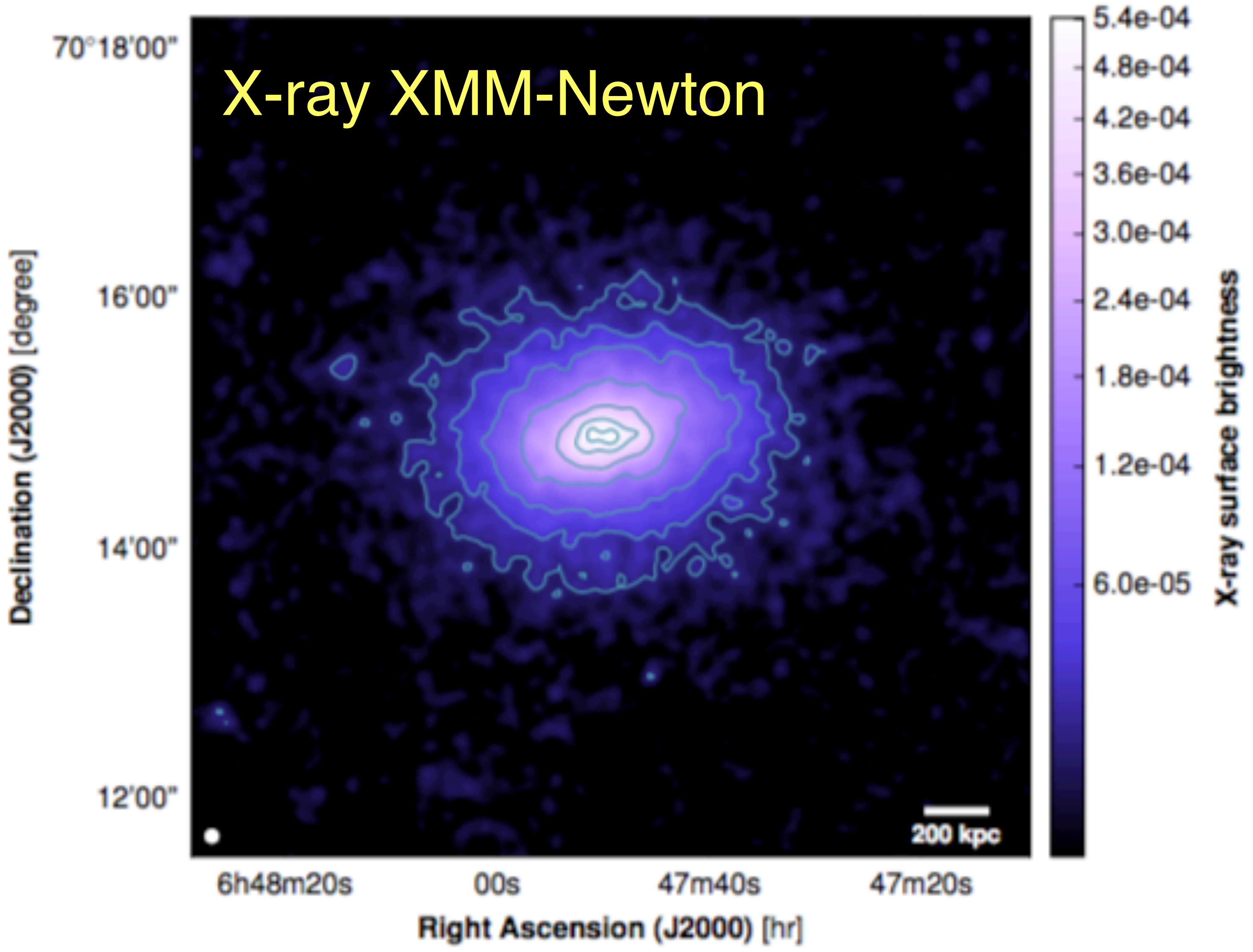
Sunyaev-Zel'dovich map of a galaxy cluster



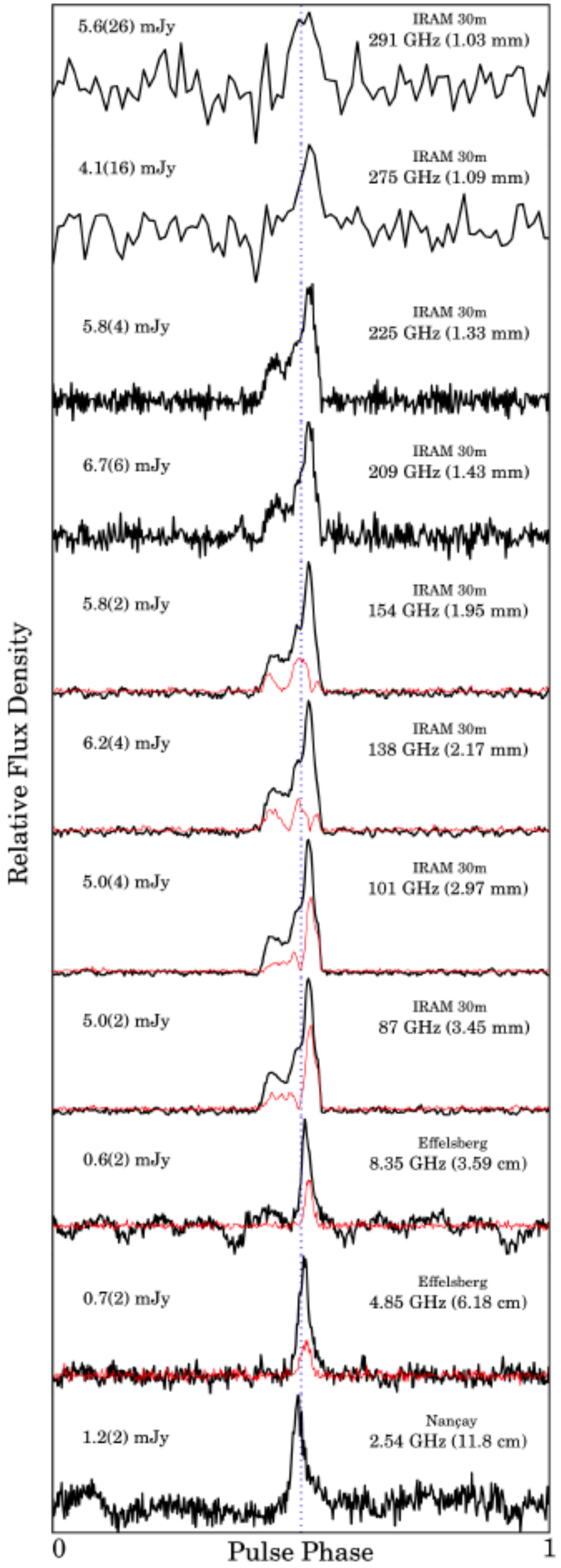


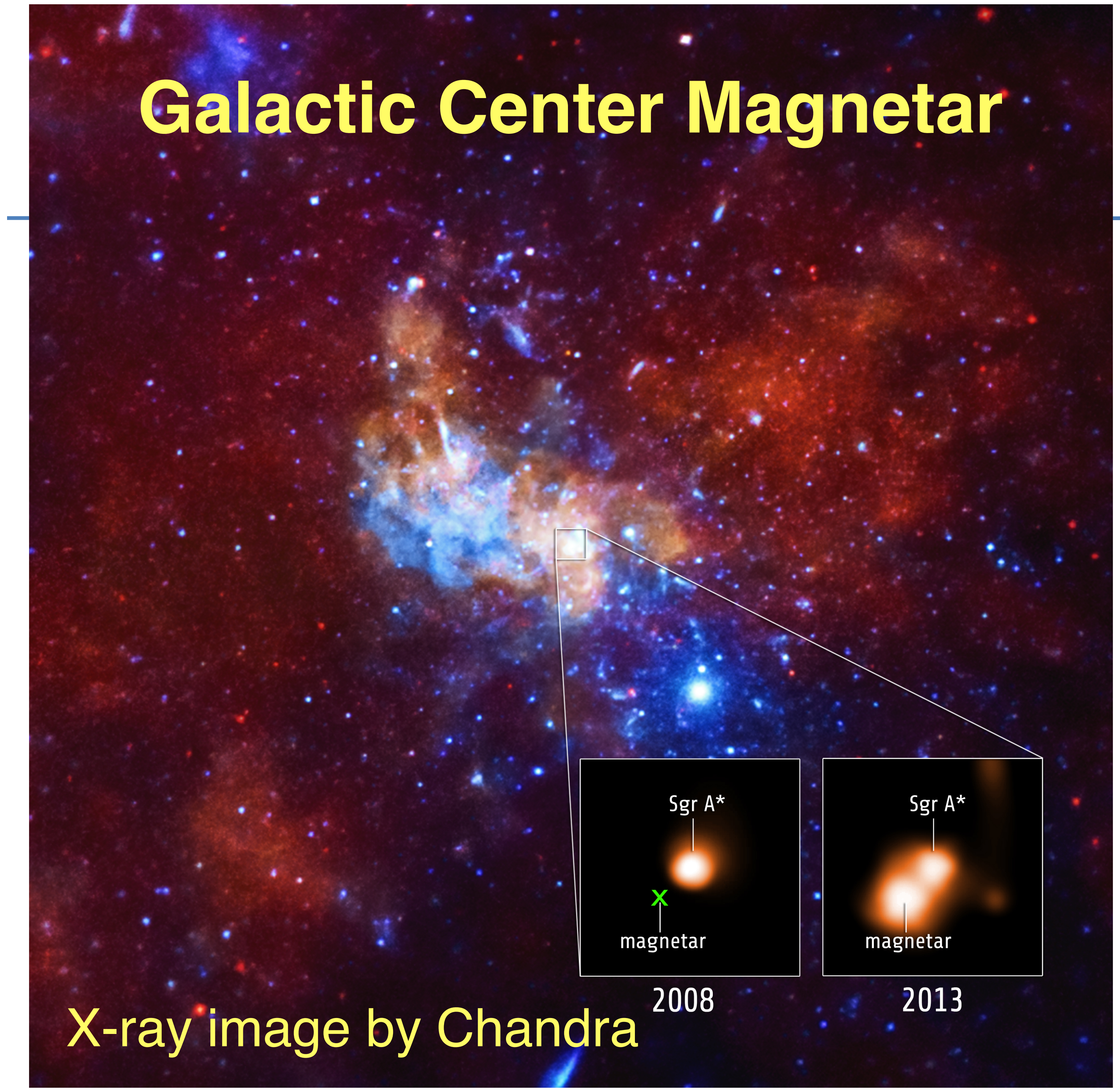
thermal SZ-effect: Inverse Compton scattering of Cosmic Background photons on electrons of the hot intra-cluster medium, leads to distortion of CMB spectrum.

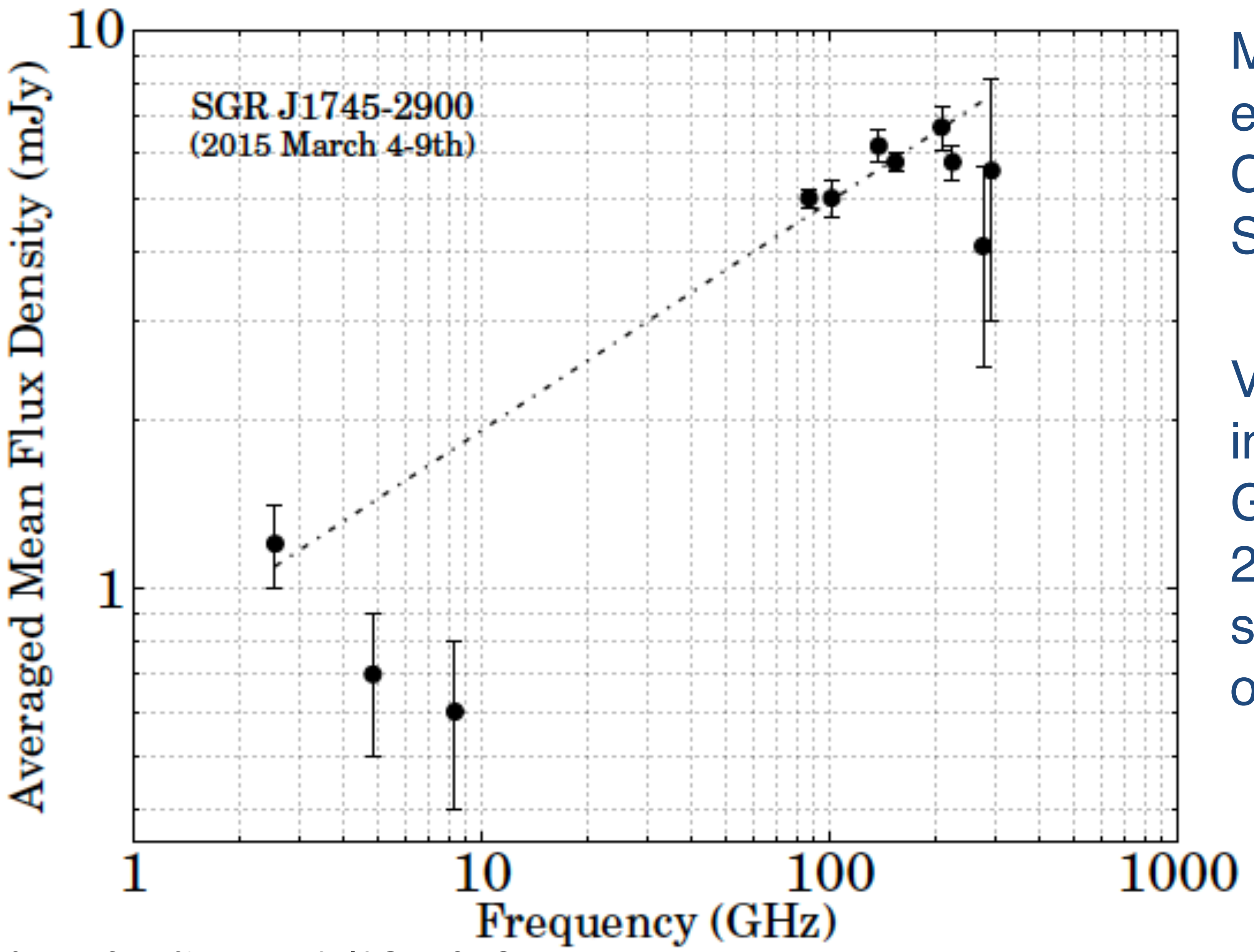




- Sunyaev-Zeldovich map of the galaxy cluster PSZ2G144.83+25.11 at z=0.58
- 11 hours observation time in April 2017 under average summer conditions
- Thermal pressure profile from NIKA2/30m
- combined with electron density profile from XMM-Newton
- Ruppin et al. 2018, A&A, accepted







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.
$\langle\alpha\rangle = +0.4$

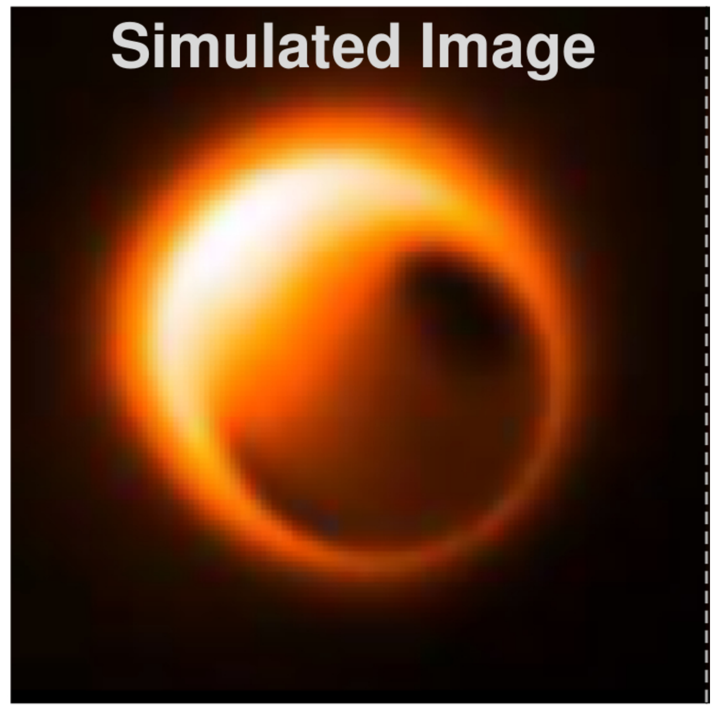
Torne et al. 2015, 2017

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.



Falcke et al. 2000