A Kinetic Inductance Detectors Focal Plane For CorE

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Institut Néel, CNRS Grenoble

Outline

1 – Short reminder: the driving needs

2 – A KID Focal Plane configuration

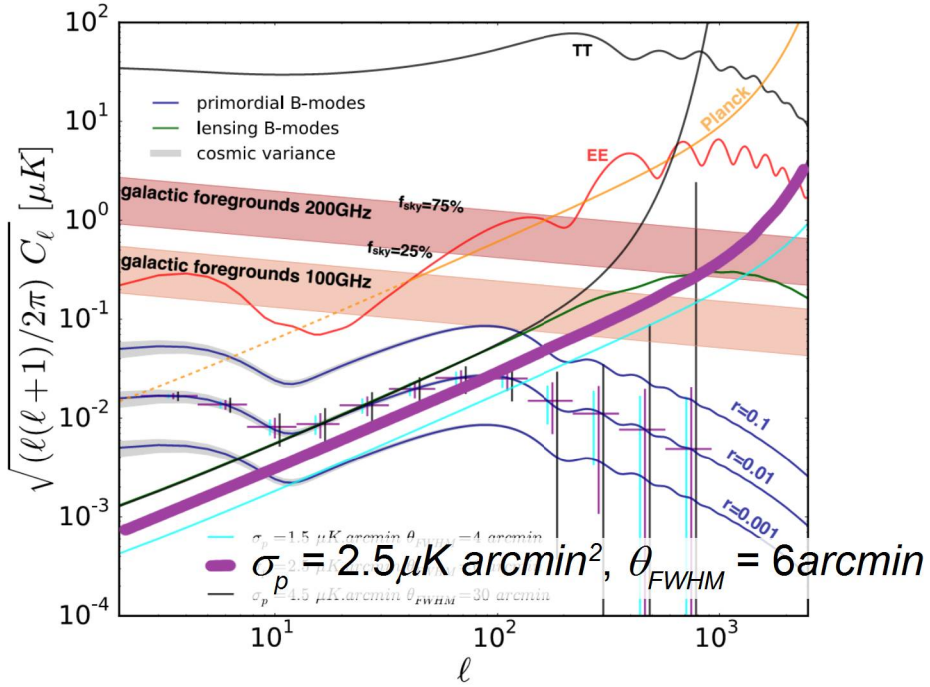
3 – Where are we now

4 – What next? (or, *homework for everyone*!)

The COrE+ requirements

COrE+ is an ambitious mission, and as such has ambitious requirements...

Figure by Josquin Errard



Astronomical point of view:

- High integrated polarization sensitivity
- Good resolution
- Many bands

The COrE+ requirements

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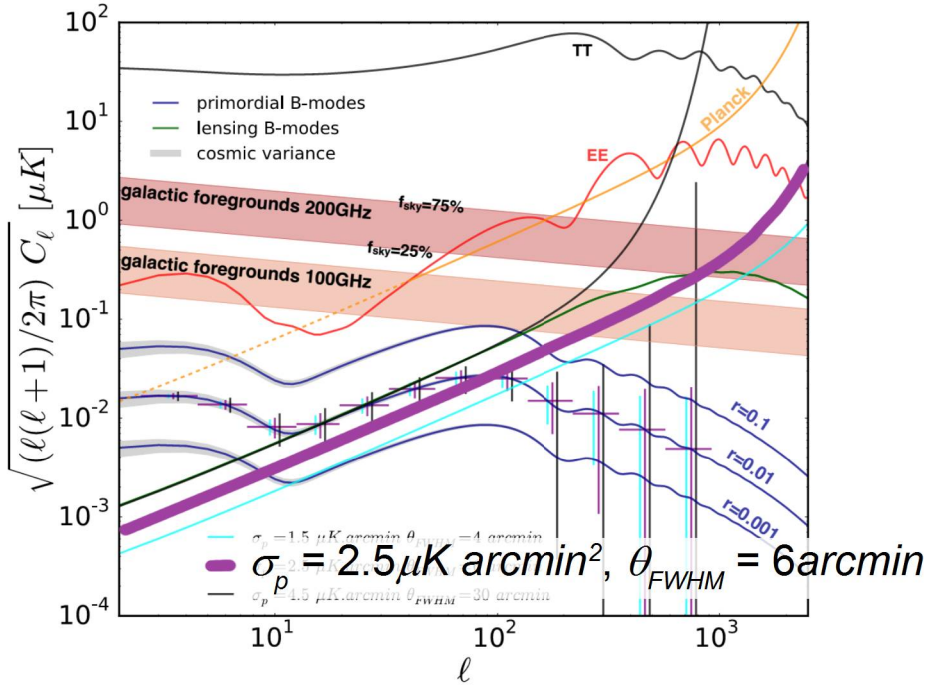

Are we asking for the moon?

Detectors point of view:

- Photon noise limited:

  NEP = 5–10 aW/Hz$^{0.5}$ (for the main bands)

- Many! **(thousands!)**
- Fast: τ_{max} **≈ 1ms**
- Suitable for wide ν range, multiplexable...

Why Kinetic Inductance Detectors

M4 proposal feedback: detectors trade-off open 

Need to choose a detectors baseline!

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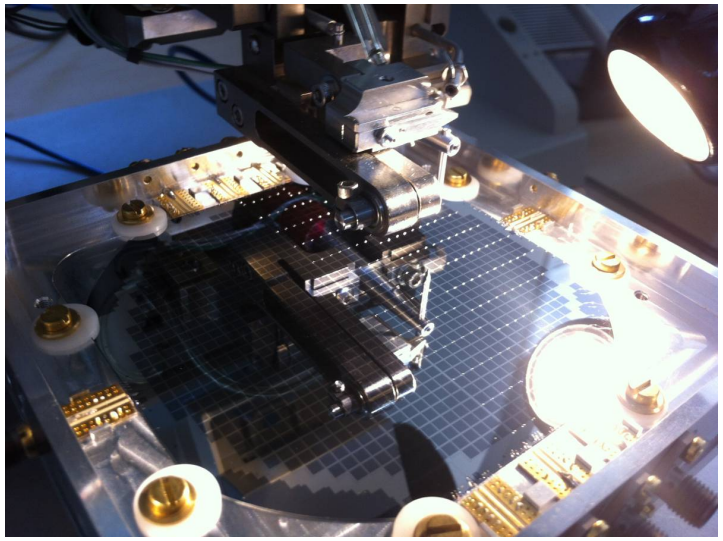
Kinetic Inductance Detectors



- Very good NEP levels achieved
- Intrinsically multiplexable
- 'Easy' fabrication
- ……

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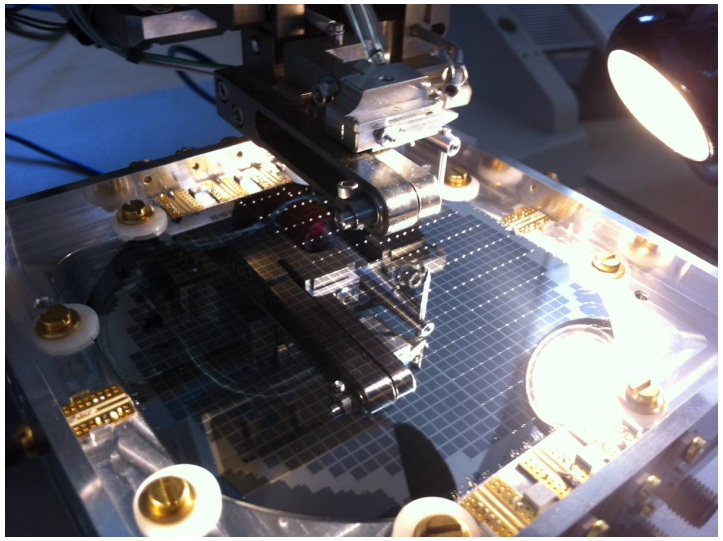
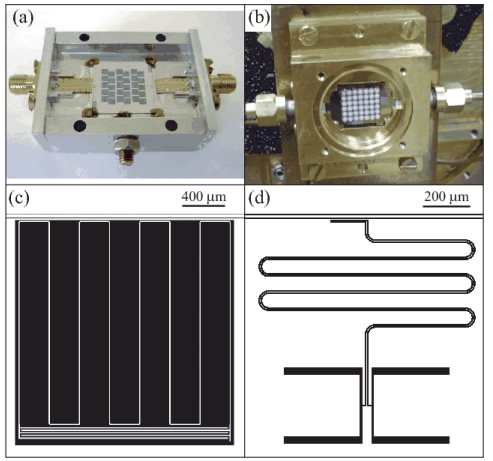
Kinetic Inductance Detectors



Advantages specific to COrE+ mission:

- Large and widespread EU experience
- Easily interchangeable blocks

NIKA1 run 1 (2009)

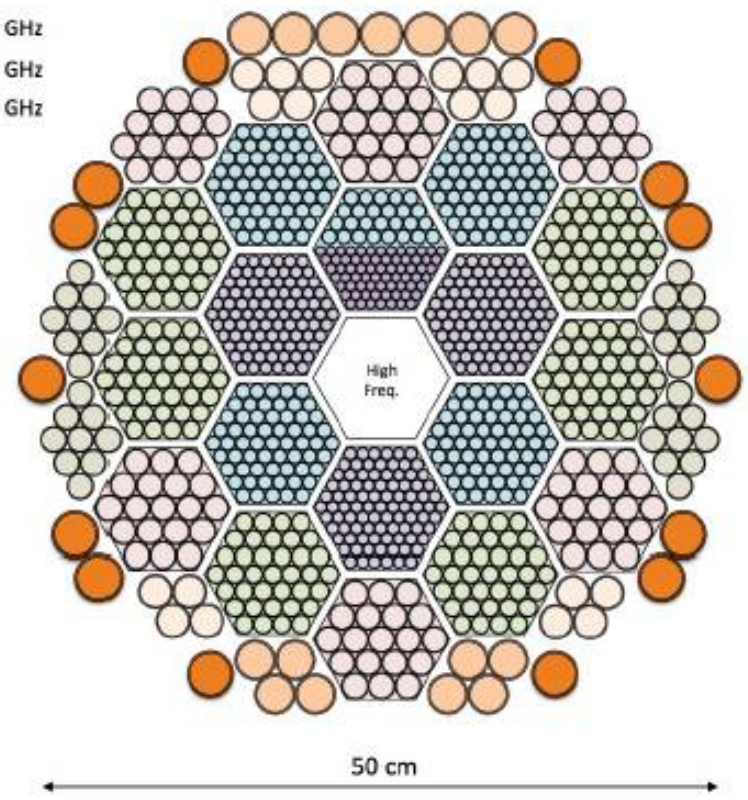


A KID Focal Plane for COrE+

The aim: keep things simple, and **achievable**! (Low TRL issue..)

- Pixel disposition and count: based on COrE+ baseline configuration

ν	$N_{det\ single}$	$N_{det\ dual}$
60	28	28
70	30	30
80	36	64
90	72	102
100	84	120
115	124	196
130	180	264
145	264	388
160	254	434
175	290	554
195	346	600
220	200	490
255	140	486
295	60	260
340	60	200
390	60	120
450	60	120
520	60	120
600	60	120
700		60
800		60



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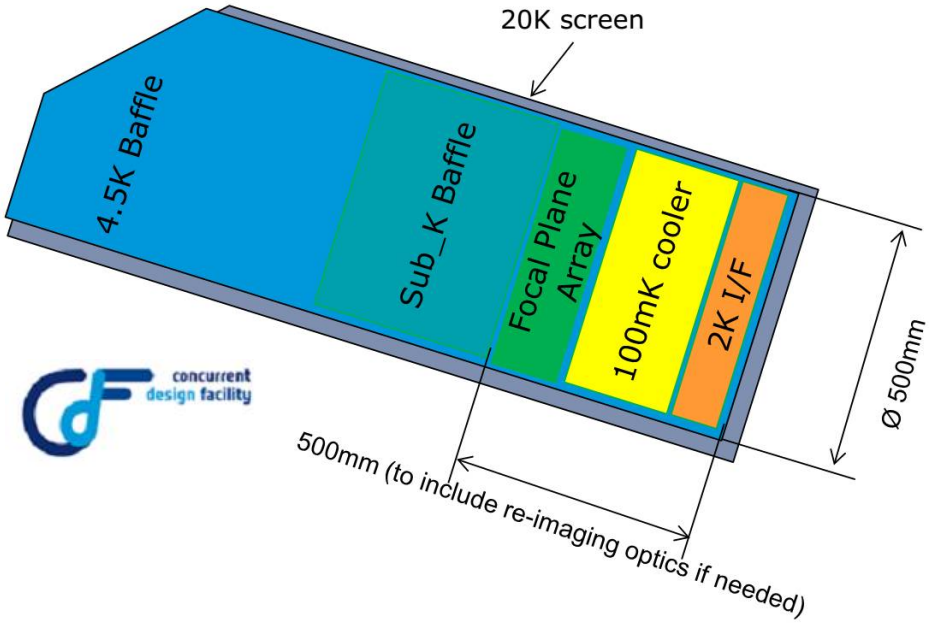
CDF: 4.5K baffle (+ extra 1K one?)



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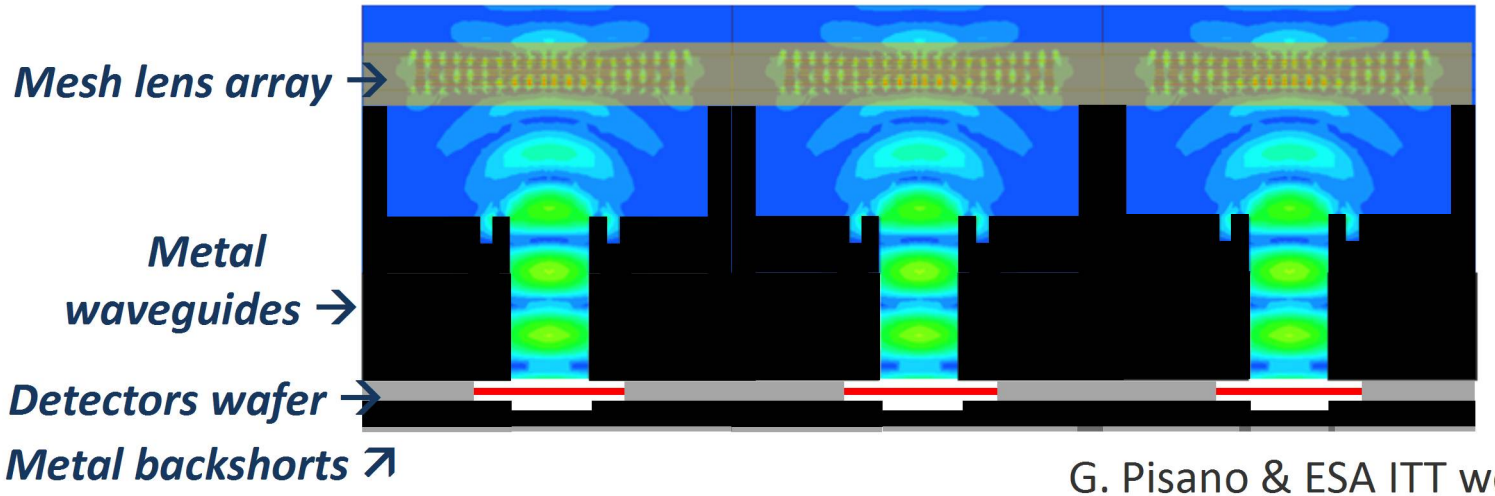
Planar multimesh lenses: tested and demonstrated (ESA ITT)

Planar multimesh lenses

Planar lenses tested coupled to a waveguide section:



G. Pisano & ESA ITT workgroup

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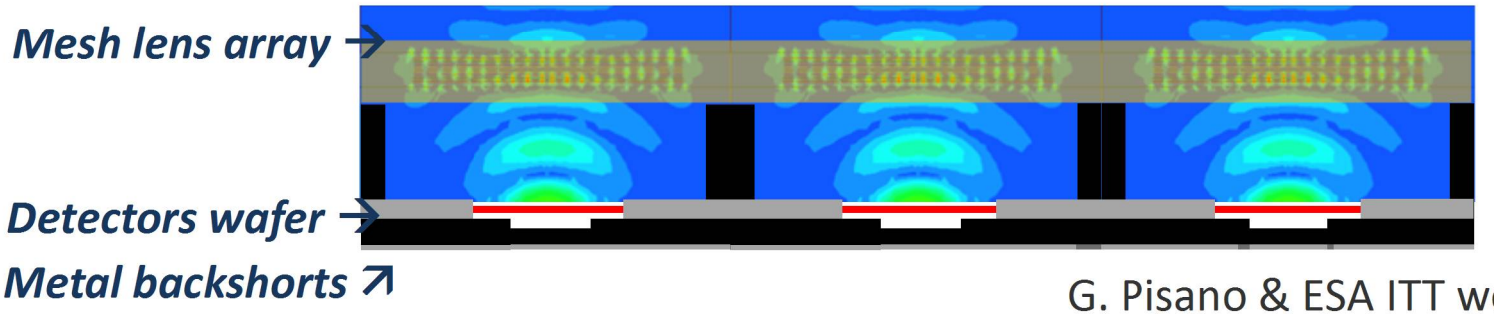

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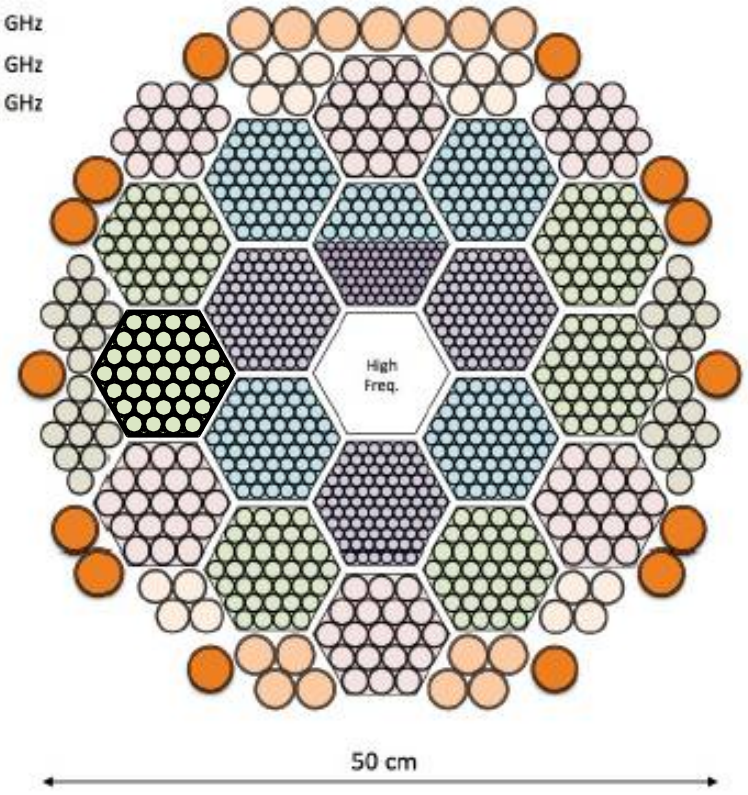

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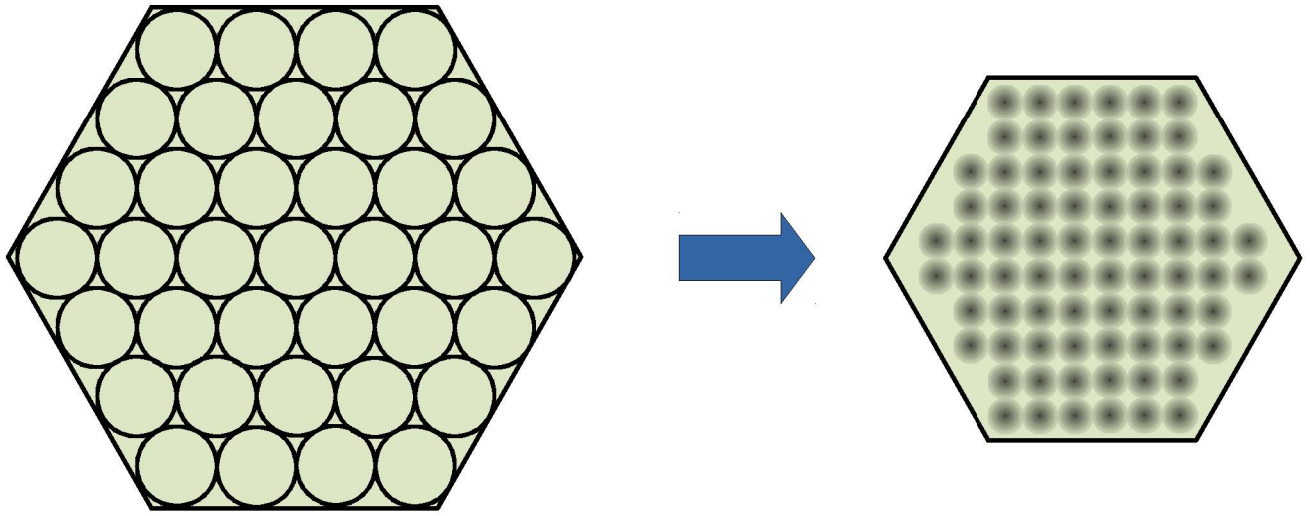

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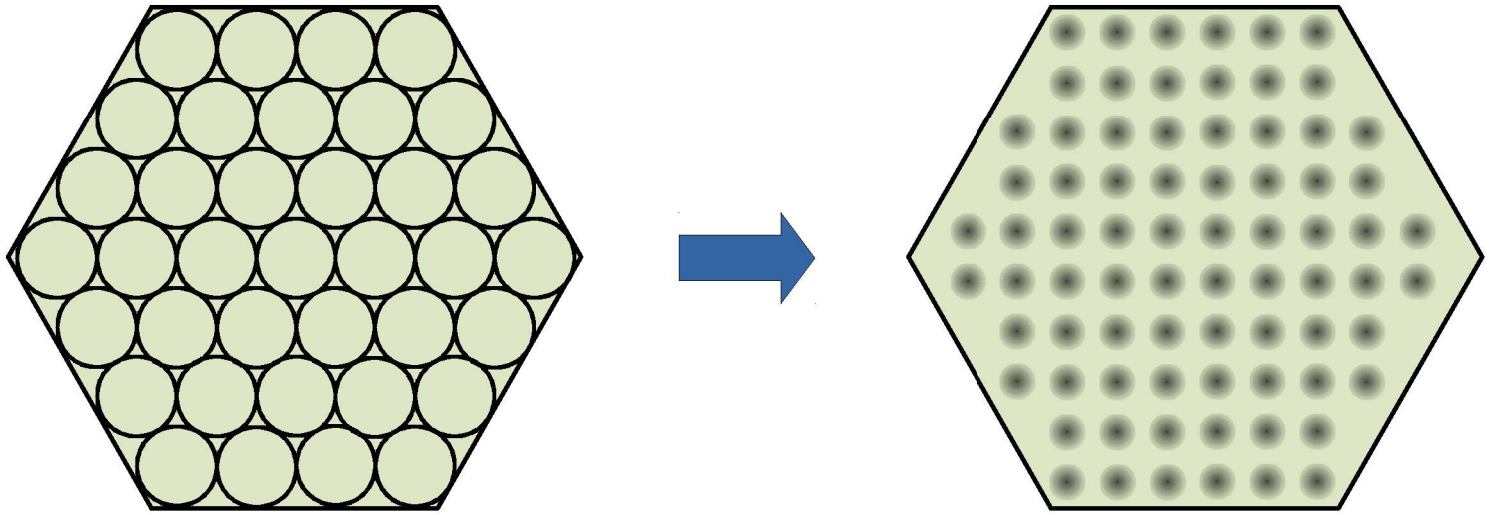

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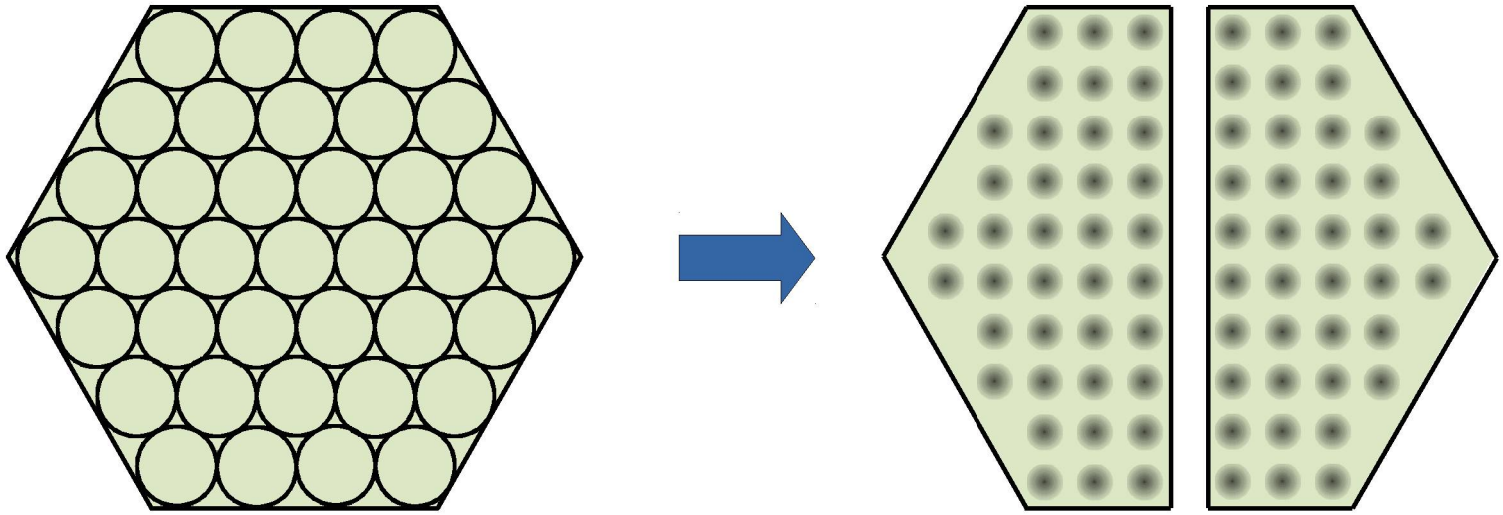


- Note: relative freedom in choice of 'basic bricks'

Impact of a KID FP: sensitivity

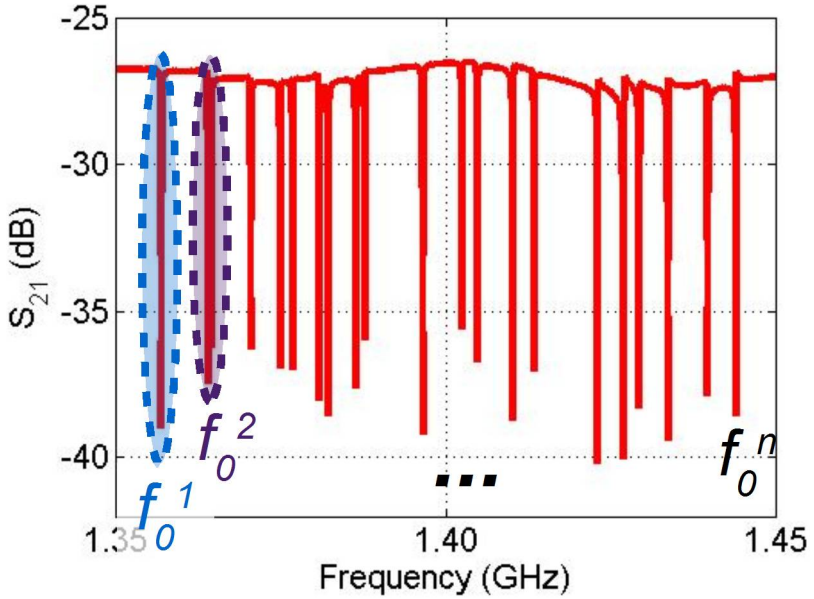
The ingredients:

- Background limited NEP
- Optical: assume for now efficiency similar to horns
- Single colour, single polarization pixels (#lenses = 2 x #horns)
- Mission duration of 3 years

Sensitivity ≈ COrE+ 'M4' baseline

KID multiplexing

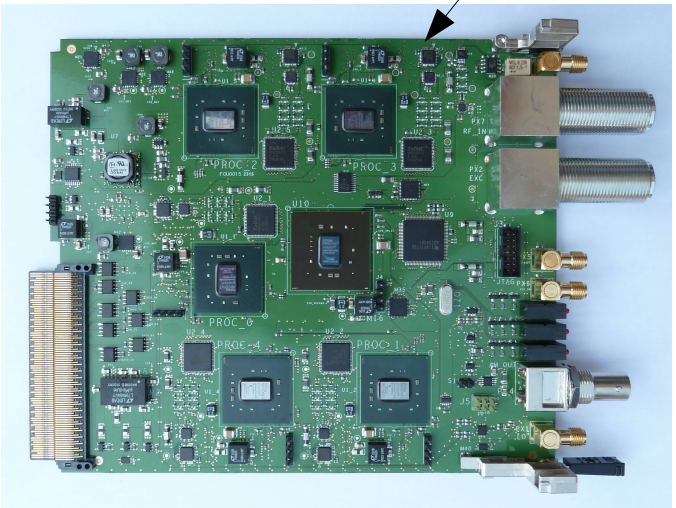
KID are superconducting resonators → intrinsically suited for FDM

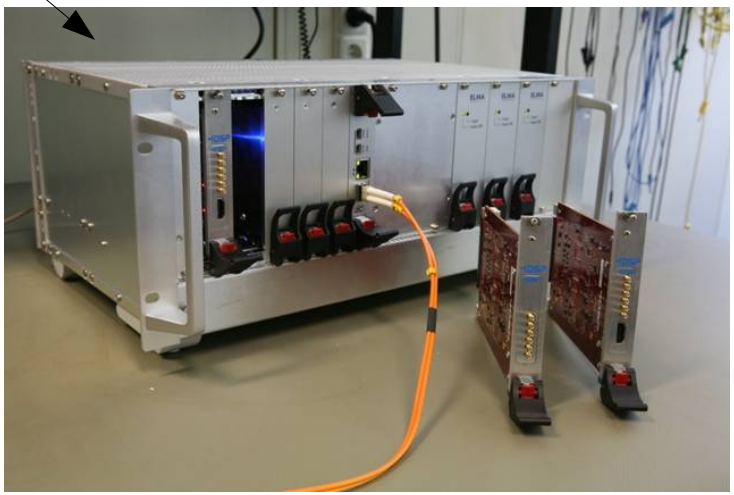


KID multiplexing

KID are superconducting resonators → intrinsically suited for FDM

- Many architecture already developed
- In EU, DDC version (LPSC) and FFT version (MPG Bonn/ SRON)





- Conservative assumptions:

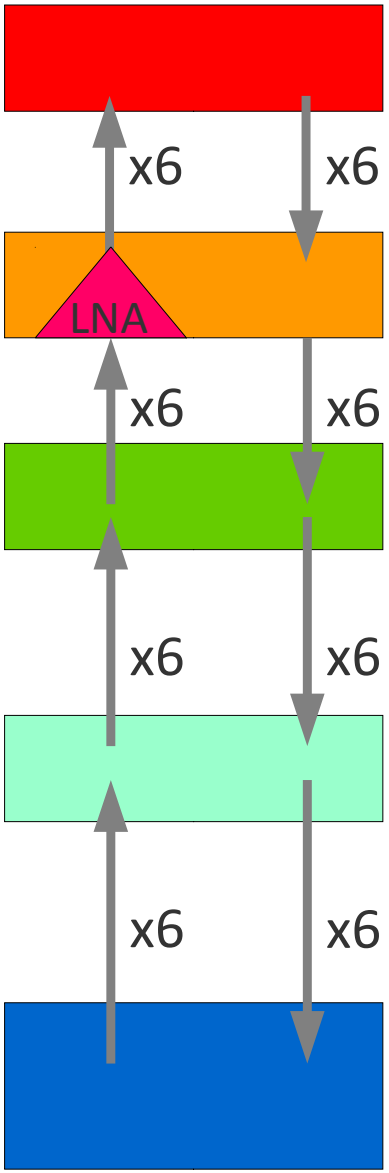
MUX factor ≈ 500

Power per pixel ≈ 0.1W

Total P @300K ≈ 250W

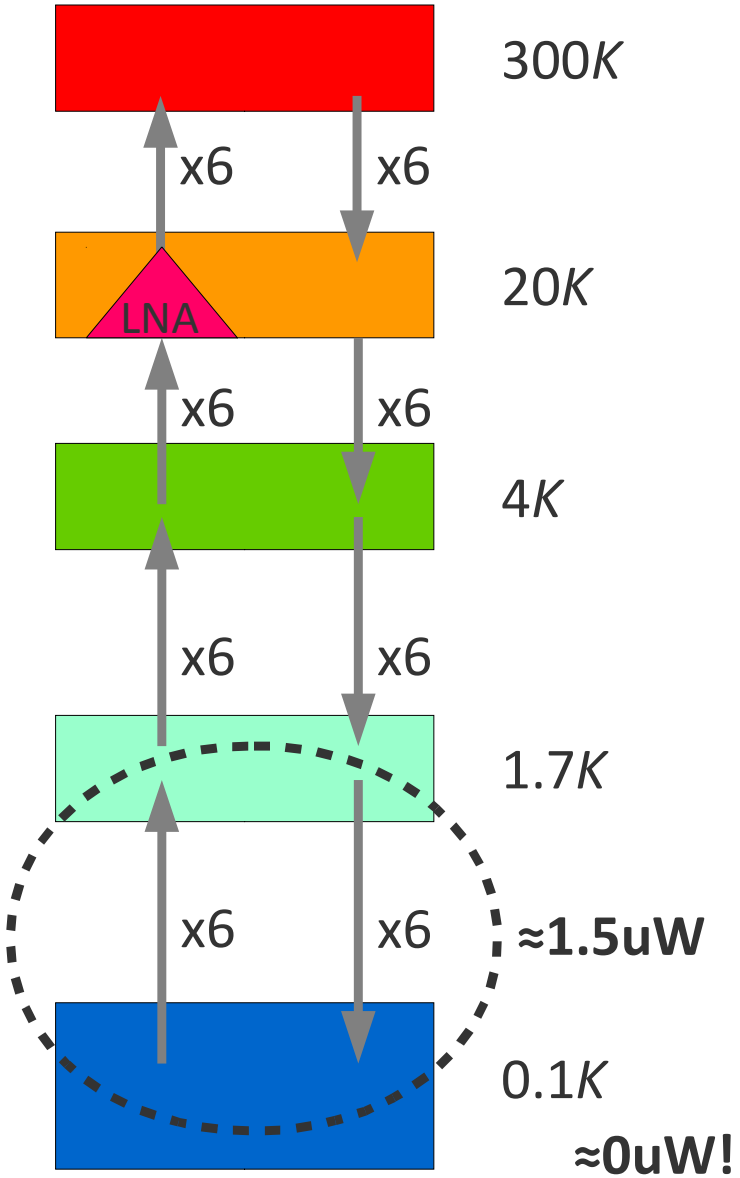
(Nothing too worrying..)

Impact of a KID FP: thermal loads



- N_{pix} = 2400
- MUX factor = 400
- 6x2 = 12 coax cables (SS, NbTi)
- 6x Low Noise Amplifier

Impact of a KID FP: thermal loads



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Coldest stages:

$P_{ro} \approx P_{opt} \approx$ 10pW/pixel

x2500x10 → **0.25uW**

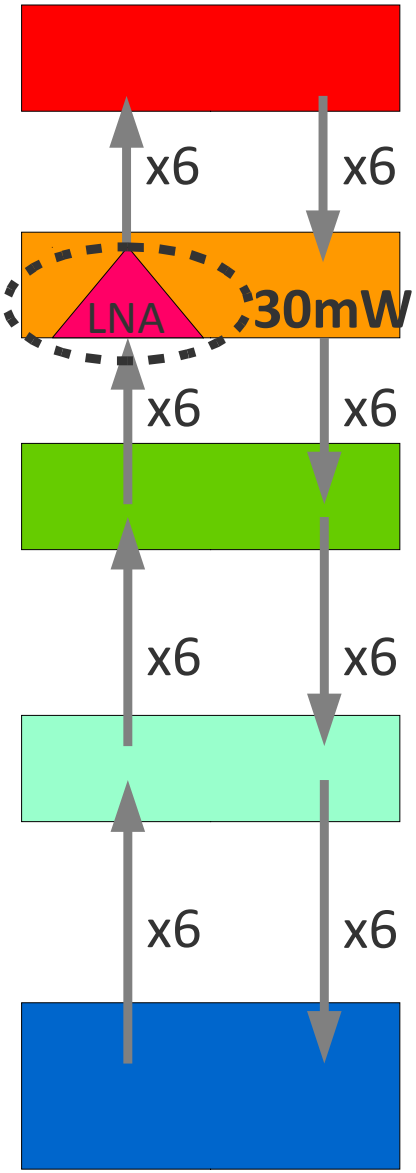
$P_{coax} \approx$ 0.1uW/coax

x12 → **1.2uW**

Distributed 0.1 … 1.7K

Intercepted by ^{3}He/^{4}He mixture!

Impact of a KID FP: thermal loads



300*K*

20*K*

≈4mW

4*K*

≈150uW

1.7*K*

≈1.5uW

0.1*K*

≈0uW!

- N_{pix} = 2400
- MUX factor = 400
- 6x2 = 12 coax cables (SS, NbTi)
- 6x Low Noise Amplifier

Intermediate stages:

P_{LNA} ≈ 5mW

x6 → **30mW**

Current status of KID in EU

KID could perfectly be coupled to a mission like COrE+

But: according to ESA evaluation, TRL is 3-4

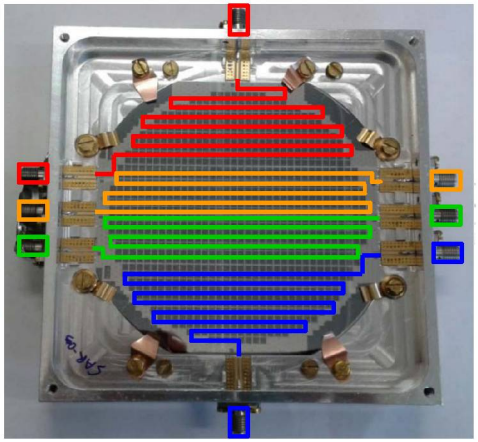
Can we reassure ESA (and ourselves!) that we can reach the specs?

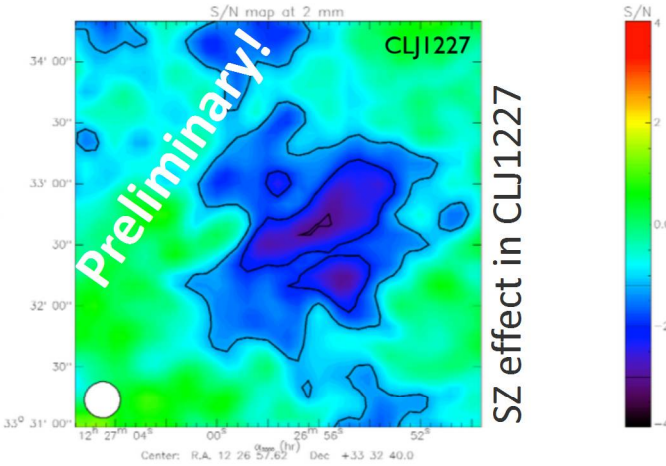
YES! (if we keep things easy and everyone contributes!)

European-led KID instruments

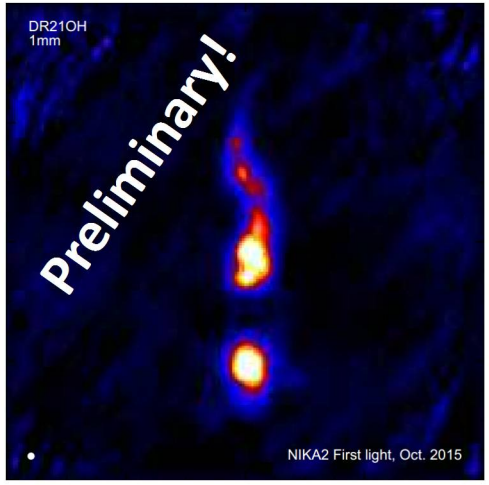
NIKA2: >3000 LEKID, 145 & 225 GHz

1000 pixels 2mm array

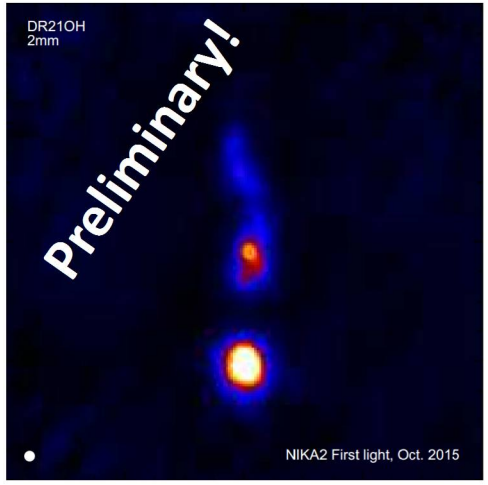




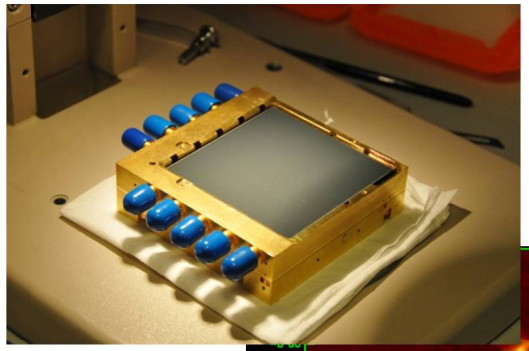
SZ effect in CLJ1227

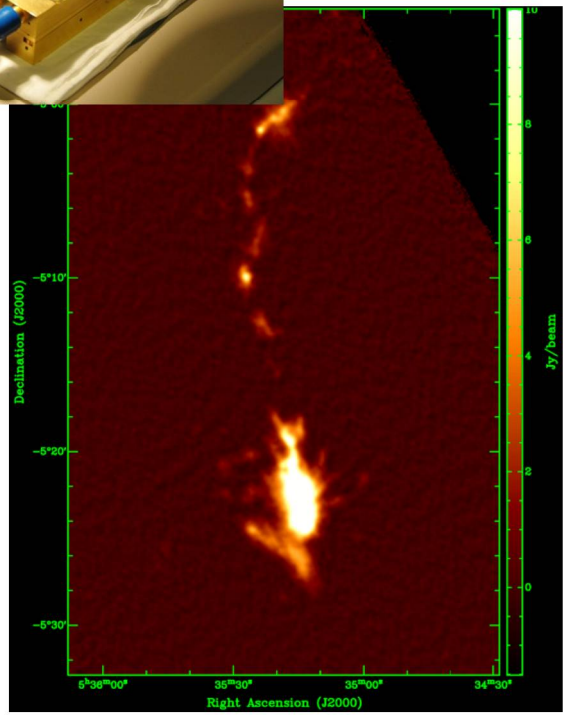


DR21OH SR region



AMKID: ≈25000 KID, 345 & 850 GHz





Orion IRc2 @ 345GHz

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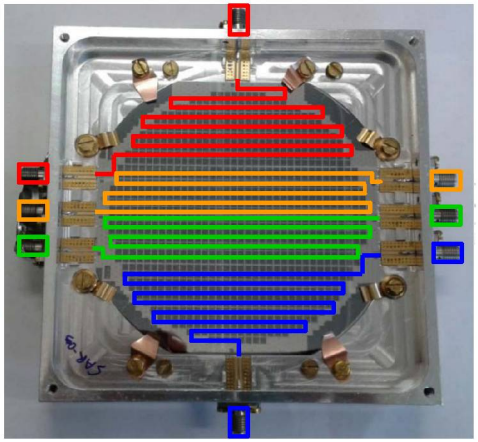
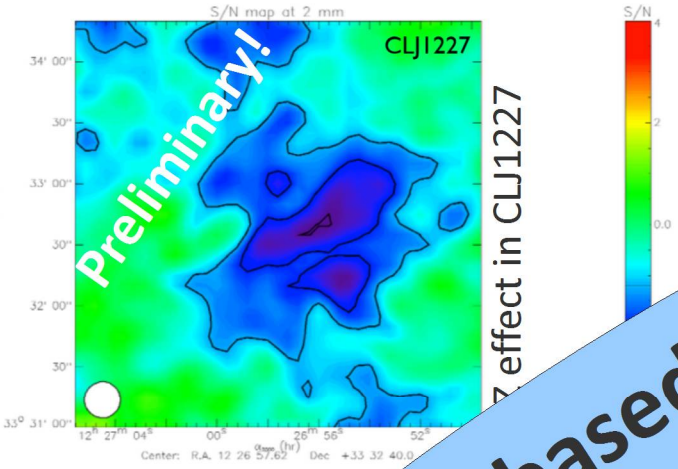
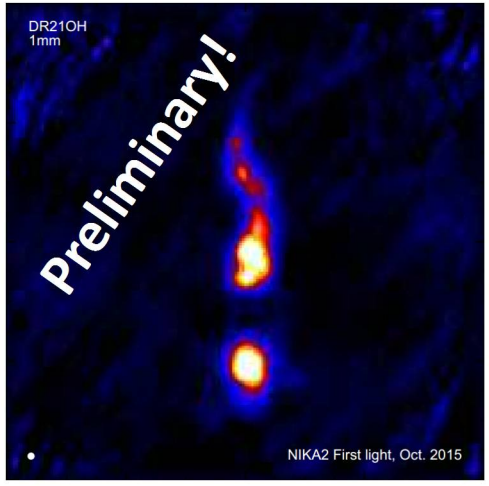




Sunyaev-Zeldovich effect in CLJ1227



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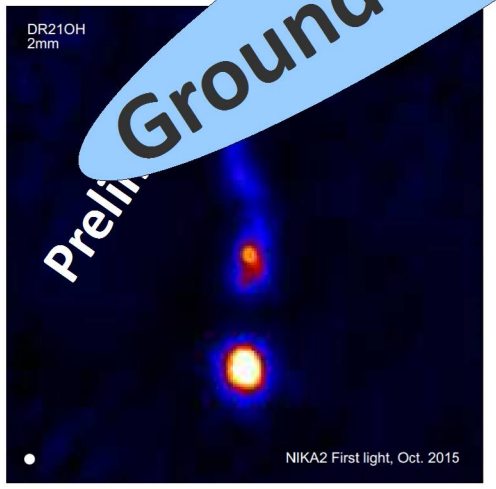

Ground-based : OK!

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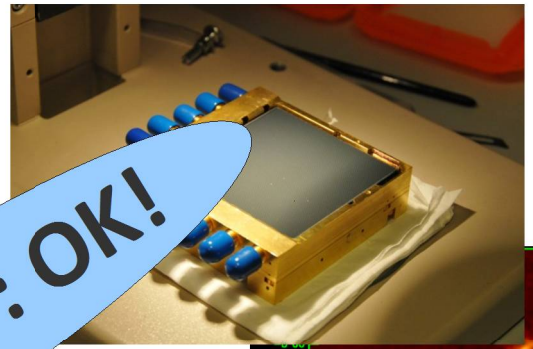
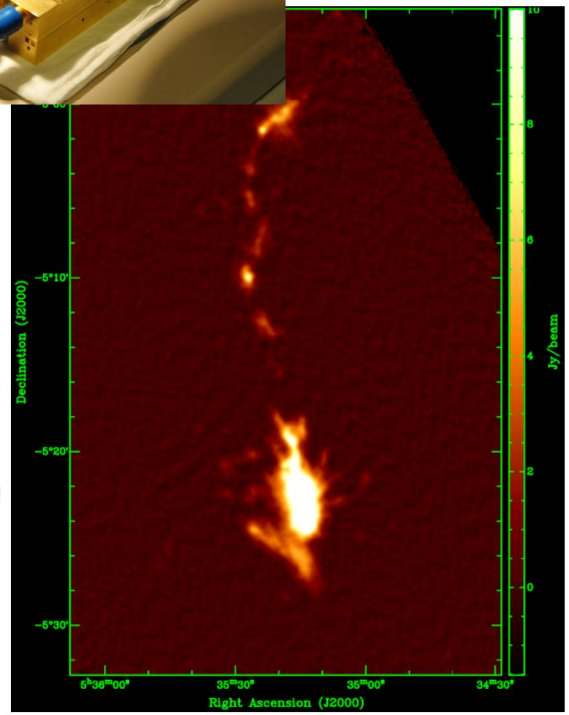




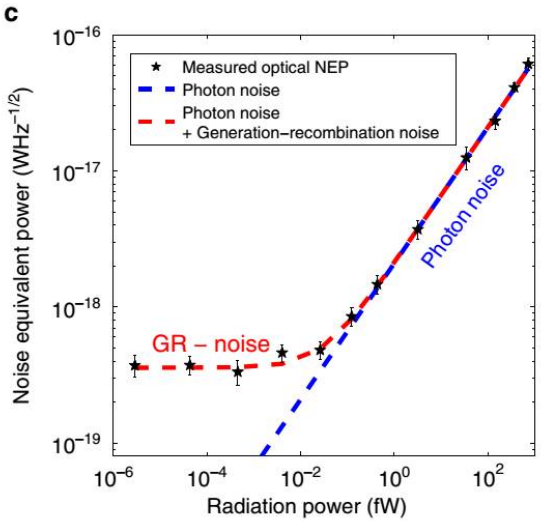
Orion IRc2 @ 345GHz

Towards space: sensitivity

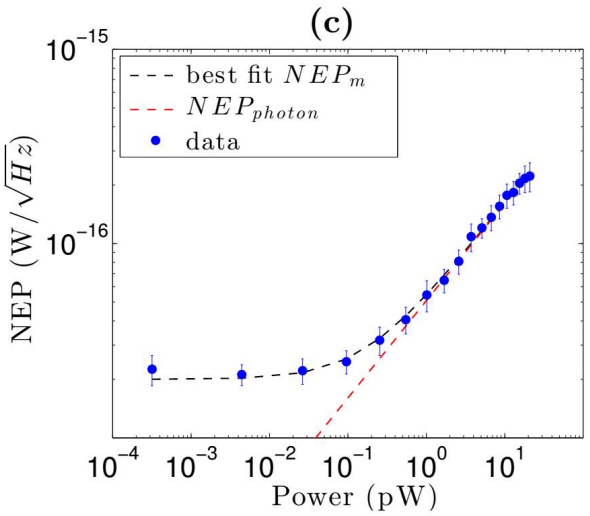
NIKA pixels are photon noise limited on ground (Mauskopf et al, JLTD 2014)

For the region between 100 and 300 GHz, already a factor ≈2 from goal without having to change the design!

Also in other bands KID have already reached the photon-noise limit



de Visser et al,
Nature Comm 2014



Hubmayr et al,
APL 2015

… expect more soon! (SpaceKIDS outcomes)

Towards space: spectral coverage

The full 60→600GHz band needs to be covered

100GHz *300GHz*

100→300GHz : ok! (NIKA+NIKA2 legacy)

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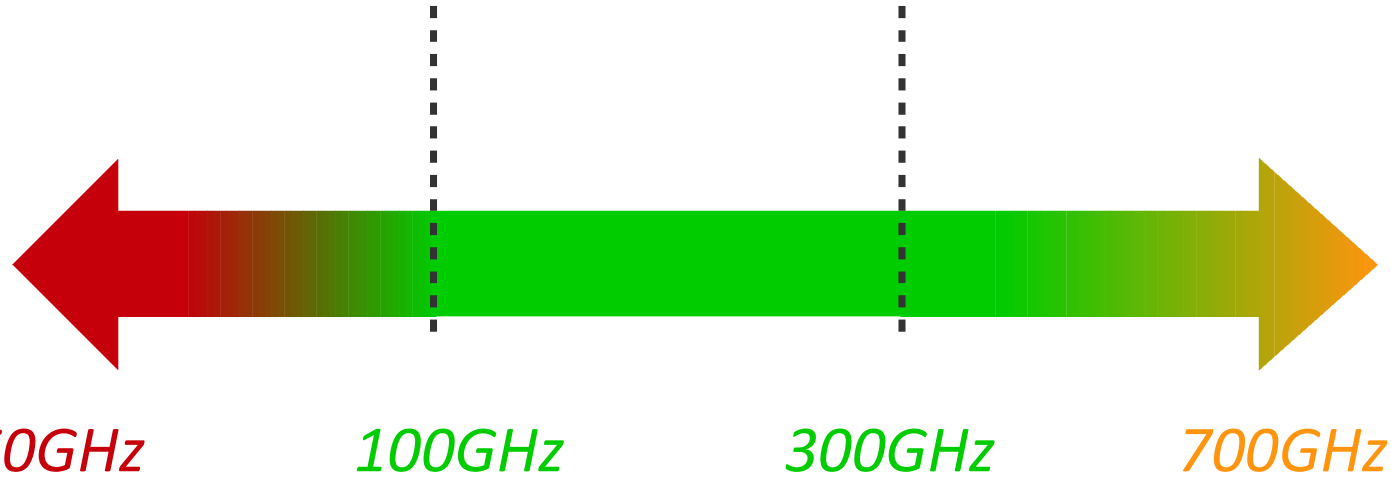


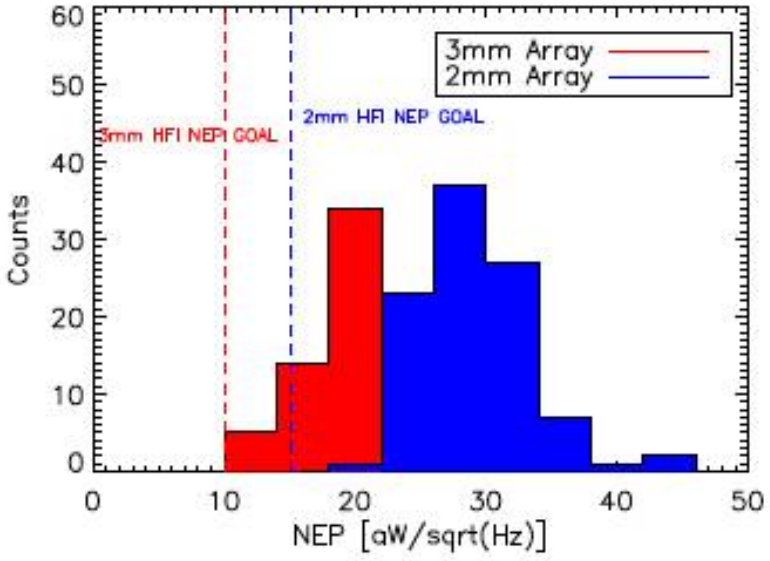
100→300GHz : ok! (NIKA+NIKA2 legacy)

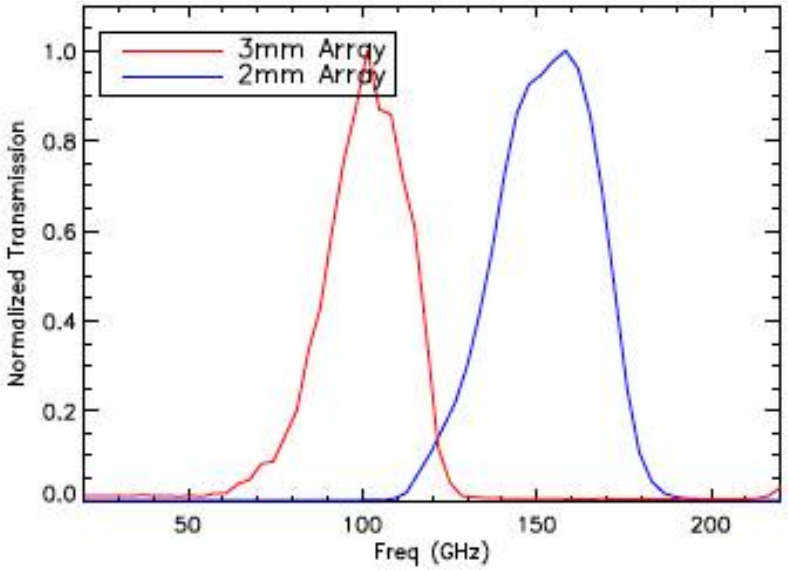
300→600GHz : no intrinsic problems, already many developments

60→100GHz : need new materials (eg: TiAl). First data very promising!

Towards space: spectral coverage

	3mm array	2mm array
Valid Pixels [#]	132	132
Pixel size [mm]	2.3	2.3
Film	Titanium-Aluminium bi-layer	Aluminium
Film Thickness [nm]	10-25	18
Silicon Wafer Thickness [μm]	525	300
Transition Critical Temp [K]	0.9	1.3
Frequency Cut-off [GHz]	65	110
Polarised Sensitive Detectors	non	non
Optical Background [pW]	0.3	0.5
Angular Size [$F\lambda$]	0.75	0.75
Overall Optical Efficiency [%]	30	30



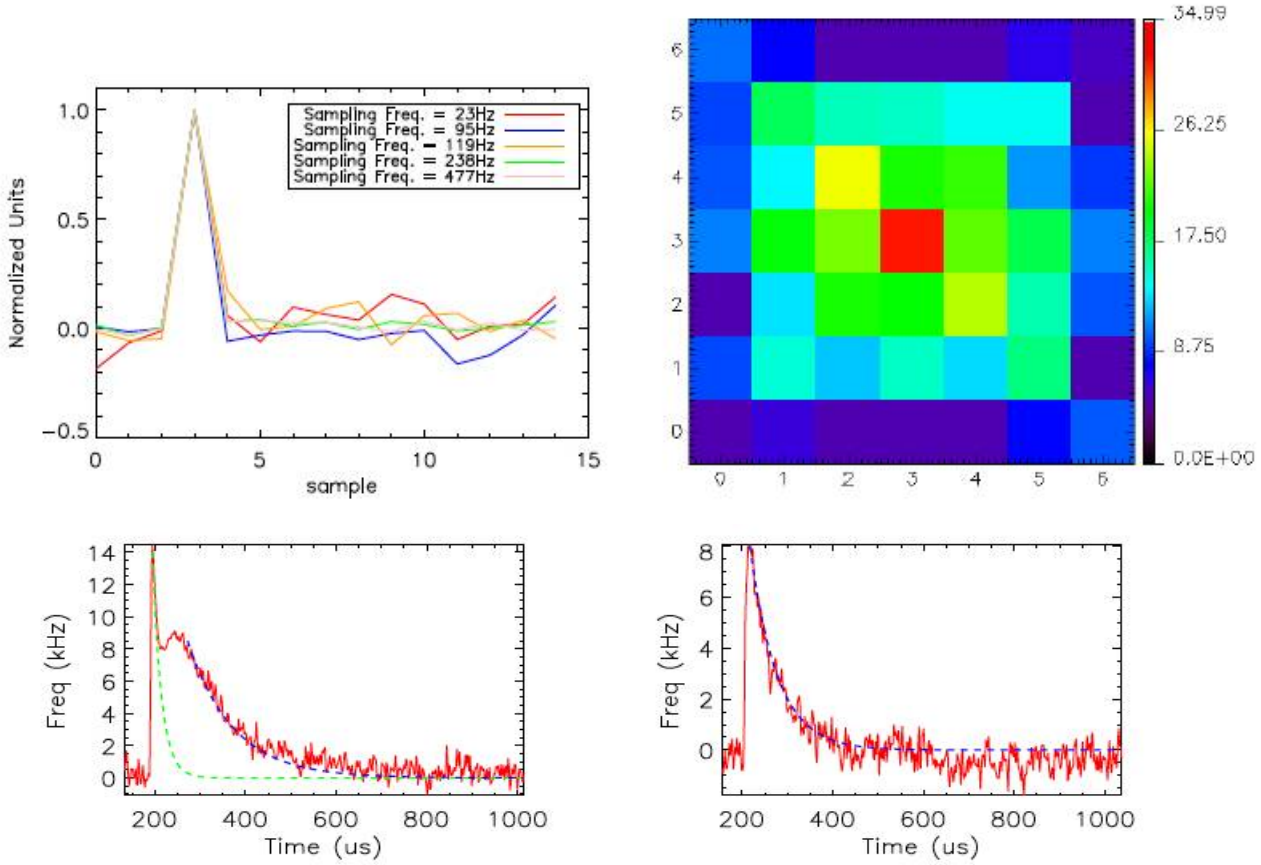


Catalano et al, A&A 2015
Catalano et al, JLTP 2016

Towards space: CR impacts

Studied in detail in the framework of SpaceKIDS project

Should not represent an issue (fast response of detector + use of phonon absorbers)



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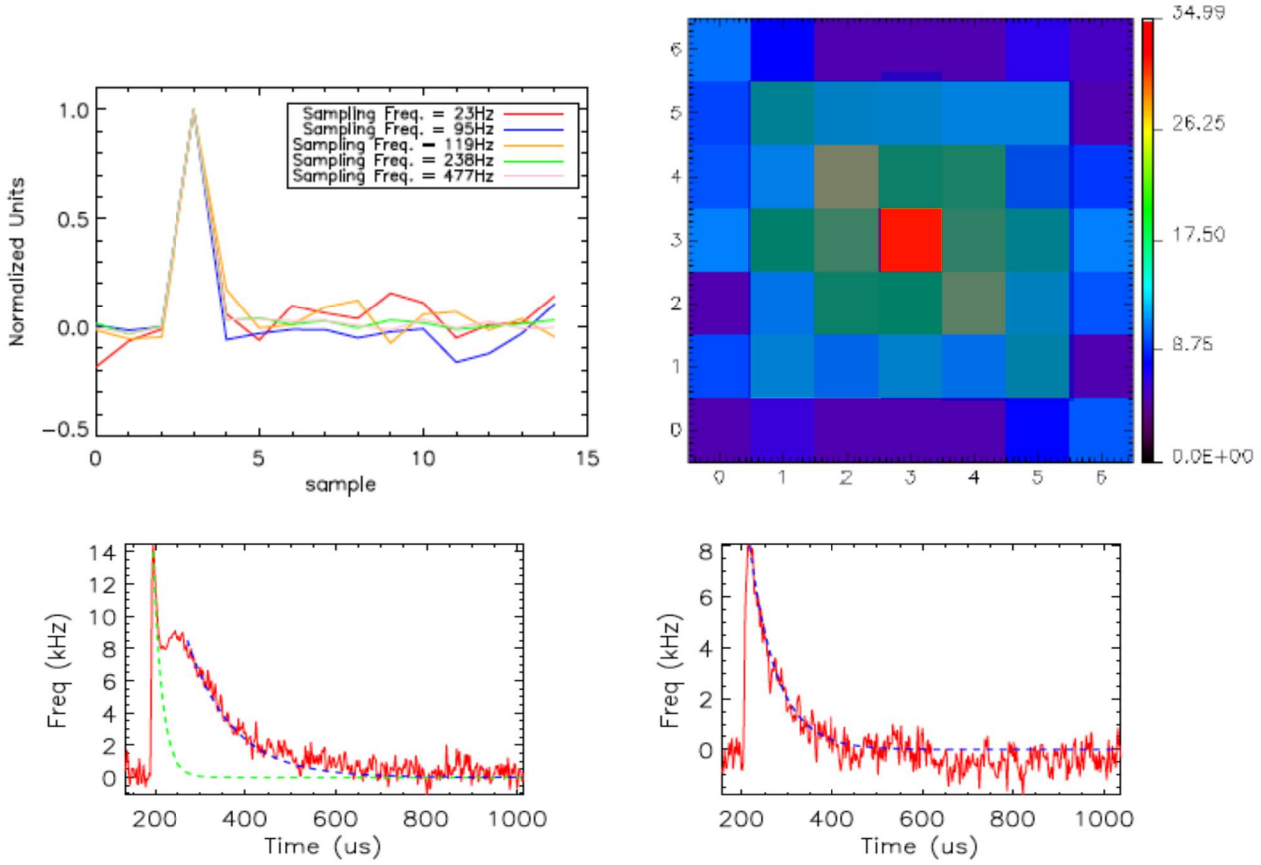


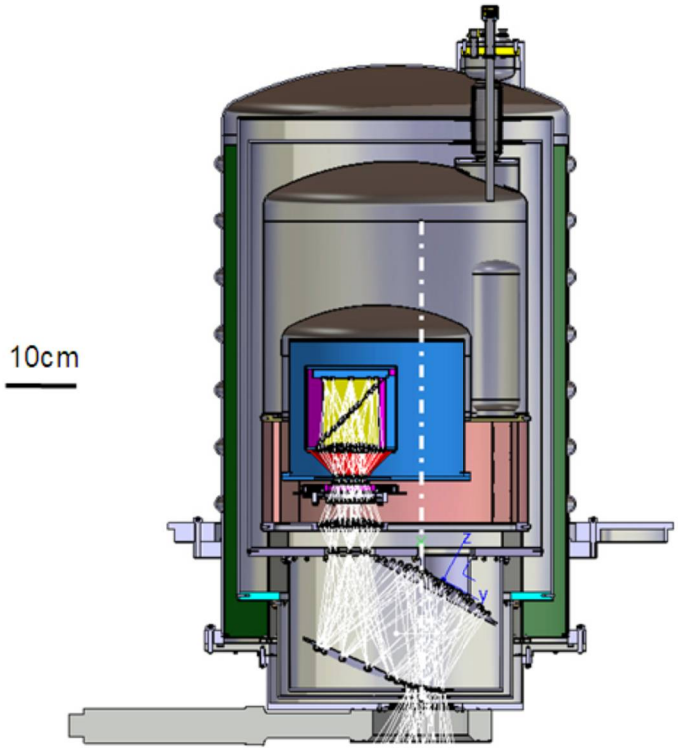
Catalano et al, JLTP 2016

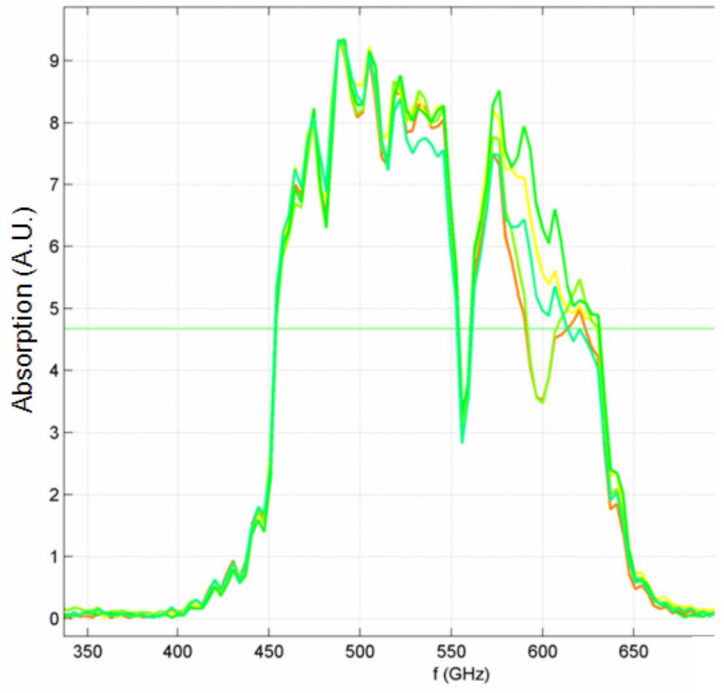
The BSIDE baloon experiment

Devoted to the study of polarized dust emission

Will be a key step in putting all this together in a 'representative environment'

Big step forward in TRL!!





Launch: 2018/2019

The EU panorama

Many groups with experience in the field of KID

- France: IN, LPSC, IRAM, IPAG (Grenoble), APC (Paris)

  NIKA+NIKA2, tests on new materials, particle impacts, ...

- Italy: Sapienza, INFN (Rome), Bicocca (Milan), FBK (Trento)

  New materials, synergies with particle physics, ...

- Spain: CAB (Madrid)

  Fabrication of samples, test platform,...

- UK: AIG (Cardiff)

  Detector design and modelling, test platform, FTS...

- Netherlands: SRON (Groneningen, Utrecht)

  AMKID, lens-coupled MKID, sub-mm bands, ...

The work to do

We have all the ingredients… *But we are not there yet!*

Even demonstrating the baseline will need a real contribution by all people involved!

Most straightforward way: *band splitting*

Details of array geometry, exact number of pixels etc can be fixed during phase A

Work must start *now* on the design and test of pixels optimized for COrE+ optical loads and frequency bands!

The (other) work to do

- Put in place the needed facilities for testing
- Define common tests to compare different detectors
- Sharing resources can be easily envisaged
  - *Demonstrate the baseline!*

Once this is achieved, we can push further:

- *Dual-pol KID*
- *Multichroic KID*

Conclusions

- A KID Focal Plane is very well adapted for COrE+
- The EU community has all the needed know-how
- We need a real contribution by all groups to achieve the goal!
- After that, we can go further...

Thank you!