CONCERTO: instrument and first results

Observing the Universe at mm wavelengths
27 June 2023

Alessandro Fasano on behalf of the
CONCERTO collaboration

Contents

I.
Project overview and science drivers

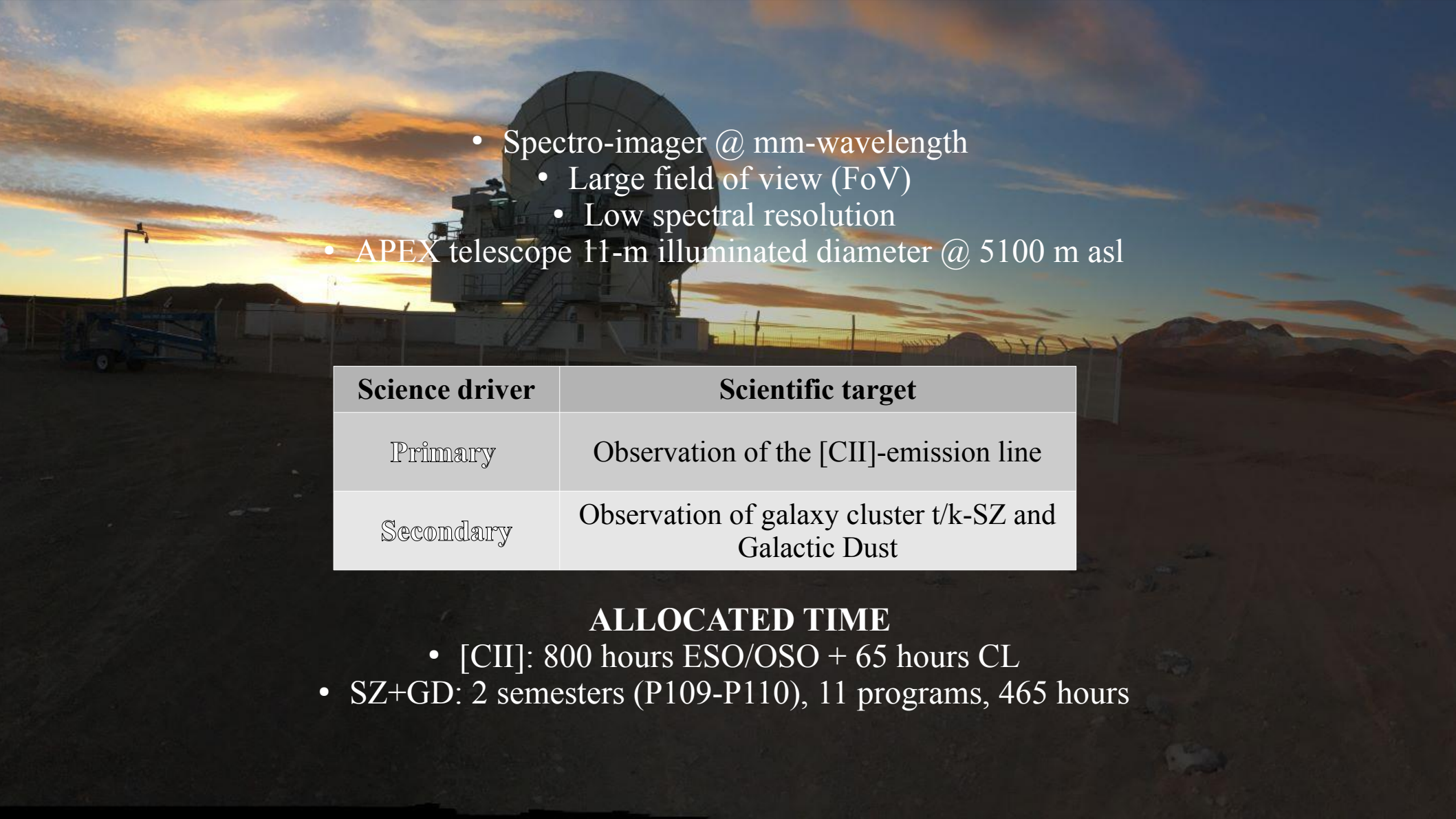
The CONCERTO project

Grant ERC funding to fabricate, install and observe with the CONCERTO instrument @ APEX telescope.

Start: January 2019.

LAM and Grenoble (Institut Néel, IPAG and LPSC) collaboration.
PI: Guilaine Lagache (LAM)
Instrument PI: Alessandro Monfardini (Institut Néel)

ERC (project CONCERTO , grant agreement No78812)
LabEx FOCUS ANR-11-LABX-0013



- Spectro-imager @ mm-wavelength
  - Large field of view (FoV)
  - Low spectral resolution
- APEX telescope 11-m illuminated diameter @ 5100 m asl

Science driver	Scientific target
Primary	Observation of the [CII]-emission line
Secondary	Observation of galaxy cluster t/k-SZ and Galactic Dust

ALLOCATED TIME

- [CII]: 800 hours ESO/OSO + 65 hours CL
- SZ+GD: 2 semesters (P109-P110), 11 programs, 465 hours

II.
CONCERTO instrument

The CONCERTO chart: the instrument in numbers

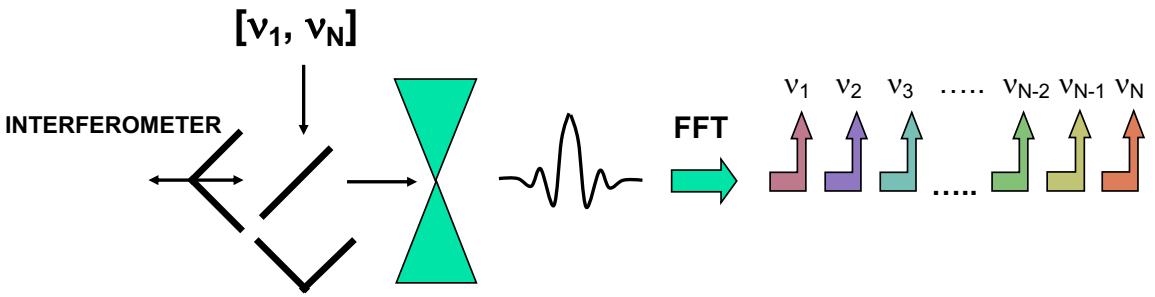
REQUIREMENTS

1) Maximum sensitivity and fast response
high sensitivity detectors
2) Large survey area and band 130-310 GHz
~few degrees
3) Low Spectral resolution
~1.5 GHz
4) Moderate angular resolution
at small angular scales 3-D power spectrum is dominated by shot noise rather than clustering of galaxies.

TECHNOLOGICAL SOLUTIONS

[Catalano et al. EPJ 2022]

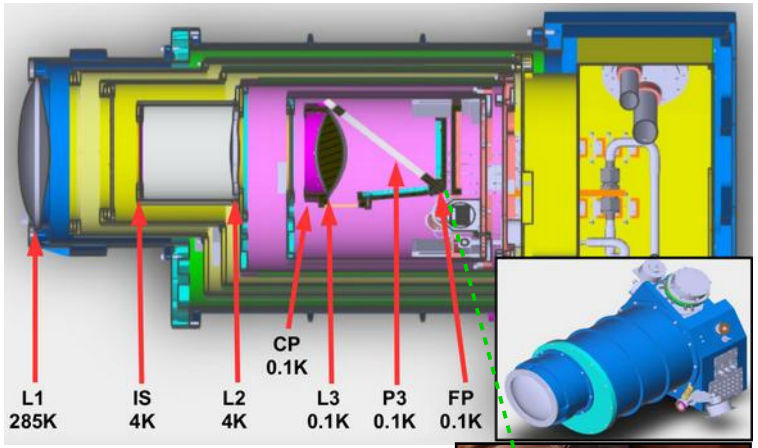
1) FTS Technique - Fast spectrometer
70 mm excursion, fast acquisition, avoid 1/f noise from the atmosphere
2) Double-array composed of 4 304 total KIDs
3) Telescope : 11-m illuminated, APEX
~ 18.6 arcmin corrected FP angular resolution from about 35 to 30 arcsec



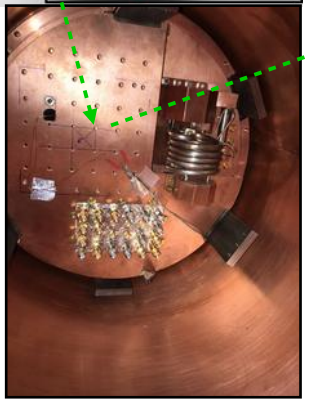
1 KID recovering all the spectrum with one interferogram.
"Interferogram": the interferometric pattern obtained by introducing an optical path difference.

The CONCERTO instrument

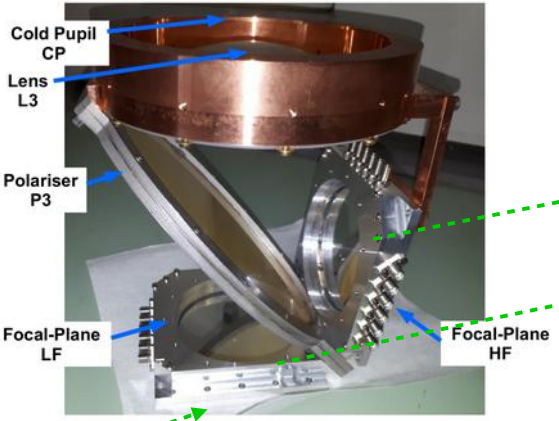
The focal plane is cooled-down to 60.0±0.1 mK:
- Pulse-Tube cryocooler,
- custom dilution He3/He4 refrigerator.



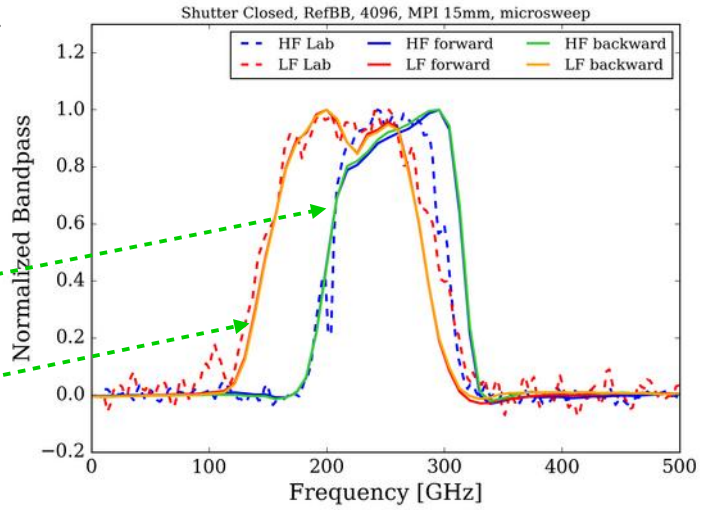
[The CONCERTO Collaboration A&A 2021]

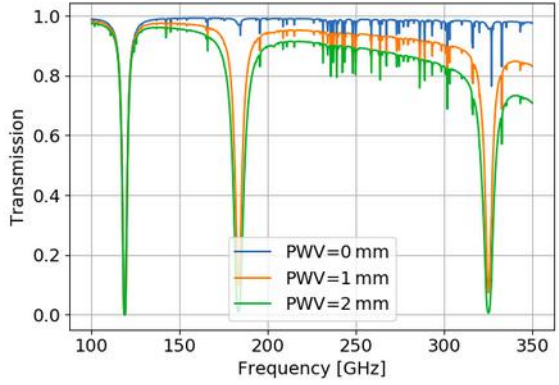


The dilution with the readout connections

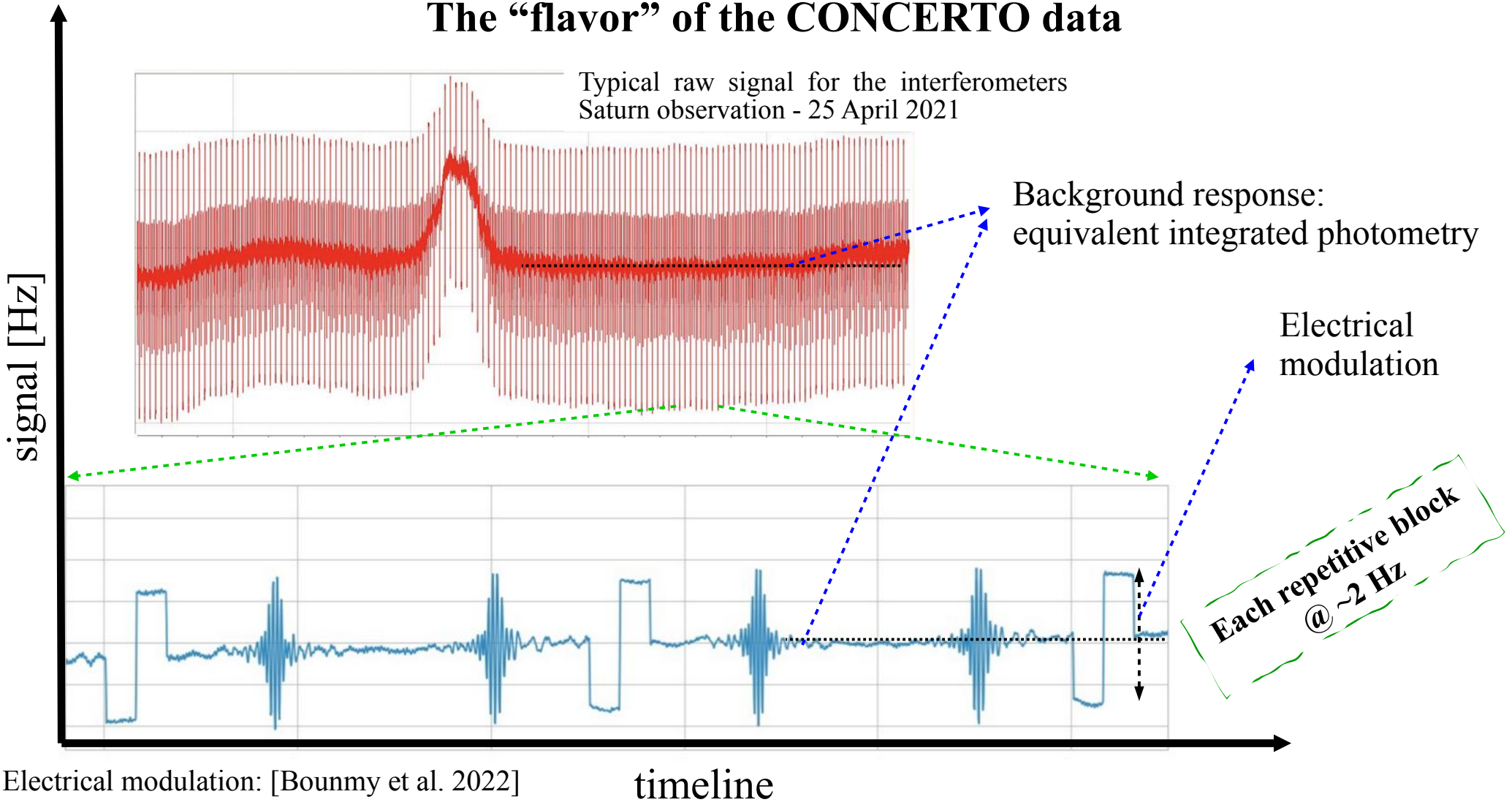


Double focal plane
LF: 130-270 GHz
HF: 195-310 GHz





The “flavor” of the CONCERTO data



Electrical modulation: [Bounmy et al. 2022]

III.
Installation and first results

Installation to APEX telescope in Chile
(5 100 m a.s.l.)

2021

6th April, installation start

10th April, cooldown start

12th April, base temperature achieved (60 mK)

Technical commissioning start

2nd of May → Crab

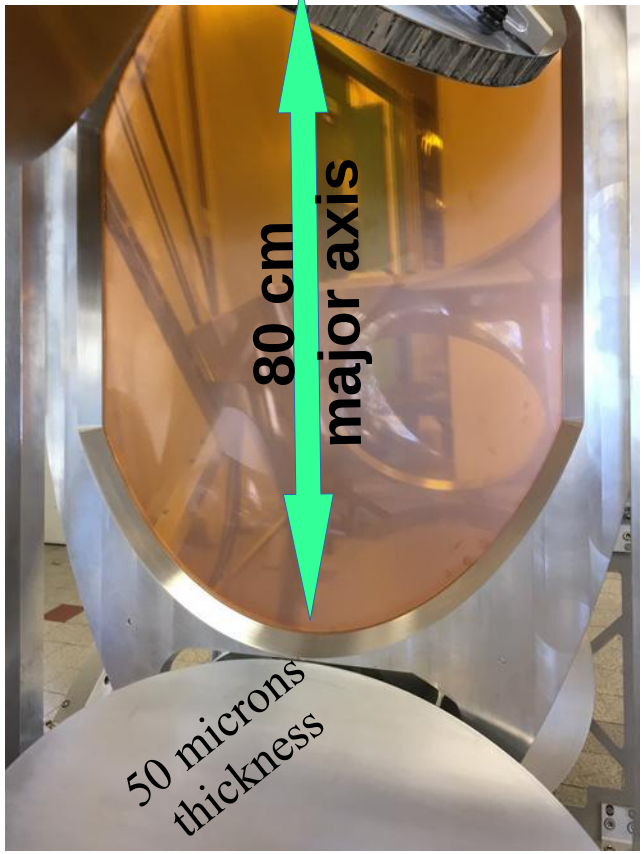
4th May, first observation from remote

The major systematics tackled

The vibration of the FTS polarizer

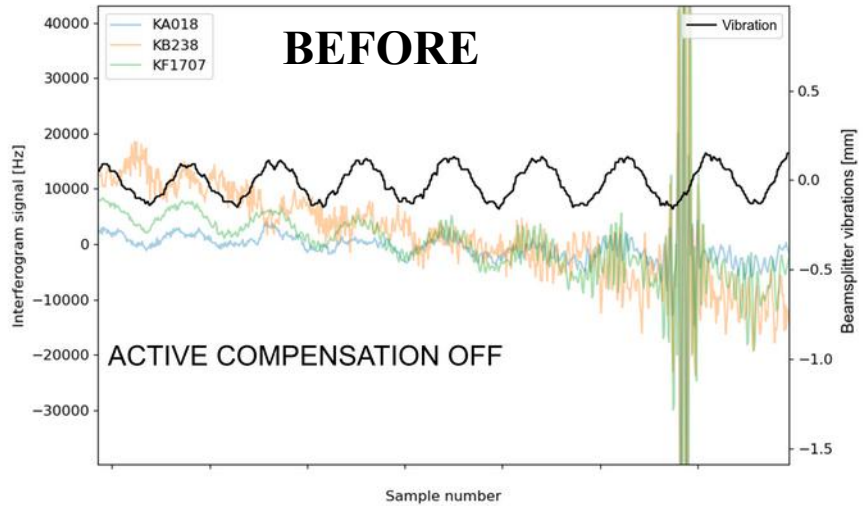
[Fasano et al. SPIE 2022]

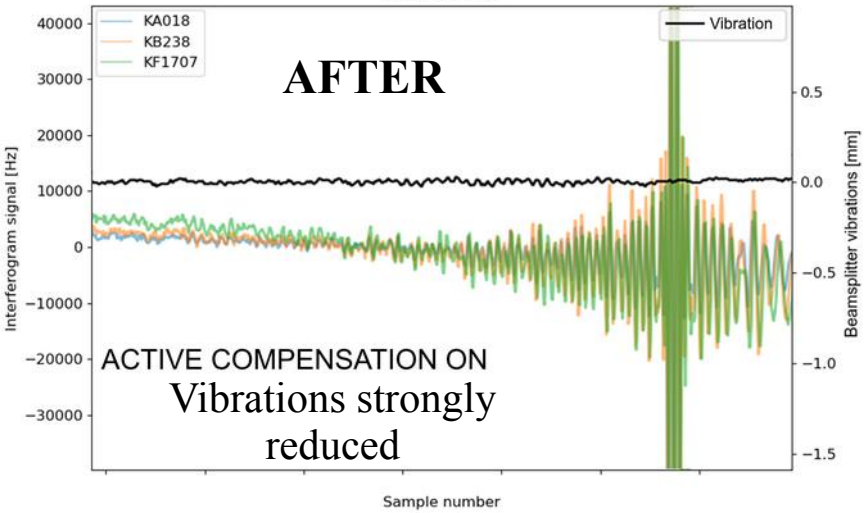
The FTS motor creates vibrations transmitted to the FTS polarizer.



We deployed a compensation system to counter these vibrations

Since December 2021





ESO press release

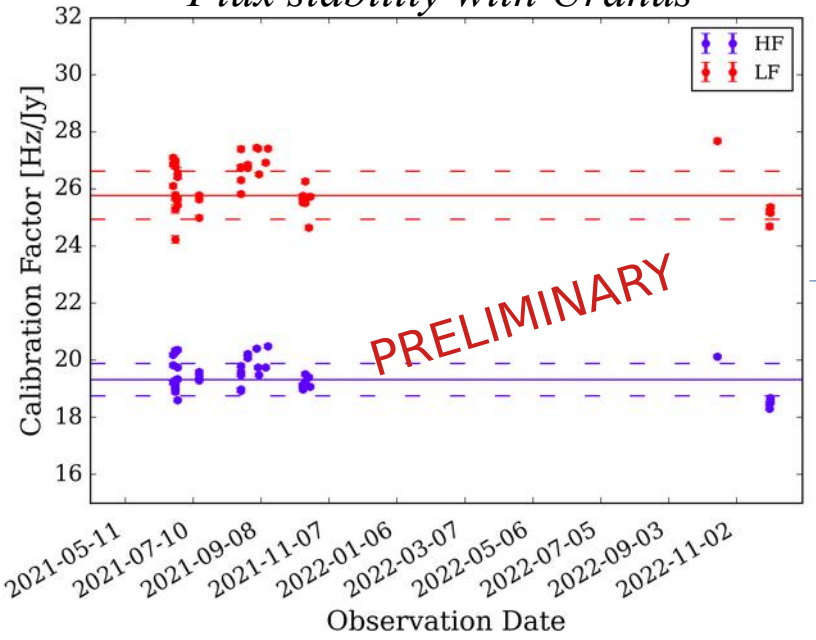
First extended source detected: Crab nebula
2.5 minutes of integration

Cat's Paw nebula
16 minutes of integration

Results on-sky

Photometric measurements

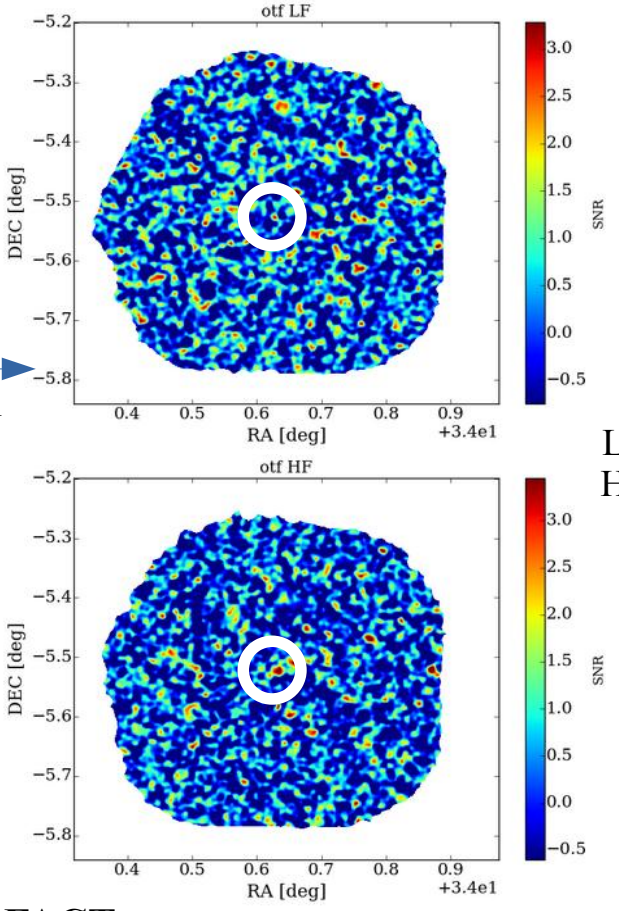
Flux stability with Uranus



Measured calibrations:
LF: 25.8±0.8 Hz/Jy
HF: 19.3±0.6 Hz/Jy

[Hu et al. in preparation]

Calibration employed for sub-Jy source



AS2UDS0001.0
Modeled by modified BB central source:
17.7 mJy @ 250 GHz

Measured (4.5 hours):
LF: 18.9±6.4 mJy @ SNR=3.0
HF: 17.6±5.2 mJy @ SNR=3.5

PRELIMINARY

FACTs:

- Photometric stability of ~5%
- Capability of mapping sub-Jy structures over hundreds of arcmin^2

Results on-sky

Noise equivalent flux density (NEFD)

Measured NEFD on COSMOS field:
LF: 138.7±0.2 mJy·$s^{0.5}$
HF: 155.4±0.2 mJy·$s^{0.5}$

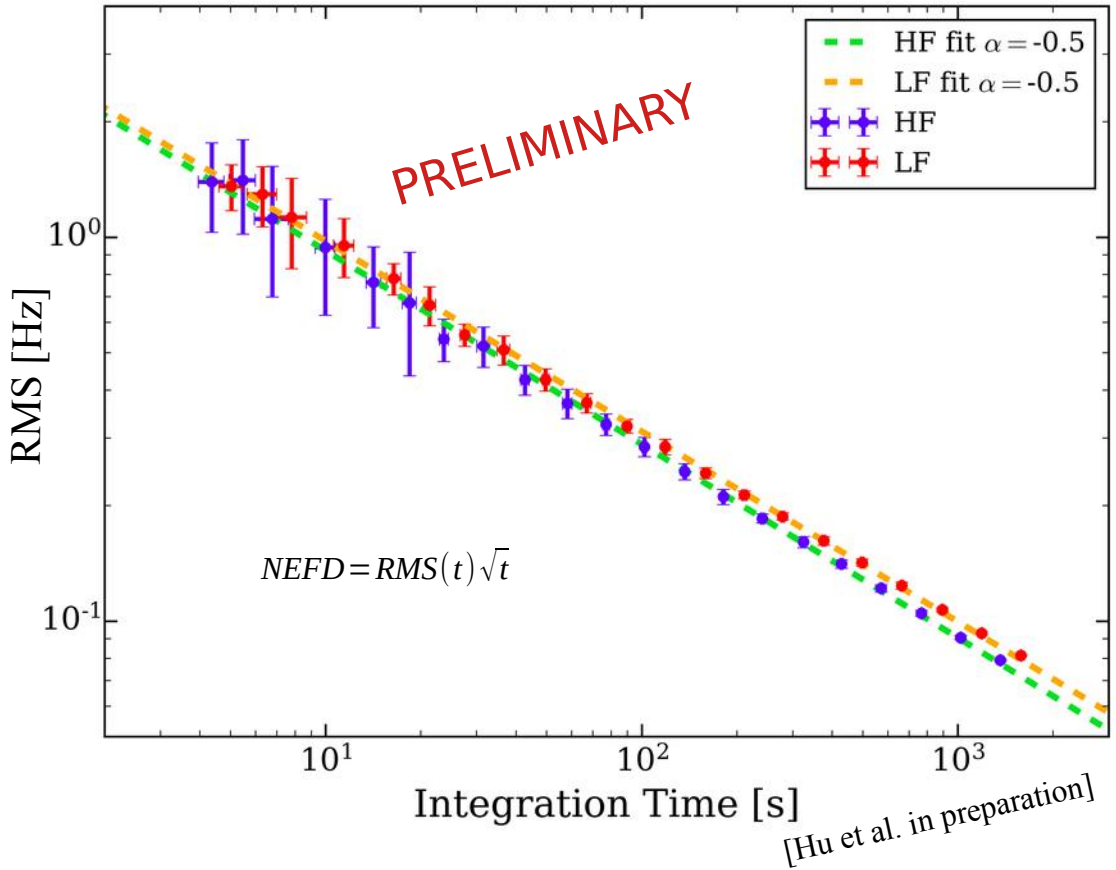
comparable with NIKA2 “interpolation”:
LF: 82±20 mJy·$s^{0.5}$
HF: 135±45 mJy·$s^{0.5}$
[Concerto collaboration A&A 2020]

The RMS follows:

$RMS(t) \propto t^{\alpha}$

$\alpha_{LF} = -0.505 \pm 0.001$

$\alpha_{HF} = -0.502 \pm 0.001$



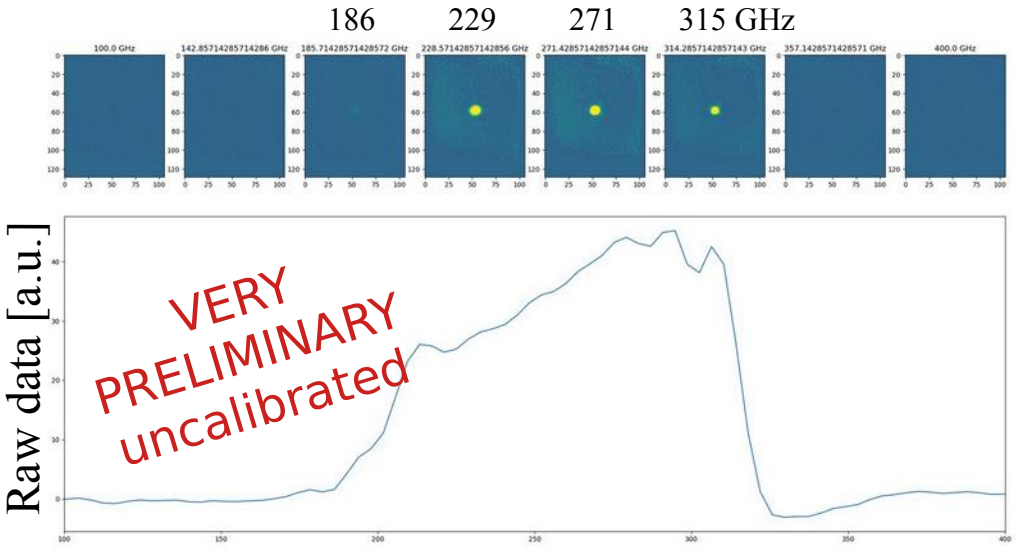
[Hu et al. in preparation]

Thus, no major issue is highlighted in the observations in terms of overall noise.

Results on-sky

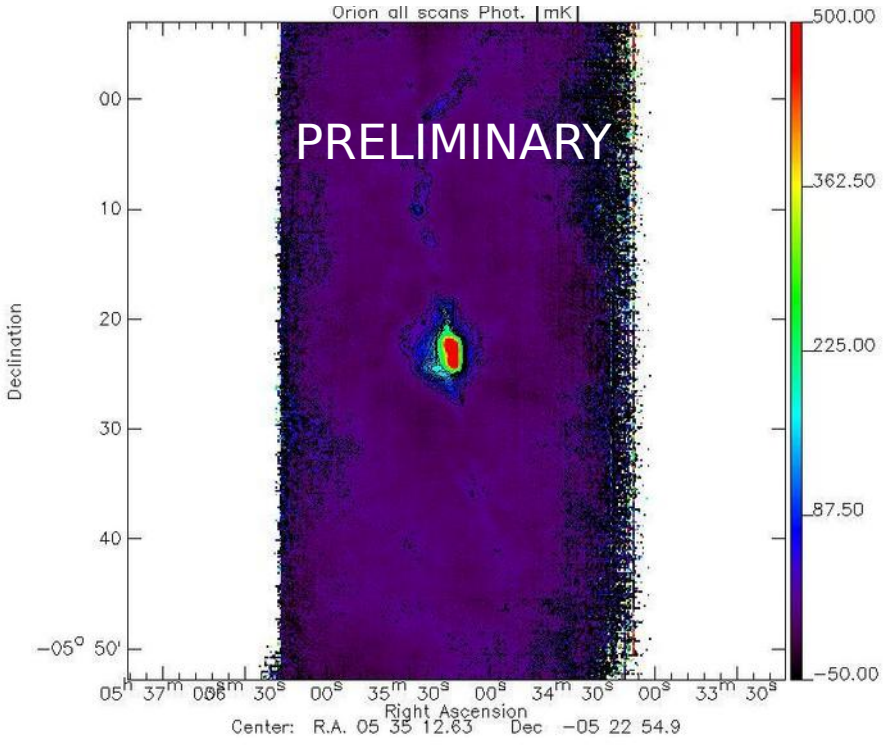
Preliminary spectroscopic results

Spectral mapping of Mars



Orion pure photometry

Integrating 30x60 arcmin^2 for 2 h



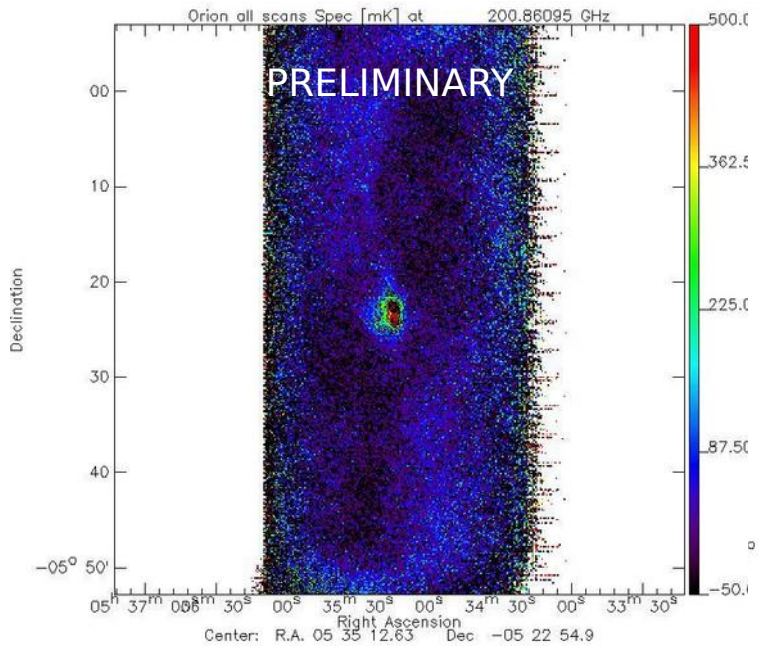
Study the dust emission

Results on-sky

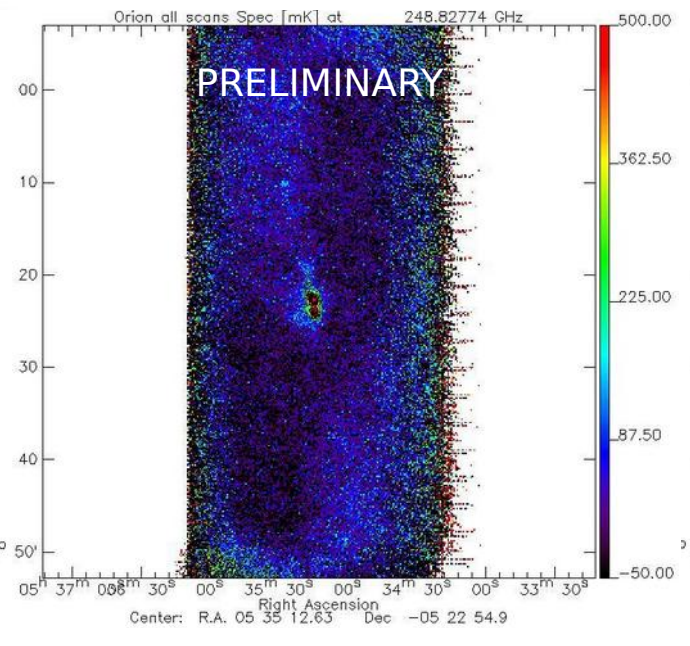
Orion spectral mapping

Example of spectral binning @ 6 GHz resolution

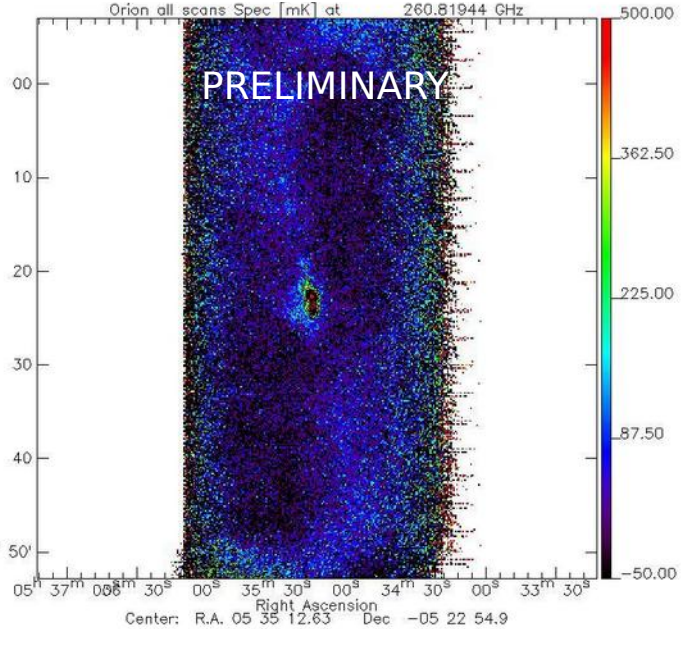
200



249



261 GHz



<u>FACT:</u>

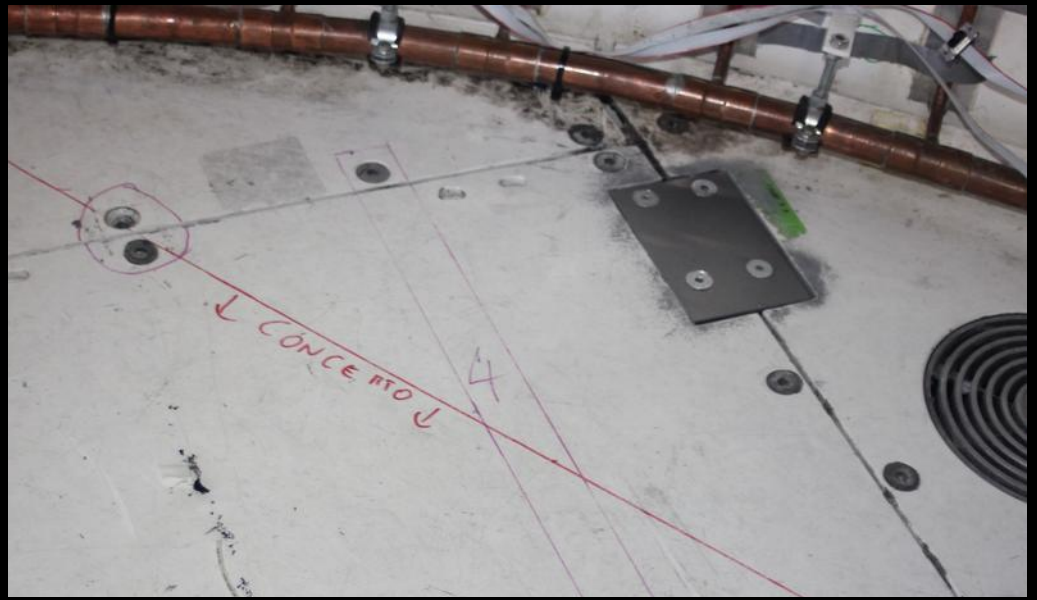
- Spectral mapping capability for large areas

CONCERTO uninstall

May 2023

Lifted in the boxes to be shipped-back to Europe

The empty space left in the APEX C-cabin



all good things must come to an end

Conclusions

CONCERTO has been successfully installed at APEX in April 2021,
in time with the ERC schedule (despite the SARS-CoV-2 related difficulties).

649 hours collected on-field for the COSMOS project.
300 hours collected for galaxy clusters.
A total of 50 days of data for 174 Tb (compression factor: 5)

CONCERTO instrument uninstalled from APEX telescope in May 2023.

Full collaboration thrust focused on spectroscopy.
We entered in the phase of the data exploitation.

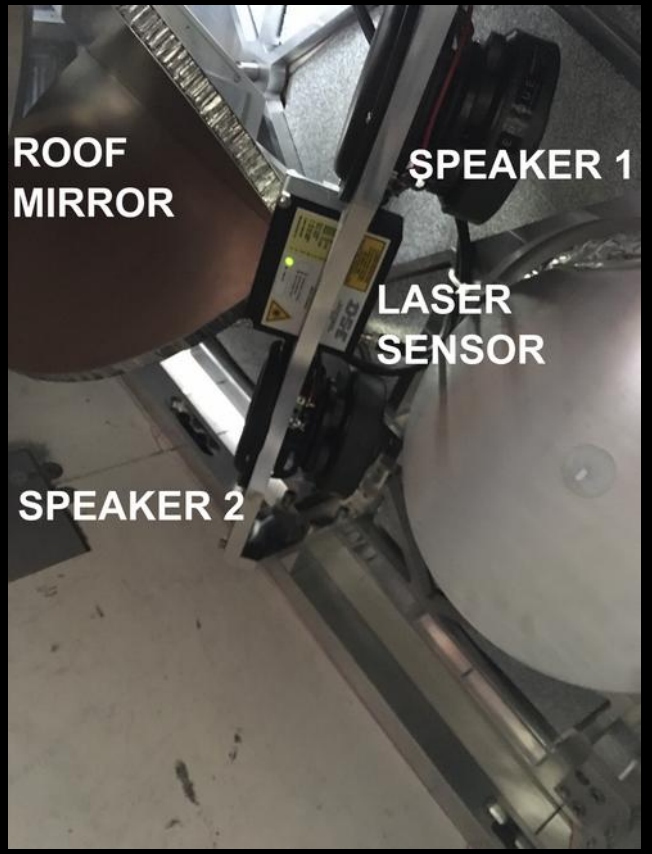
FOCUS
Focal Plane Array for Universe Sensing

erc

… at the Atacama desert

EXTRA

Measurement and compensation of the membrane vibrations



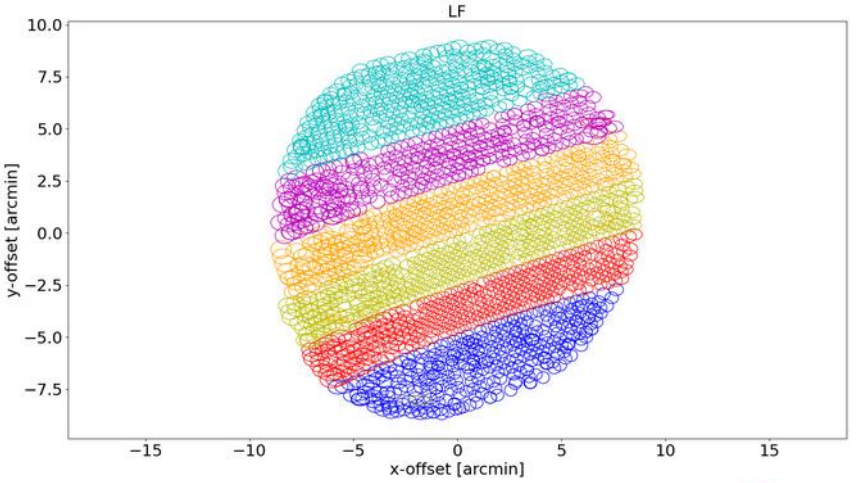
Fully operational:

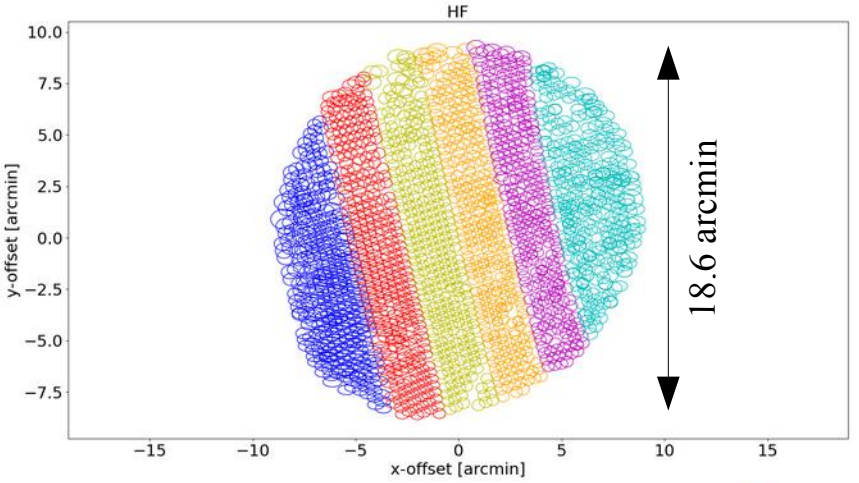
- from December 2021: OPD distortion monitoring,
- From April 2022: active counter system.

Commissioning results on-sky

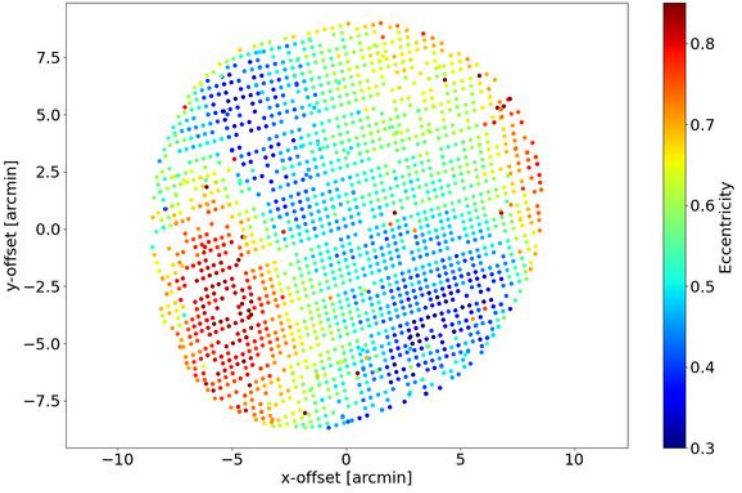
Focal plane

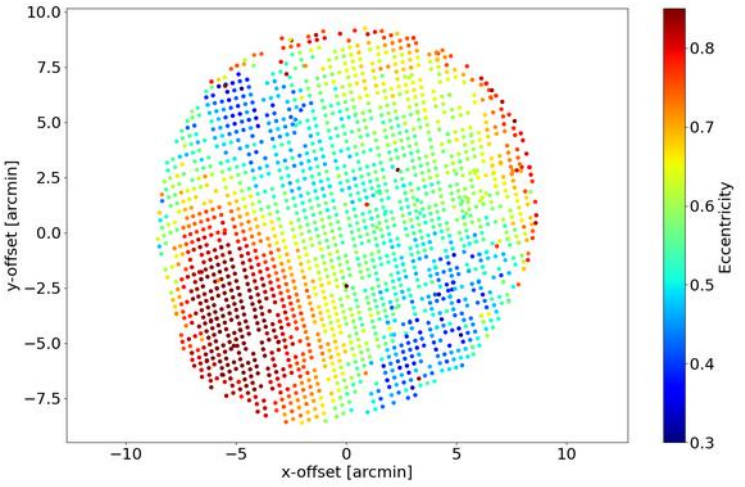
Geometry





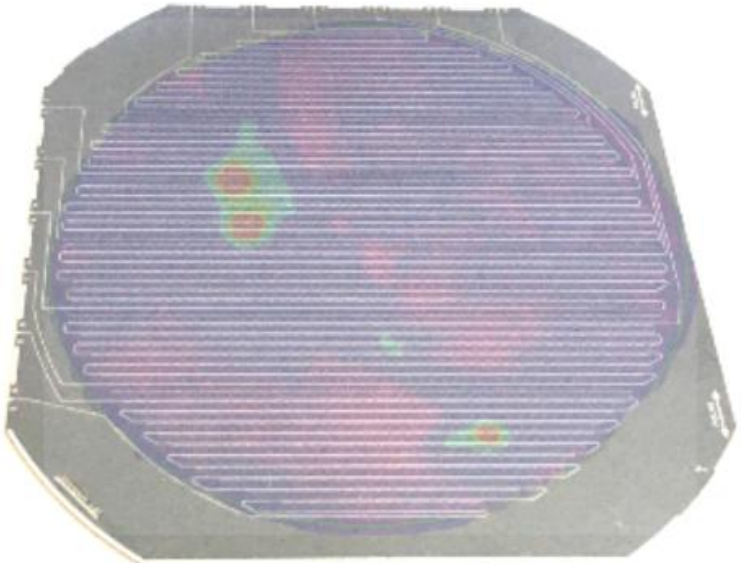
Eccentricity





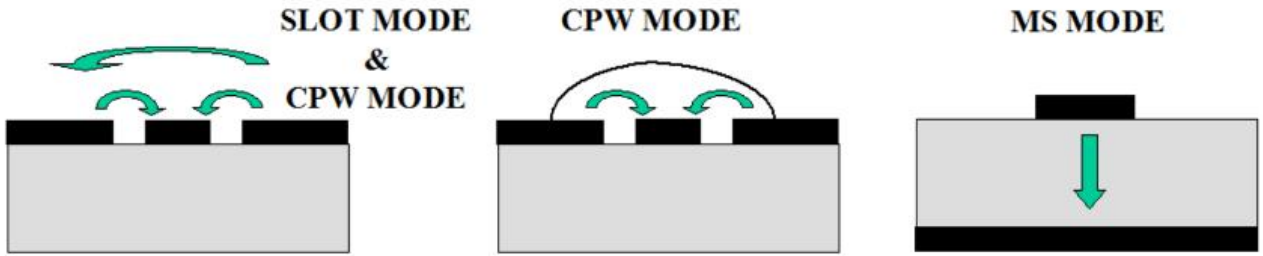
The CONCERTO detectors

A CONCERTO 2152-LEKID-pixels
Six feedlines, microstrip coupling
(front-illuminated) array



Cat's Paw nebula (**NGC6334**) size on top of a CONCERTO array (18.6arc-min)

CPW (NIKA1, KISS) versus Microstrip (NIKA2, CONCERTO)



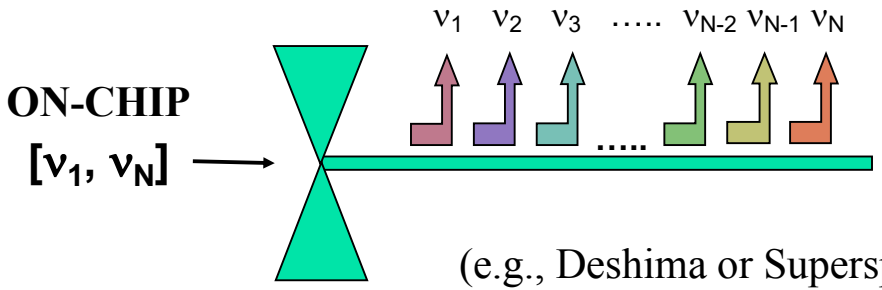
For CONCERTO bands, we have used ad-hoc substrates of 105µm (HF) and 125µm (LF).

Thin Al (20nm) on the front, Al-Au on the back (RF and thermalisation)

→ **High array yield** (no more limited by litho but wafer manipulation)
→ Typically **around 90% identified resonances**
→ Made a number of arrays to select the "flight" ones

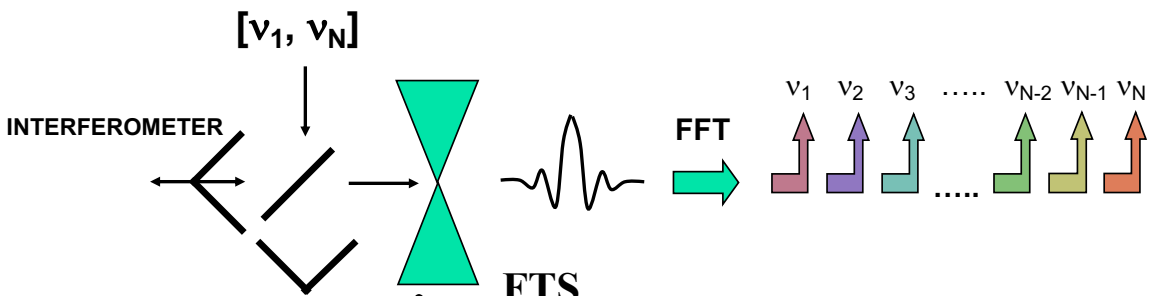
Credit: A. Monfardini

Spectrometry solutions



(e.g., Deshima or Superspec)

N pixels one per each band of e.m. frequency observing instantaneously a point on the sky.



FTS
(e.g., KISS, CONCERTO)

1 pixel recovering all the bins of e.m. frequency observing a point on the sky in a Δt (one interferogram).

"Interferogram": the interferometric pattern.

$$SNR_{\Delta\nu}^{disp} = \frac{S_{\Delta\nu}}{\sigma_{\Delta\nu}\sqrt{N}}$$

$$SNR_{\Delta\nu}^{FTS} = \frac{S_{\Delta\nu}}{\sigma_{\Delta\nu}N}$$

NO advantage in terms of RMS

Science driver I:
Intensity mapping of [CII]-line

[CII]-line
It is among the brightest lines originating from star-forming galaxies and it is a reliable tracer of star formation on global scale.
Red-shifted on transparent mm-atmospheric window.

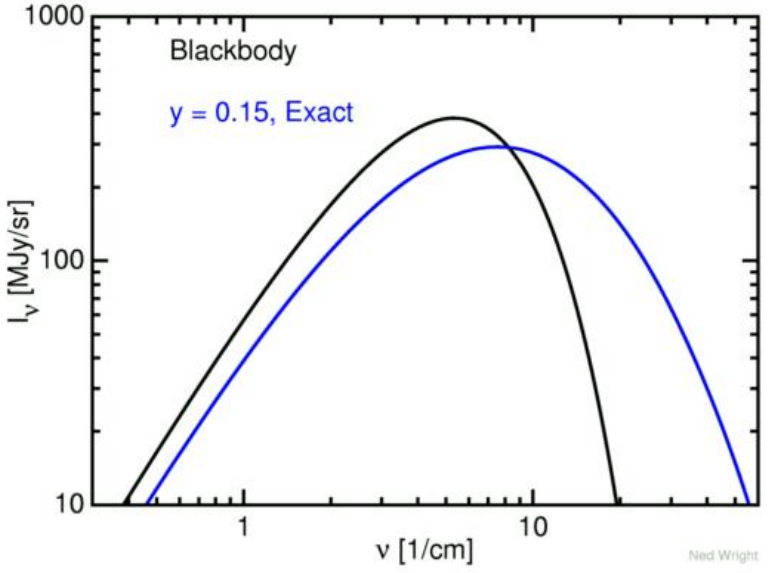
Goal	Answer the questions of whether dusty star-formation contributes to early galaxy evolution, and whether dusty galaxies play an important role in reionization
Strategy	3-D intensity mapping of the [CII] fluctuations

3-D mapping:
the third dimension is obtained observing at several frequencies, i.e, several redshifts.

Intensity mapping:
measure angular fluctuations in the brightness of the sky.

Science driver II:
Galaxy cluster via Sunyaev-Zel'dovich effect

SZ is a spectral distortion of the CMB



Goal	Use spectroscopy to fully separate the different components and extract physical information: pressure, temperature, density and LOS velocity
Strategy	Spectrometric mapping