11/April/2019

Alessandro Fasano

An overview of KISS

A spectrum-imager dedicated to the study of the secondary anisotropies of the CMB

Ph.D. in instrumental technology for mm-astronomy

I. Science context and requirements
- Sunyaev Zel'dovich Effect

II. Observation strategy and instrument design
- Fourier Transformation Spectrometry
- Fast detectors: Kinetic Inductance Detectors

III. Laboratory tests and characterization
- Detectors performances
- Geometrical characterization

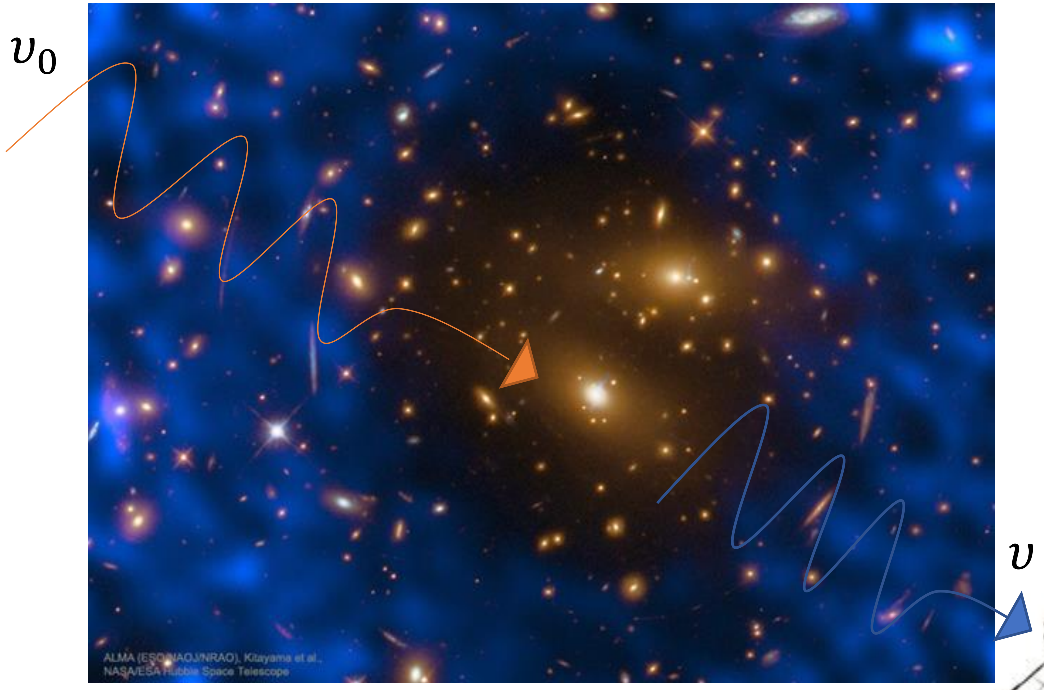
IV. Installation and observations
- My role in this phase
- The Moon observations
- Focus on the pointing model

V. Conclusions and perspectives

Inverse Compton scattering CMB-IntraClusterMedium

RXJ1347.5

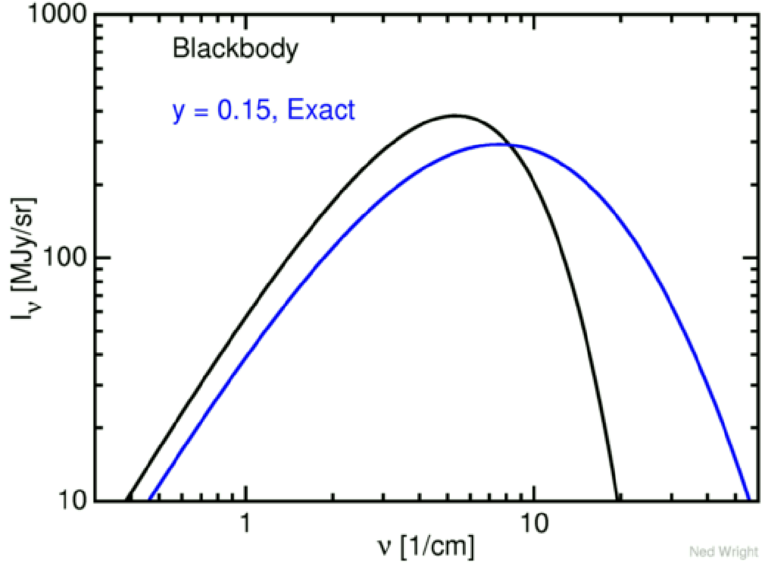
υ_0



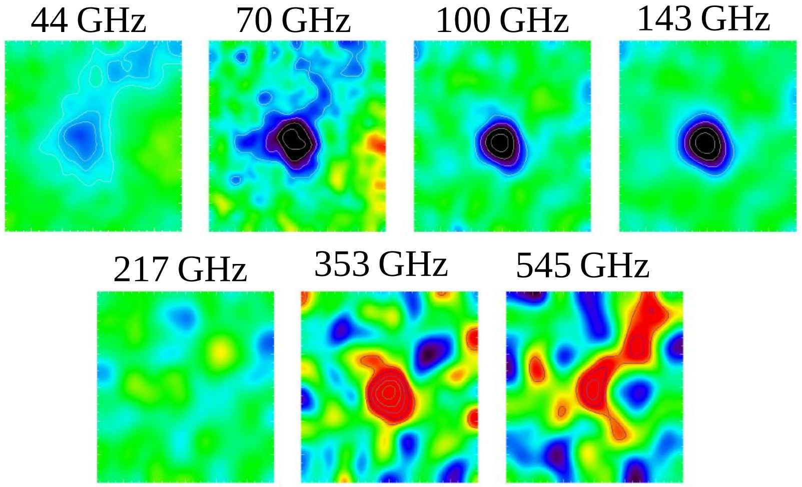
$\upsilon > \upsilon_0$

[Kitayama, T. et al.: 2016]

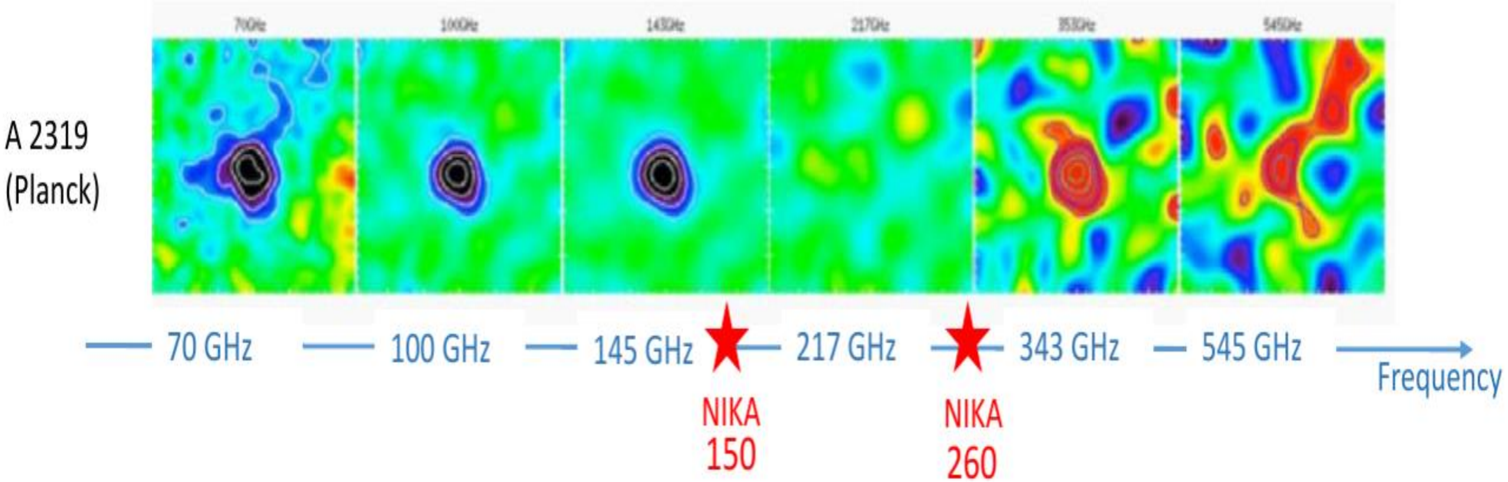
$$\frac{\Delta T_{SZE}}{T_{CMB}} \approx \frac{\Delta \upsilon}{\upsilon} \cdot \tau \approx 10^{-4}$$



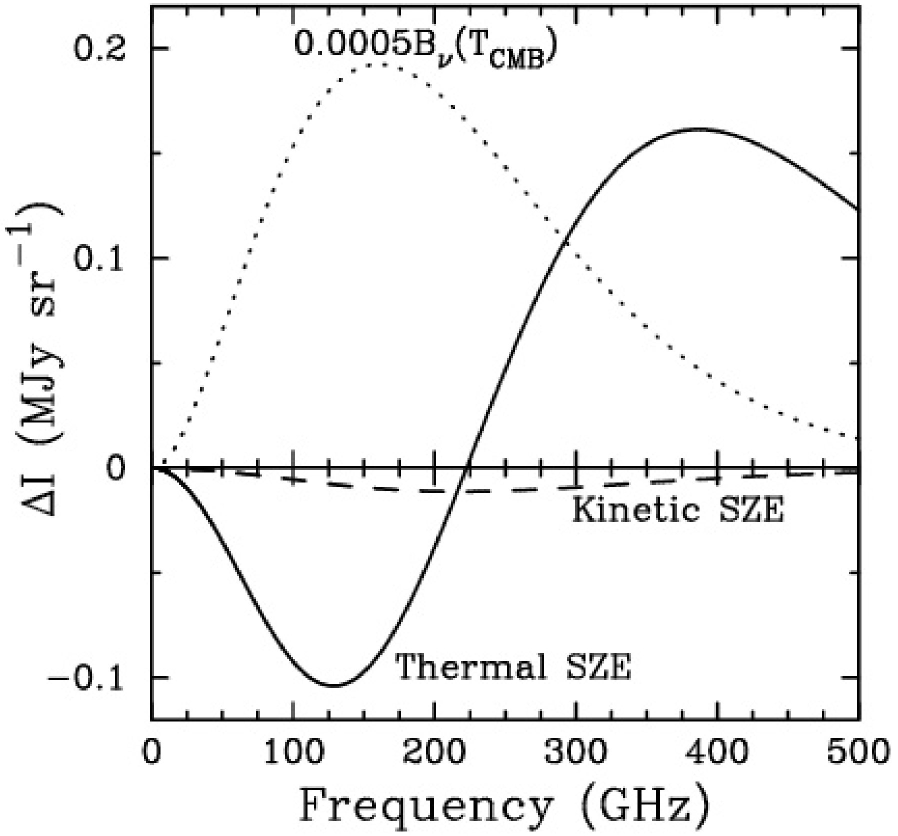
[Wright, E., L.: 2007]



[Abell 2319, Planck results: 2010]



70 GHz ← **KISS** (100 frequencies) → 300 GHz



Experiment	# frequencies	angular resolution @ 150 GHz	# pixels
Planck	6	5 arcmin	52
NIKA2	2	20 arcsec	5’000
KISS	100	4 arcmin	632

Observing several frequencies to separate the SZ components

GOAL

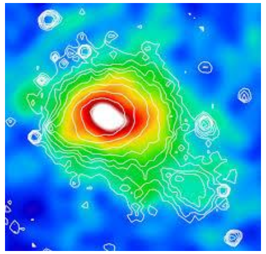
Low resolution spectroscopy observations of known low redshift galaxies at mm wavelenghts to map cluster physical properties from spectral distortions.

STRATEGY

Compensate relative expected low sensitivity with respect to Planck or photometric ground-based instrument by integrating longer (tens of hours per cluster).

Use spectroscopy to fully separate different components and extract physical information from spectral distortions: pressure, temperature, density, mass, LOS velocity

Possible target
COMA cluster



1) Low angular Resolution
(low redshift clusters)
2) Large FOV and band 100-300GHz
(~1 Degree)
3) Low Spectral resolution
(~1.5-10GHz at least 20 bins to separate properly different contributions)
4) Maximum Sensitivity
(photon noise detectors)

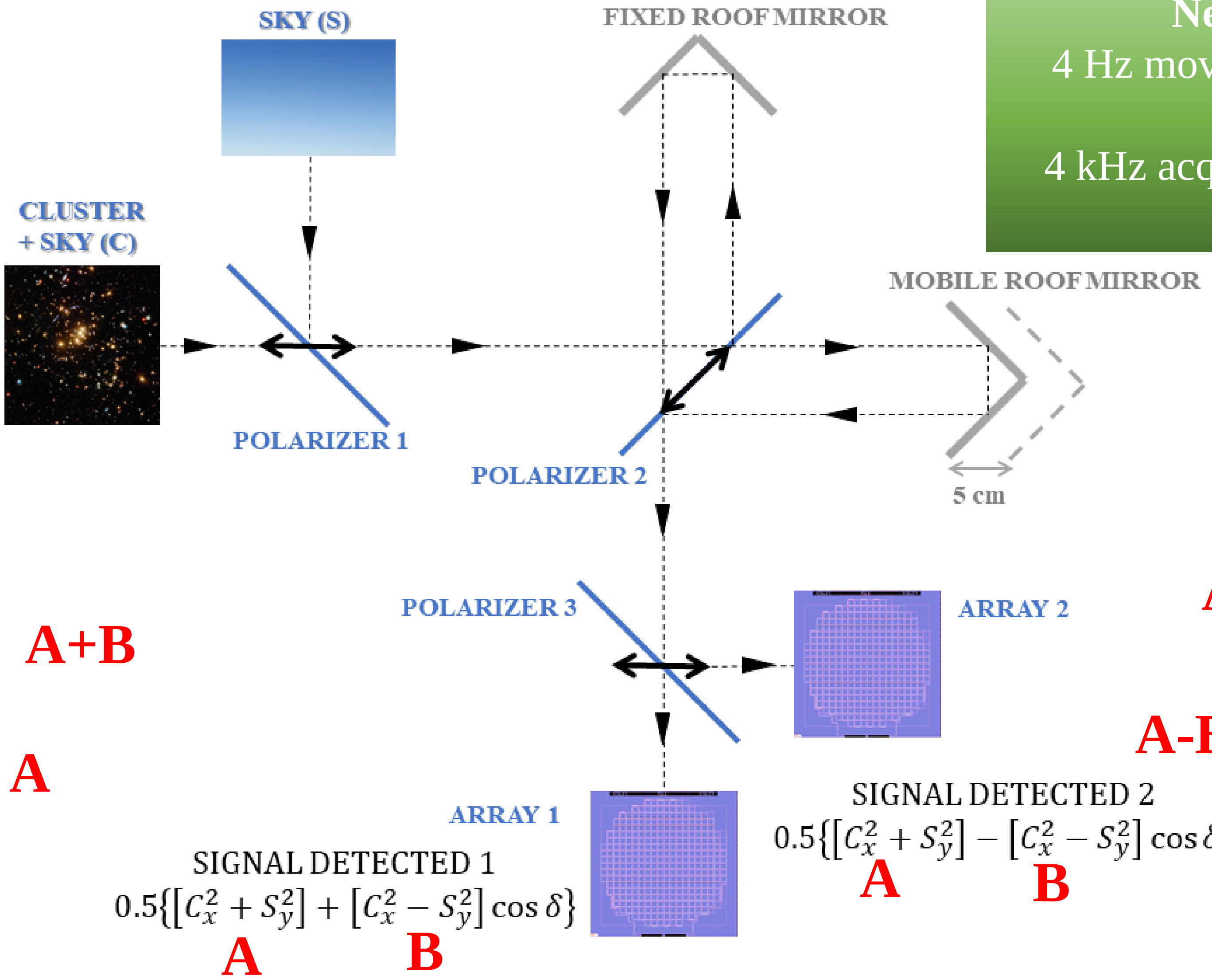
→

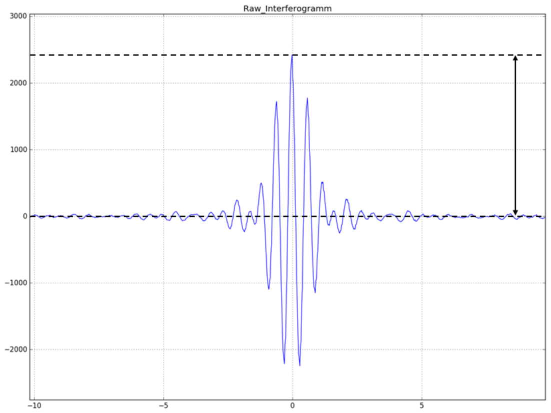
1) Telescope : 2.5m - Quijote
(~ few degrees corrected FP angular resolution from about 2 to 5 arcmin)
2) FTS Technique - Fast MPI
(10 cm excursion , fast acquisition, avoid 1/f noise from the atmosphere.)
3) 2 Arrays of 300 pixels

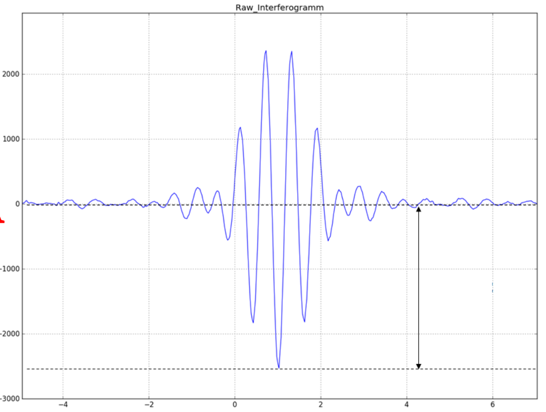
Fourier Transformation Spectrometry

MPI definition:
a **M**artin-**P**uplett **I**nterferometer measures the difference between the powers of the two input beams.

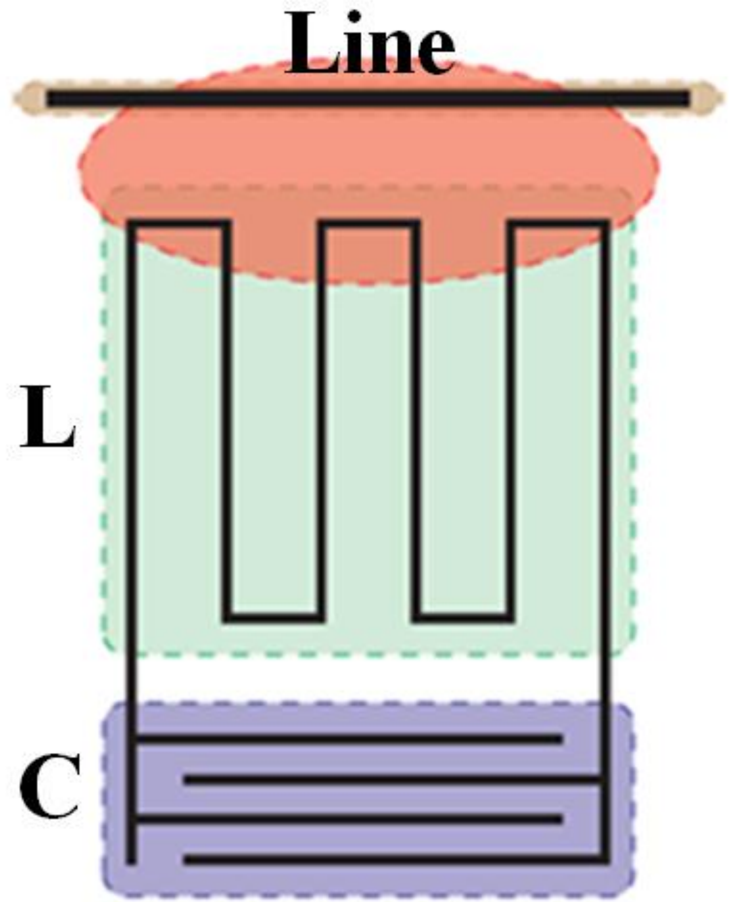
Necessity to be fast:
4 Hz moving mirror -> atmosphere fluctuations
4 kHz acquisition rate -> 100 points spectrum



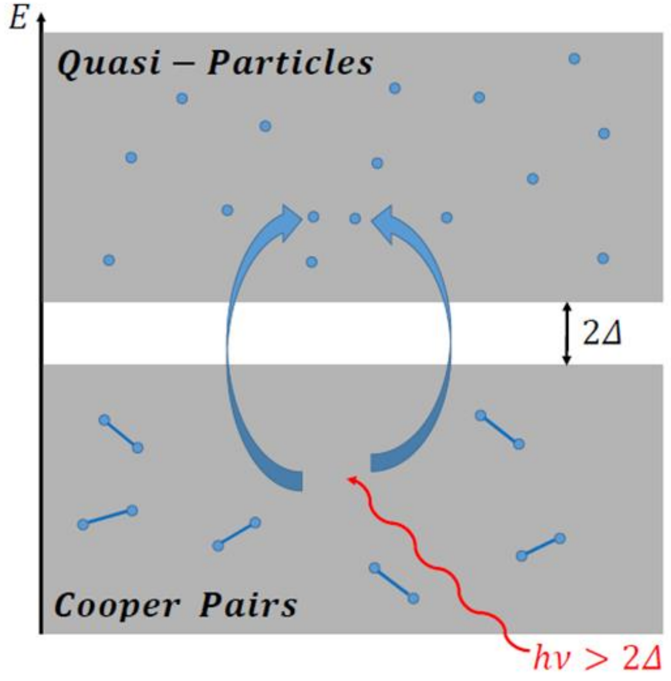




High-Q LC series circuit, feedline coupled, working at superconducting regime



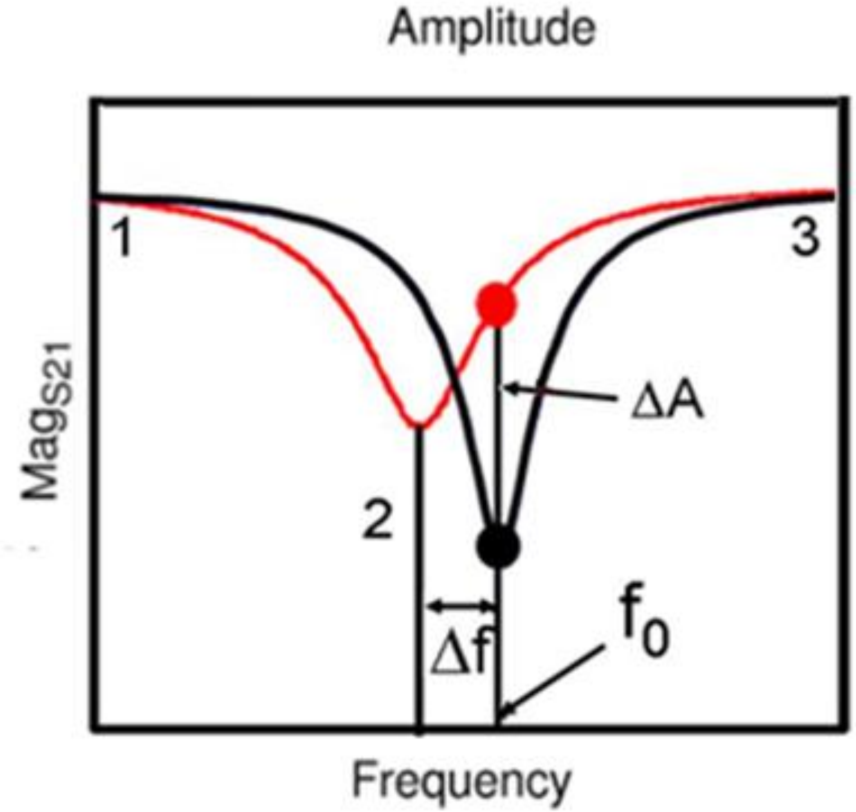
A KID measures the variation of the population of the quasi-particles in a superconducting resonator



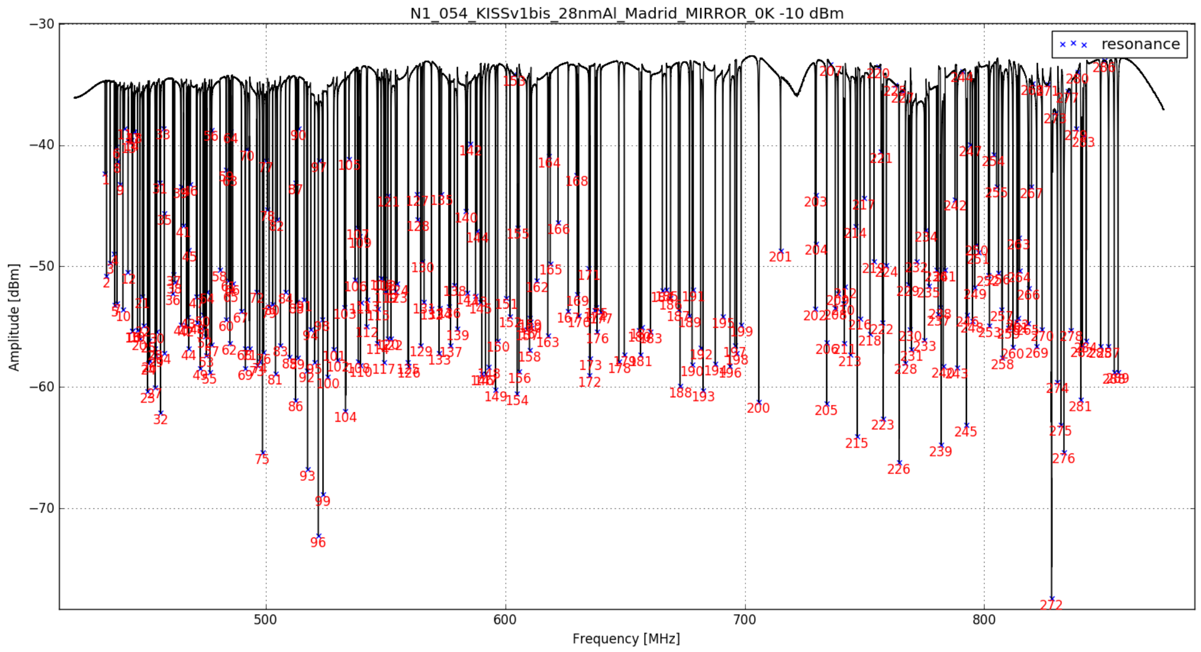
Binding Energy

$2\Delta = 3.5 k_B T_c$

$$\nu_0 = \frac{1}{2\pi\sqrt{LC}}$$



Very low temperatures required order of 100 mK

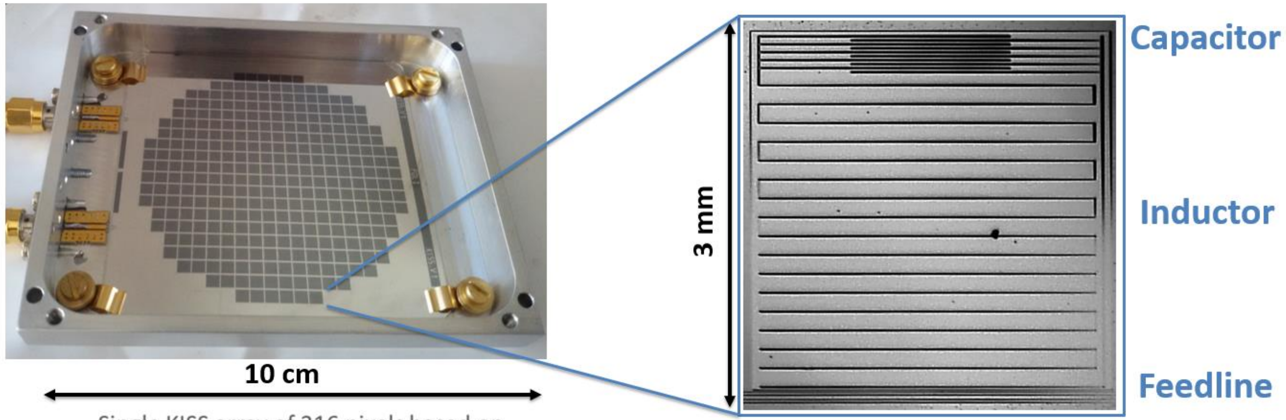


Multiplexed array
300 pixels

The realization of an array with a zoom over a pixel

KIDs reach the intrinsic limitation of sensitivity

Superconducting LC circuit with high Quality factor

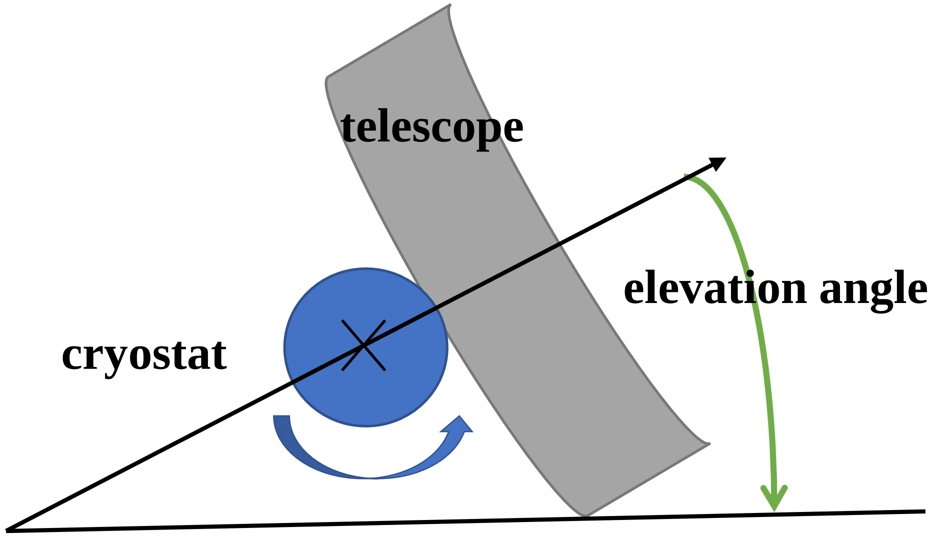


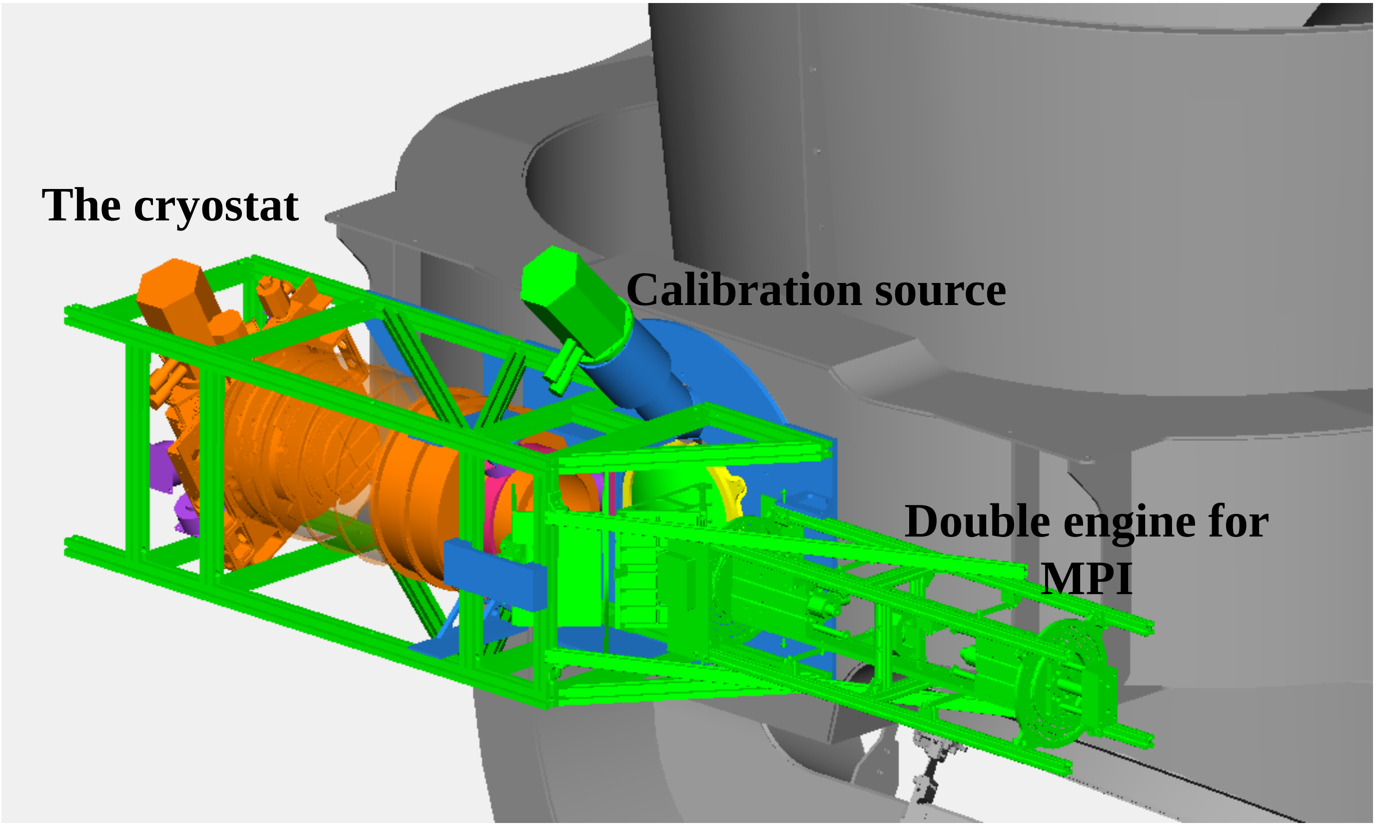
Single KISS array of 316 pixels based on Ti-Al bilayers ($T_C \approx 0.95\ K$) .

One of the 632 pixels within the KISS camera

Technological constraints:

- calibration source for the MPI
- double MPI engine to delete the vibrations
- stable temperature cryostat for the focal plane





III. Laboratory tests and characterization

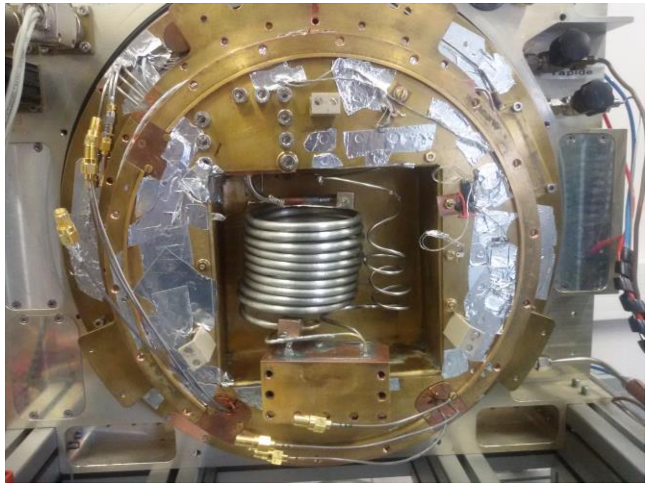
First year of thesis

October 2017 – October 2018

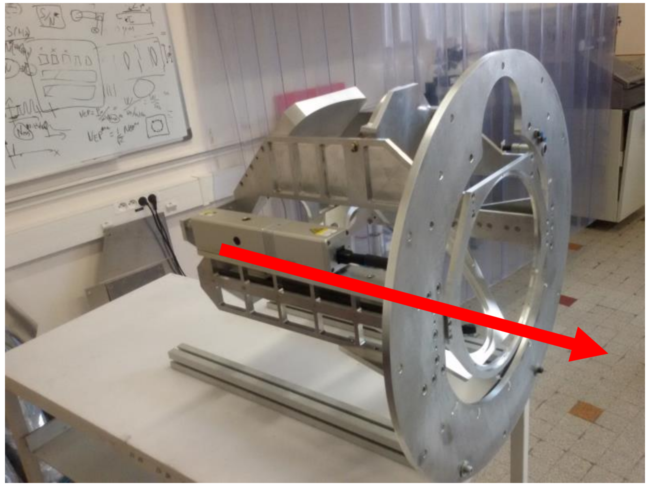
III. Laboratory tests and characterization
Fast Detectors: Kinetic Inductance Detectors

Implementation:
- Focus interface
- Subsystem integration
- Daily laboratory life (problem solving for day-by-day issues)

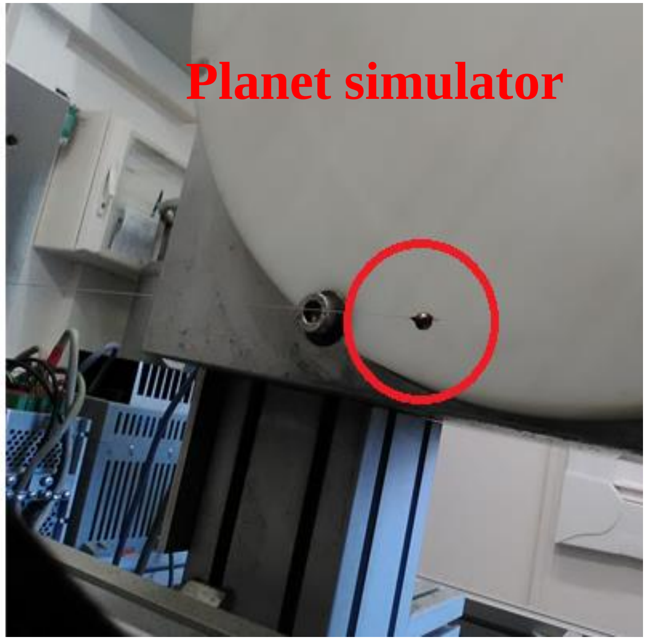
Measurements and characterization:
- Simulations of the single pixel with quality requirements
- MPI simulation
- Data analysis for electric proprieties of the detectors
- Sensitivity measurement
- Geometrical characterization of the matrix



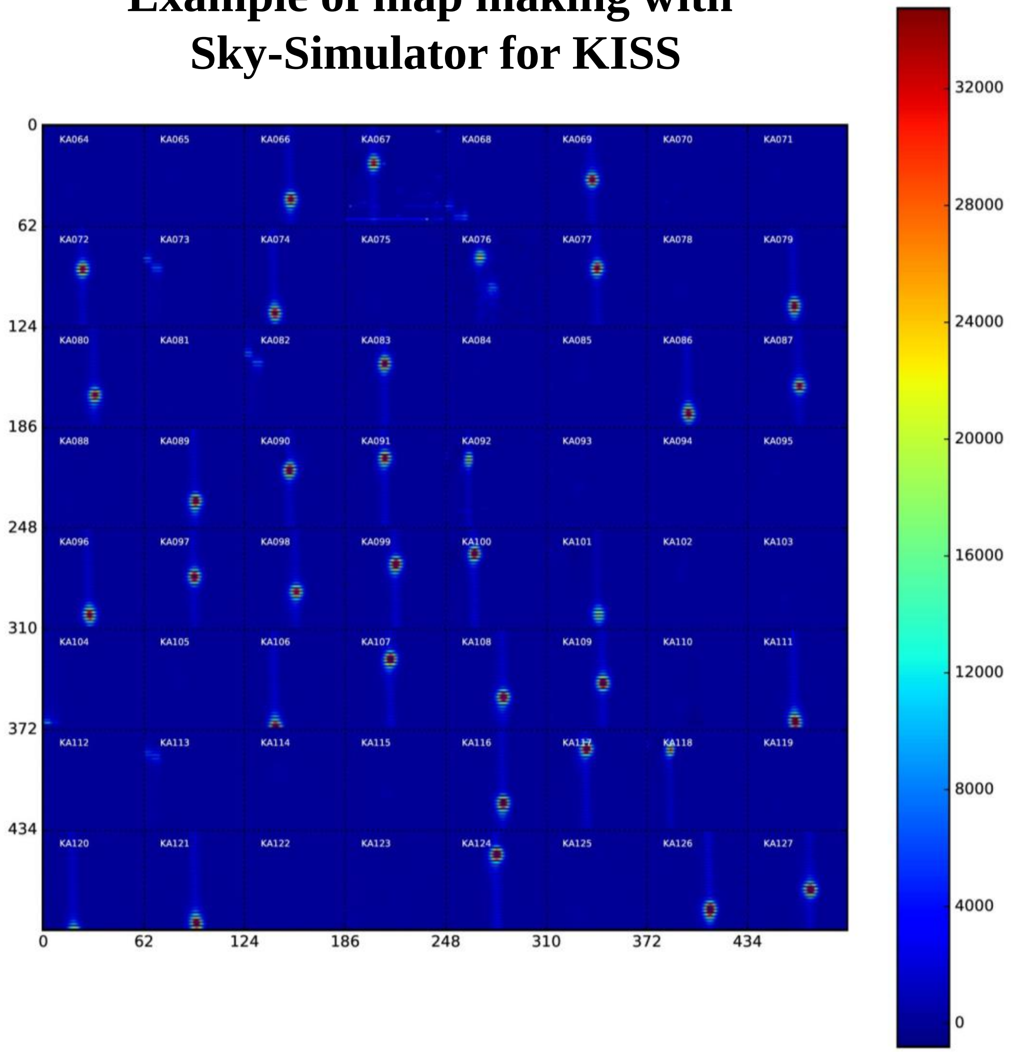
Inner part of the cryostat



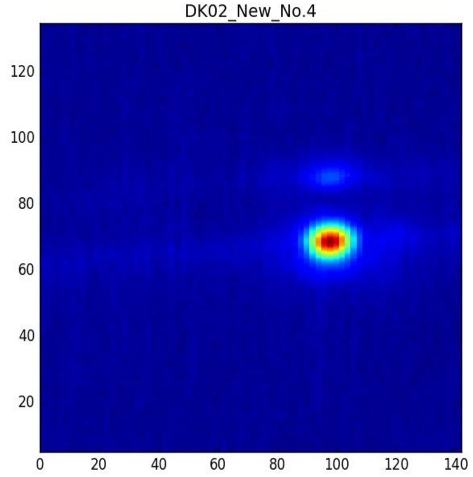
Engine to control the focus



Example of map making with Sky-Simulator for KISS



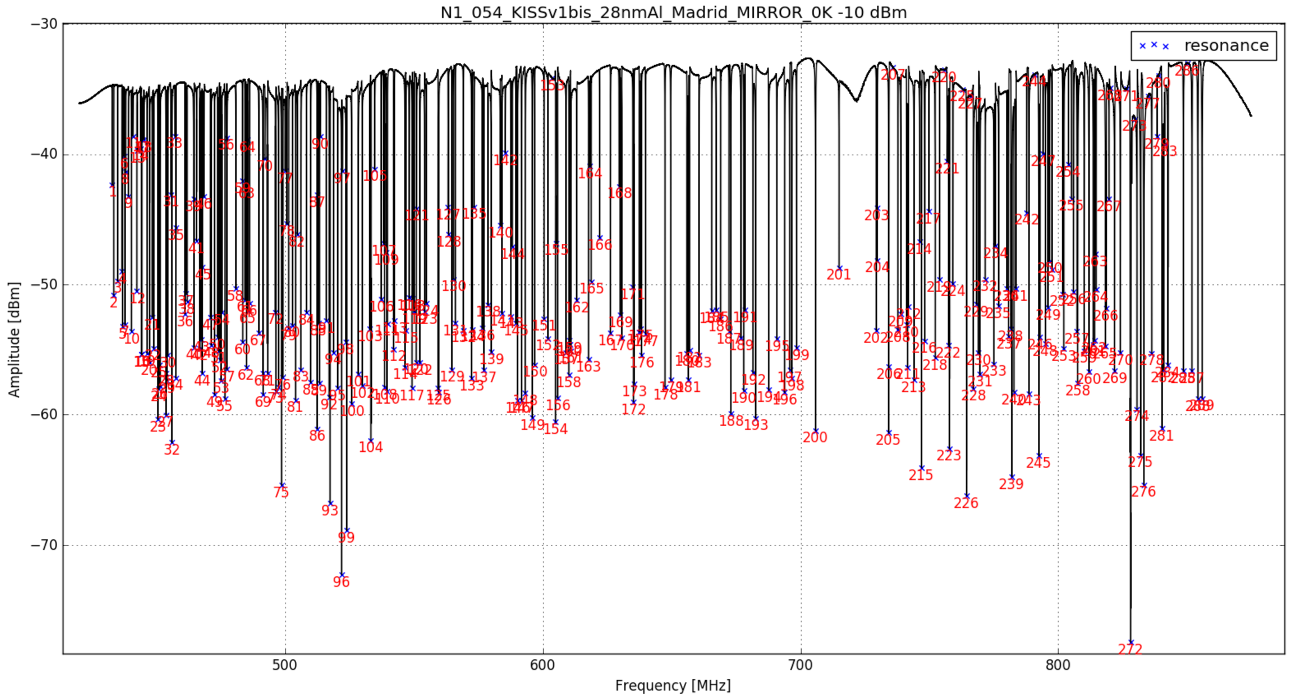
The Sky Simulator is a crucial tool to validate the instrument



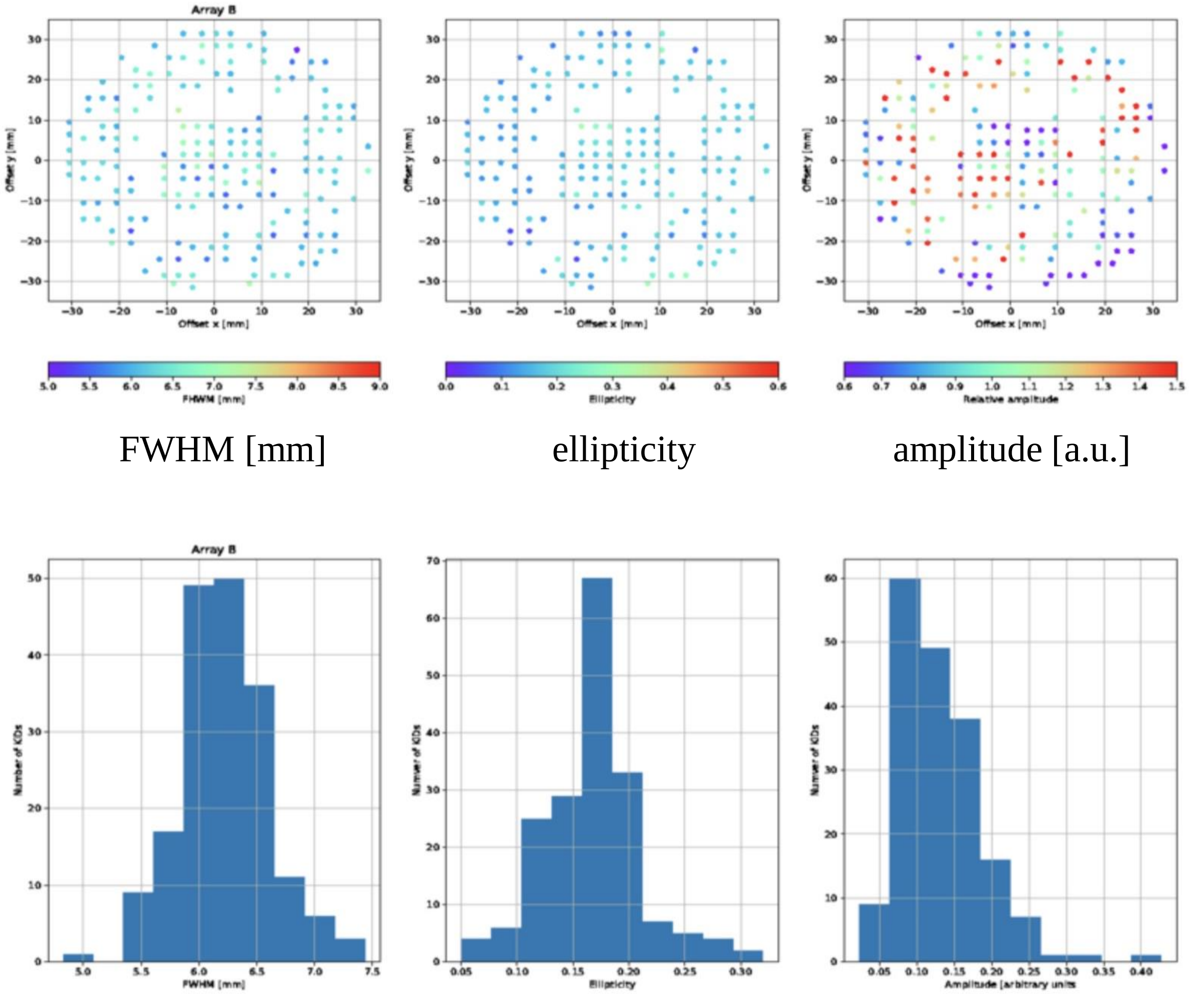
Each pixel is a frequency

Geometric distribution constrained with the sky-simulator

23	18	0	35
28	34	6	27
14	1	21	11
33	8	26	16



Geometrical characterization of the array



IV. Installation and observations

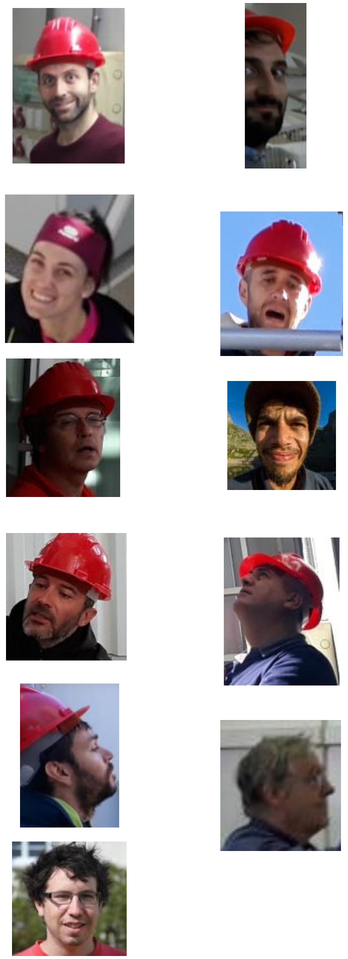
Second year of thesis

November 2018 – NOW

Installation [November 2018- January 2019]:
- transportation of the instrument (4-days journey)
- direct interface with local team
- mechanical, electrical and network installation
- interface with the telescope

Operation [February 2019 - NOW]:
- maintenance in situ
- active partecipation with local research group
- commisioning phase [in progress]

INSTALLATION TEAM



13/60 whole days of observation (and almost everyday to solve the issues)

22 March 2019

Jupiter

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	size map	pointing mod	analysis
moon	--	5/4Khz	04h28	cold	sciencemap - H_2O=11% - we stop before the end	23	255	size 240x150 ', step=10' v=5'/s	AzEl? (shift Az=1deg, El=0)	
moon	--	5/4Khz	05h28	cold	sciencemap - H_2O=10% - we stop before the end	23	256	size 120x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
moon	--	5/4Khz	05h28	cold	sciencemap - H_2O=10% - we stop before the end	23	257	size 200x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
moon	--	5/4Khz	05h44	cold	sciencemap - H_2O=10% - we stop before the end	23	258	size 200x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
moon	--	5/4Khz	04h54	cold	sciencemap - H_2O=11% - we stop before the end	50	259	size 200x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
moon	--	5/4Khz	05h00	cold	sciencemap - H_2O=11% - we stop before the end	23	260	size 200x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
moon	--	5/4Khz	05h33	cold	sciencemap - H_2O=11% - we stop before the end	50	261	size 200x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
Jupiter	--	5/4Khz	06h00	cold	sciencemap - H_2O=11% - too slow, Jupiter in advance wrt the map. Not observed	50	262	size 200x120 ', step=5' v=5'/s	AzEl? (shift Az=1deg, El=0.5)	
Jupiter	--	5/4Khz	06h15	cold	sciencemap - H_2O=10% - well in the middle. Maybe Jupiter observed	50	264	size 200x180 ', step=8' v=5'/s	AzEl? (shift Az=2deg, El=-0.5)	
Jupiter	--	5/4Khz	06h25	cold	sciencemap - H_2O=12% - well in the middle. Maybe Jupiter observed	50	266	size 200x90 ', step=4' v=5'/s	AzEl? (shift Az=2deg, El=0)	
--	5/4Khz	05h41	cold	sciencemap - H_2O=12% - well in the middle. Maybe Jupiter observed	50	267	size 200x120 ', step=4' v=5'/s	AzEl? (shift Az=0deg, El=0)		

19 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	size map	pointing mod	analysis
jupiter	23	5/4Khz	06h50	cold	sciencemap - H_2O=4% - we didn't see jupiter	20	226	size 120x120 ', step=5' v=5'/s	AzEl? p.model offset=(-1,0)	-
jupiter	23	5/4Khz	6h59	cold	sciencemap - H_2O=4% - we didn't see jupiter	20	227	size 120x120 ', step=5' v=5'/s	RaDec?	-
jupiter	23	5/4Khz	7h09	cold	sciencemap - H_2O=4% - we didn't see jupiter	20	228	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(-2,0)	-
jupiter	23	5/4Khz	7h29	cold	sciencemap - H_2O=4% - we didn't see jupiter (in telekiss: no source)	20	231	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(-2,0)	-
jupiter	23	5/4Khz	7h41	cold	sciencemap - H_2O=4% - it seems to be visible	40	232	size 180x120 ', step=5' v=5'/s	RaDec?	todo
jupiter	23	5/4Khz	7h59	cold	sciencemap - H_2O=4% - not sure	25	233	size 180x120 ', step=5' v=5'/s	RaDec?	-
jupiter	23	5/4Khz	8h11	cold	sciencemap - H_2O=4%	50	234	size 210x120 ', step=7' v=5'/s	RaDec?	-
venus	23	5/4Khz	8h24	cold	sciencemap - H_2O=4%	50	235	size 180x120 ', step=5' v=5'/s	RaDec?	-
venus	23	5/4Khz		cold	sciencemap - H_2O=4% - not seen	50	240	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(-0.5,-0.5)	-
venus	23	5/4Khz	9h27	cold	sciencemap - H_2O=4%	50	241	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(-1.5,-1) - nothing seen	-
venus	23	5/4Khz	9h25	cold	sciencemap - H_2O=4% - nothing seen	25	242	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(-1.5,-1) -	-
venus	23	5/4Khz	9h34	cold	sciencemap - H_2O=4%	25	243	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(-2,-1) -	-
venus	23	5/4Khz	9h40	cold	sciencemap - H_2O=4% - IT SEEMS THERE: just one point	25	244	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(+2,-1)	todo
venus	23	5/4Khz	9h46	cold	sciencemap - H_2O=4% - IT SEEMS THERE: just one point	25	245	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(+2,-1)	-
venus	23	5/4Khz		cold	sciencemap - H_2O=4%	25	247	size 180x120 ', step=5' v=5'/s	AzEl? p.model offset=(+2,-1) - not seen	-

18 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	size map	pointing mod	analysis
moon	23	5/4Khz	19h40	cold	sciencemap - H_2O=7% - we didn't see the moon	20	212	size 290x120 ', step=10' v=5'/s	RaDec?	-
moon	23	5/4Khz	19h55	cold	sciencemap - H_2O=8% - we didn't see the moon	20	213	size 340x120 ', step=10' v=5'/s	RaDec?	-
moon	23	5/4Khz	20h12	cold	sciencemap - H_2O=7% - we didn't see the moon	20	214	size 340x120 ', step=10' v=5'/s	AzEl? p.model	
moon	23	5/4Khz	20h33	cold	sciencemap - H_2O=7% -	20	215	size 340x240 ', step=10' v=5'/s	AzEl? p.model	-
moon	23	5/4Khz		cold	sciencemap - H_2O=6% - we saw the moon, the problem seemed to be that we lost the Moon because it flew away	20	219	size 90x120 ', step=10' v=5'/s	AzEl? p.model	
moon	23	5/4Khz		cold	sciencemap - H_2O=6% -	20	220	size 60x60 ', step=10' v=5'/s, on the moon we see 100 kHz on KA, 80 kHz KB	AzEl? p.model	
moon	23	5/4Khz	21h54	cold	sciencemap - H_2O=6% -	20	221	size 120x60 ', step=5' v=3'/s	AzEl? p.model	
moon	23	5/4Khz	22h05	cold	sciencemap - H_2O=7% - we tried to anticipate the moon and we saw it, a discontinuity appears	20	222	size 120x60 ', step=5' v=3'/s	AzEl? p.model offset (-1,-1)	
moon	23	5/4Khz	22h13	cold	sciencemap - H_2O=7% - we tried to anticipate the moon and we saw it	20	223	size 120x120 ', step=10' v=5'/s	AzEl? p.model offset= (-1.5,-1.5)	
moon	23	5/4Khz	22h20	cold	sciencemap - H_2O=7% we saw the moon	20	224	size 120x120 ', step=10' v=5'/s	RaDec?	
moon	23	5/4Khz	22h26	cold	sciencemap - H_2O=7% we saw the moon	20	225	size 120x120 ', step=10' v=3'/s	RaDec?	

15 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	23	5/4Khz	20h28	cold	sciencemap - nothing seen - H_2O=35%	40	170	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	20h48	cold	sciencemap - nothing seen - H_2O=35%	40	171	size 290x240 ', step=10' v=5'/s
moon	23	5/4Khz	21h15	cold	sciencemap - we saw the moon - H_2O=36%	40	172	size 290x290 ', step=10' v=5'/s
moon	23	5/4Khz	21h35	cold	sciencemap - we saw the moon - H_2O=36%	40	173	size 290x150 ', step=10' v=5'/s
moon	23	5/4Khz	21h47	cold	sciencemap - we saw the moon - H_2O=36% - photo analyzed by A.J.	40	174	size 320x120 ', step=10' v=5'/s
moon	23	5/4Khz	22h03	cold	sciencemap - we saw the moon at 8 kHz in amplitude - H_2O=37% - photo analyzed by A.J.	43	175	size 320x120 ', step=10' v=5'/s
moon	23	5/4Khz	22h20	cold	sciencemap - we saw the moon a bit less than 8 kHz in amplitude - H_2O=37% - photo analyzed by A.J.	45	176	size 320x120 ', step=10' v=5'/s
moon	23	5/4Khz	22h32	cold	sciencemap - we saw the moon a bit less than 8 kHz in amplitude - H_2O=37% - photo analyzed by A.J.	50	177	size 320x120 ', step=10' v=5'/s
moon	23	5/4Khz	22h44	cold	sciencemap - we saw the moon a bit less than 8 kHz in amplitude - H_2O=37% - photo analyzed by A.J.	20	178	size 320x120 ', step=10' v=5'/s
moon	23	5/4Khz	22h53	cold	sciencemap - we saw the moon - H_2O=32%	20	179	size 320x120 ', step=10' v=5'/s
moon	23	5/4Khz	23h04	cold	sciencemap - we saw the moon - H_2O=36% - photo analyzed by A.J.	20	180	size 320x120 ', step=4' v=5'/s
moon	23	5/4Khz	23h13	cold	sciencemap - we saw the moon - H_2O=36% - photo analyzed by A.J.	20	181	size 320x120 ', step=2' v=5'/s
venus	23	5/4Khz	8h22	cold	sciencemap - H_2O=34%	40	168	size 120x120 ', step=5' v=5'/s
venus	23	5/4Khz	8h34	cold	sciencemap - H_2O=34%	40	169	size 120x120 ', step=5' v=5'/s

14 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	23	5/4Khz	18h39	cold	sciencemap - source covered by clouds - H_2O=35%	40	166	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	18h55	cold	sciencemap - source covered by clouds - H_2O=39%	40	167	size 240x180 ', step=10' v=5'/s

14 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	23	5/4Khz	18h39	cold	sciencemap - source covered by clouds - H_2O=35%	40	166	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	18h55	cold	sciencemap - source covered by clouds - H_2O=39%	40	167	size 240x180 ', step=10' v=5'/s

13 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	23	5/4Khz	20h15	cold	sciencemap - H_2O=25%	40	158	size 180x180 ', step=10' v=5'/s
moon	23	5/4Khz	20h28	cold	sciencemap - we saw the moon - H_2O=25%	40	159	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	20h45	cold	sciencemap - we saw the moon - H_2O=25%	40	160	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	21h07	cold	sciencemap - we saw the moon - H_2O=25%	40	161	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	21h30	cold	sciencemap - we saw the moon - H_2O=25%	40	162	size 240x180 ', step=10' v=5'/s
moon	23	5/4Khz	21h48	cold	sciencemap - we enlarged in elevation because it seems that is there the problem H_2O=25% - photo analyzed by A.J.	40	162	size 240x240 ', step=10' v=5'/s
moon	23	5/4Khz	22h09	cold	sciencemap - we saw the moon - photo analyzed by A.J.	40	163	size 240x240 ', step=10' v=5'/s
moon	23	5/4Khz	22h36	cold	sciencemap - we saw the moon, really low in elevation - photo analyzed by A.J.	40	164	size 240x240 ', step=10' v=5'/s

12 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	-	5/4Khz	14h18	sky	sciencemap - no modulation	40	154	size 290x120 ', step=10' v=5'/s
moon	-	5/4Khz	14h43	sky	sciencemap - no modulation	40	155	size 290x120 ', step=10' v=5'/s
moon	-	5/4Khz	14h57	sky	sciencemap - no modulation	40	156	size 400x120 ', step=10' v=5'/s

11 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	-	5/4Khz	13h54	cold	sciencemap	40	143	size 180x120 ', step=6' v=5'/s

2 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
jupiter	23	5/4Khz	7h37	cold	sciencemap	20	138	size 100x100 arcmin, step=6' v=3'/s
jupiter	23	5/4Khz	7h49	cold	sciencemap	20	139	size 100x100 arcmin, step=6' v=3'/s
jupiter	23	5/4Khz	8h02	cold	sciencemap	40	140	size 100x100 arcmin, step=6' v=3'/s
jupiter	23	5/4Khz	8h14	cold	sciencemap	40	141	size 80x80 arcmin, step=6' v=1.5'/s
jupiter	23	5/4Khz	8h29	cold	sciencemap	40	142	size 120x120 arcmin, step=6' v=1.5'/s

1 March 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
moon	23	5/4Khz	8h36	cold	sciencemap - we didn't see the moon in trace	40	129	size 180x180 arcmin, step=7' v=6'/s
moon	23	5/4Khz	8h54	cold	sciencemap - we didn't see the moon in trace	40	130	size 240x240 arcmin, step=10' v=6'/s
moon	23	5/4Khz	9h15	cold	sciencemap - it seems visible	40	131	size 290x290 arcmin, step=10' v=10'/s
moon	23	5/4Khz	9h31	cold	sciencemap - moon in subscan 15,17 /30totale	40	132	size 290x290 arcmin, step=10' v=10'/s
moon	23	5/4Khz	10h02	cold	sciencemap - moon in subscan 7/15total in pixel KB065 & KB180 (kiss tuning wasn't working properly)	40	134	size 180x180 arcmin, step=10' v=8'/s
moon	23	5/4Khz	10h22	cold	sciencemap - we saw something but maybe we're going too fast	40	135	size 120x120 arcmin, step=5' v=6'/s
moon	23	5/4Khz	10h33	cold	sciencemap - we saw the moon in trace itfamp few kHz	40	136	size 100x100 arcmin, step=6' v=3'/s
moon	23	5/4Khz	10h45	cold	sciencemap - we saw the moon in trace itfamp few kHz	20	137	size 100x100 arcmin, step=6' v=3'/s

25 February 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
Electrical Test	-	-	12h27	cold		40	-	NO GOOD RESONANCES - we disconnected the old instrument that was connected to the ground analyzed()
Electrical Test	-	-	12h53	cold		40	-	NO GOOD RESONANCES - pumping bench pipes connected to the earth (floor ground) - R_[pumpingbench-earth]=0.02 ohm, R_[compressor-earth]=0.96 ohm
Electrical Test	-	-	13h08	cold		40	-	NO GOOD RESONANCES - as 12h53 + small pipes of dilution connected to compressor ones + bottom of pumping stage connected to the compressor
Electrical Test	-	-	13h51	cold		40	-	NO GOOD RESONANCES - PulseTube? in the ground floor
Electrical Test	-	-	15h48	cold		40	-	NO GOOD RESONANCES - all the pipes together, not anymore at the floor, but to the bottom of the compressor that is connected to the fork of the telescope

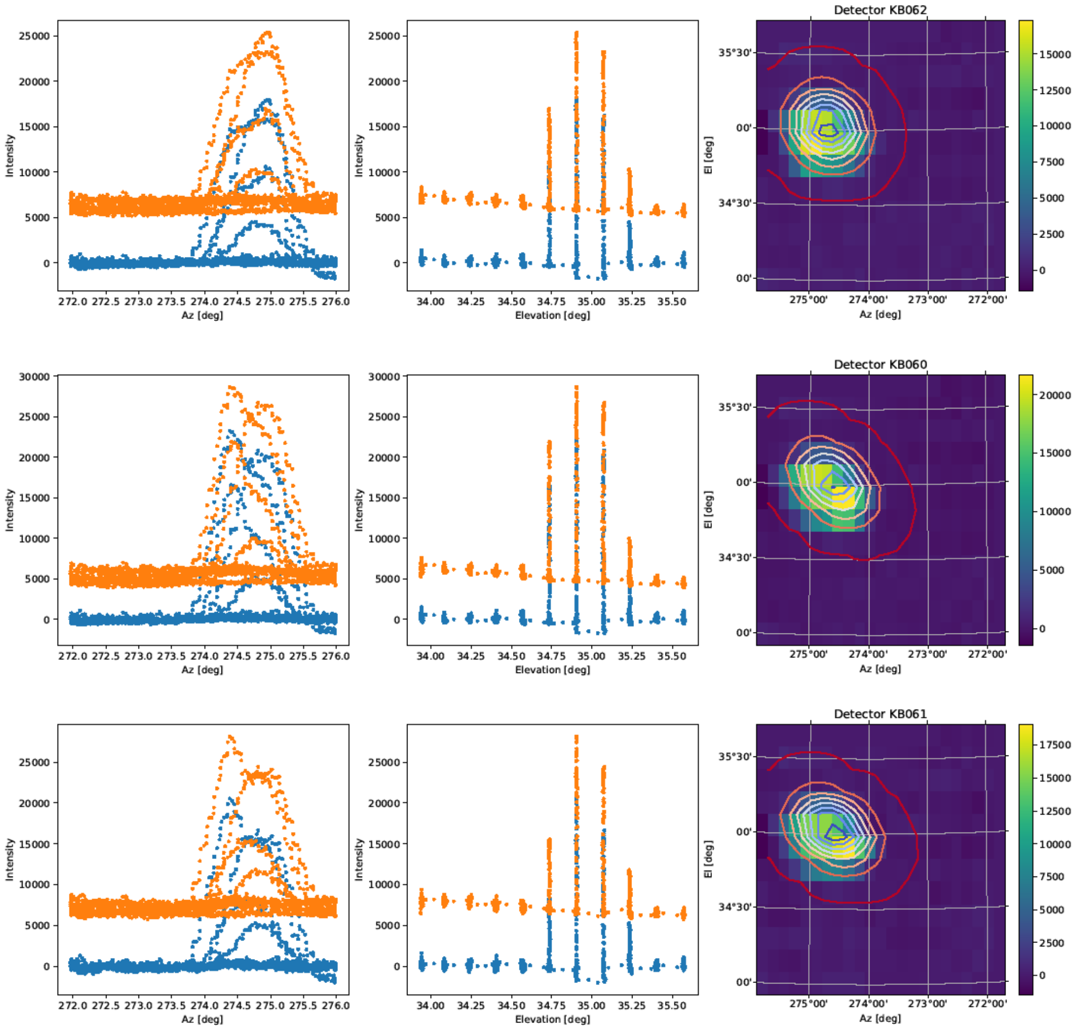
23 February 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
0745+241	-	4 kHz	00h15	cold	sciencemap - photometry	10	104	size 30x30 arcmin, step=5' v=5'/s
moon	23	4 kHz	01h30	cold	sciencemap	10	105	size 90x90 arcmin, step=7' v=4'/s
moon	23	4 kHz	01h39	cold	sciencemap	40	106	size 180x180 arcmin, step=7' v=6'/s
moon	23	4 kHz	01h55	cold	sciencemap	40	107	size 240x240 arcmin, step=10' v=10'/s
moon	23	4 kHz	02h45	cold	sciencemap	40	115	size 240x290 arcmin, step=10' v=10'/s
moon	23	4 kHz	03h05	cold	sciencemap	25	116	size 290x290 arcmin, step=10' v=10'/s
moon	23	4 kHz	03h26	cold	sciencemap	40	117	size 290x290 arcmin, step=10' v=10'/s
jupiter	23	4 kHz	07h24	cold	sciencemap	40	118	size 60x60 arcmin, step=5' v=2'/s, deplacement +3 deg in elevation
jupiter	23	4 kHz	07h31	cold	sciencemap	40	119	size 60x60 arcmin, step=5' v=2'/s, deplacement +3 deg in elevation and +1 deg in azimuth
jupiter	23	4 kHz	07h39	cold	sciencemap	40	120	size 60x60 arcmin, step=5' v=2'/s, deplacement +2 deg in elevation
jupiter	23	4 kHz	07h47	cold	sciencemap	40	121	size 60x60 arcmin, step=5' v=2'/s, deplacement +2 deg in elevation and +1 deg in azimuth
jupiter	23	4 kHz	07h55	cold	sciencemap	40	122	size 60x60 arcmin, step=5' v=2'/s, deplacement +2 deg in elevation and -1 deg in azimuth
jupiter	23	4 kHz	08h02	cold	sciencemap	40	123	size 60x60 arcmin, step=5' v=2'/s, deplacement +2 deg in elevation and -1 deg in azimuth, it's the same of the previous one
-	23	4 kHz	08h20	cold	skydip 60 el	40	124	size 30x30 arcmin, step=5' v=2'/s
-	23	4 kHz	08h28	cold	skydip 75 el	40	125	size 30x30 arcmin, step=5' v=2'/s
-	23	4 kHz	08h45	cold	skydip 82.4 el	40	127	size 30x30 arcmin, step=5' v=2'/s
-	23	4 kHz	08h47	cold	sciencemap, compressor stopped	40	127	size 30x30 arcmin, step=5' v=2'/s

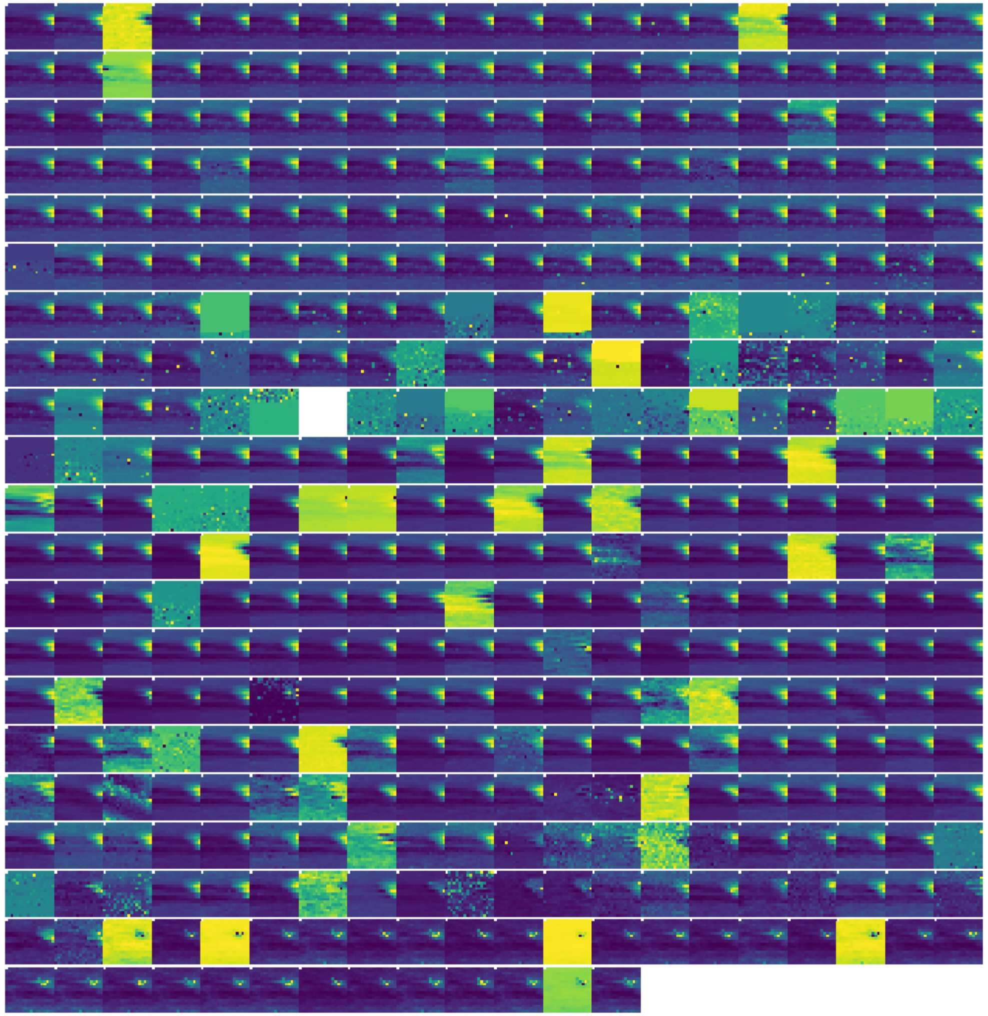
22 February 2019

name source	OP [mm]	MP/Acq frequency [Hz]	time	second source	details	focus [mm]	scan number	Size map
crab	-	95 Hz	23h16m34s	cold	pointingmap - photometry	40	-	size 180x180 arcmin, step=5' v=30'/s
crab	-	95 Hz	23h37h40	cold	pointingmap - photometry	25	-	size 180x180 arcmin, step=5' v=30'/s
crab	-	95 Hz	23h44m07	cold	pointingmap - photometry	10	-	size 180x180 arcmin, step=5' v=30'/s

Each pixel



Whole array



FACTS

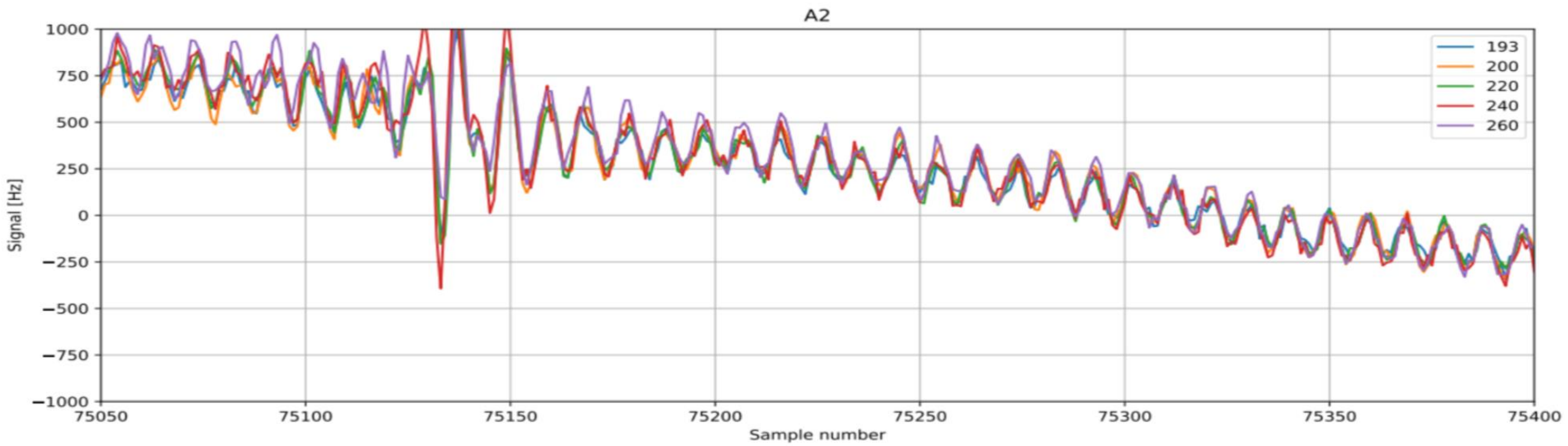
Commisioning phase in progress
and we are handling two major issues

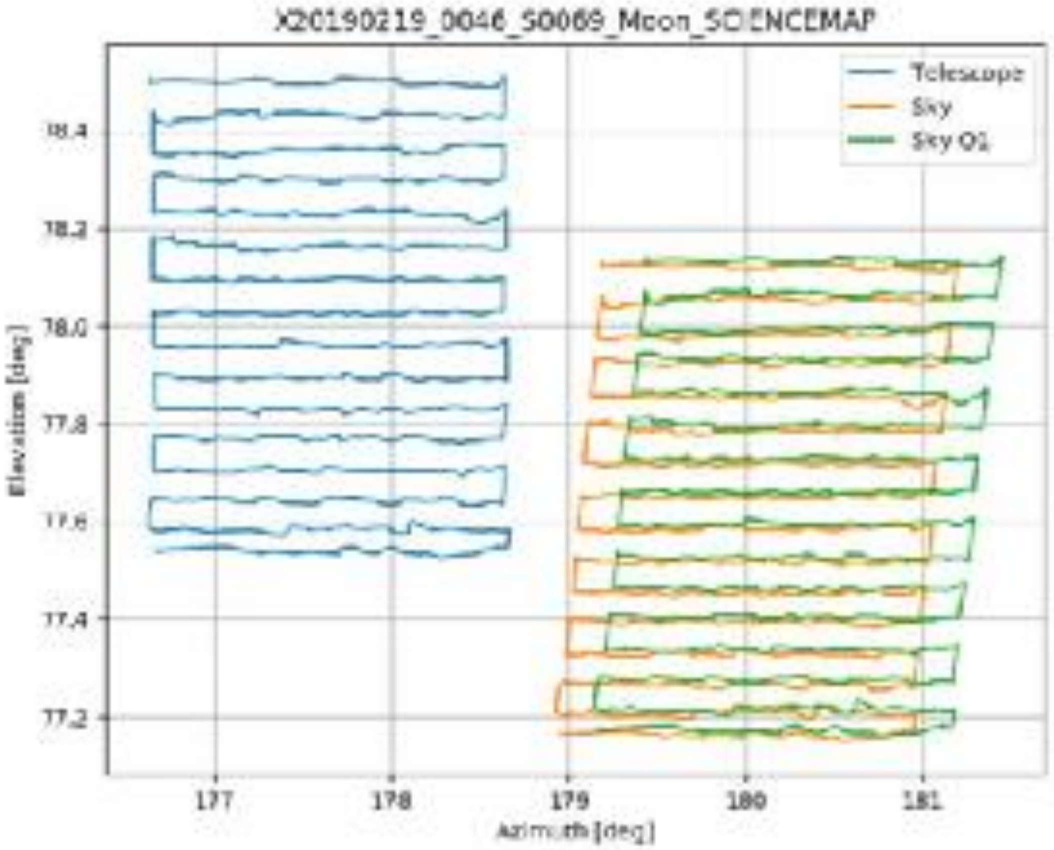
1) Noise:

source of noise at 400 Hz.

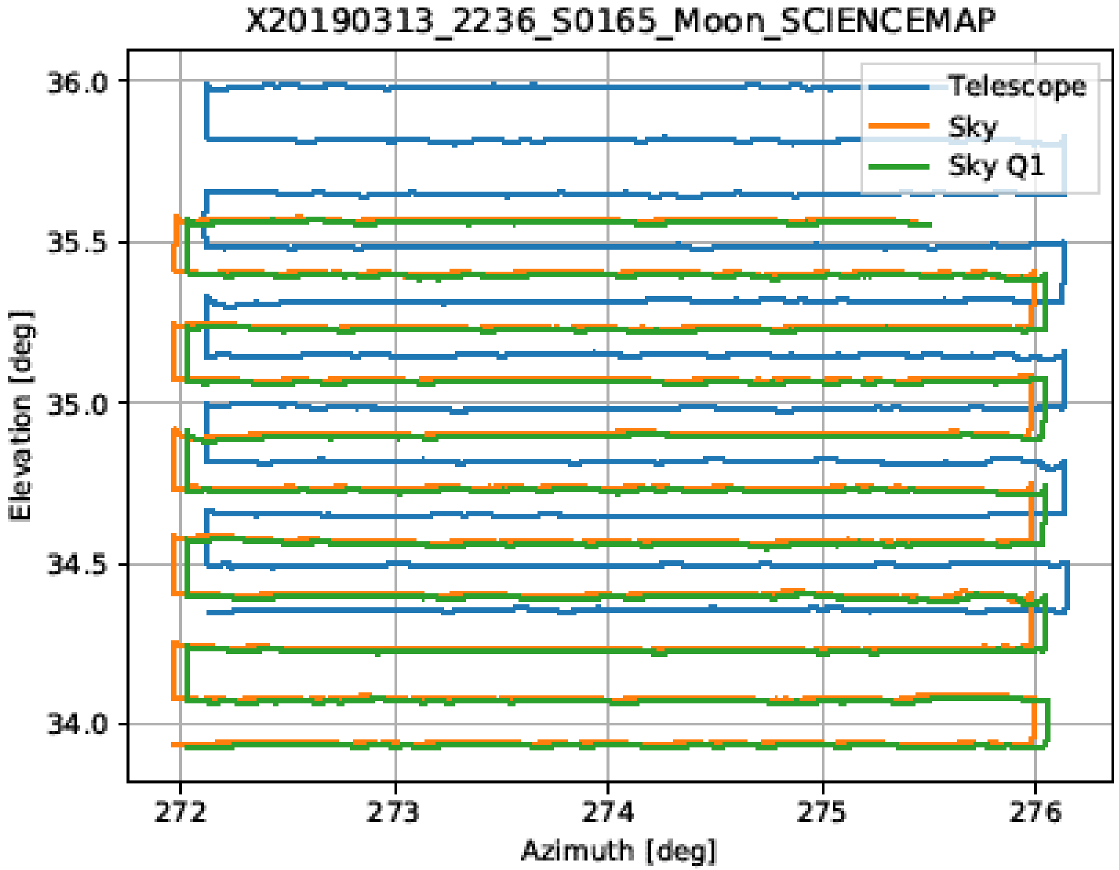
2) Pointing Model:

pointing correction are of the order of degree especially at higher elevation angles. They are due to the different distribution of weight to respect to the previous instrument installed at the same telescope.





BEFORE

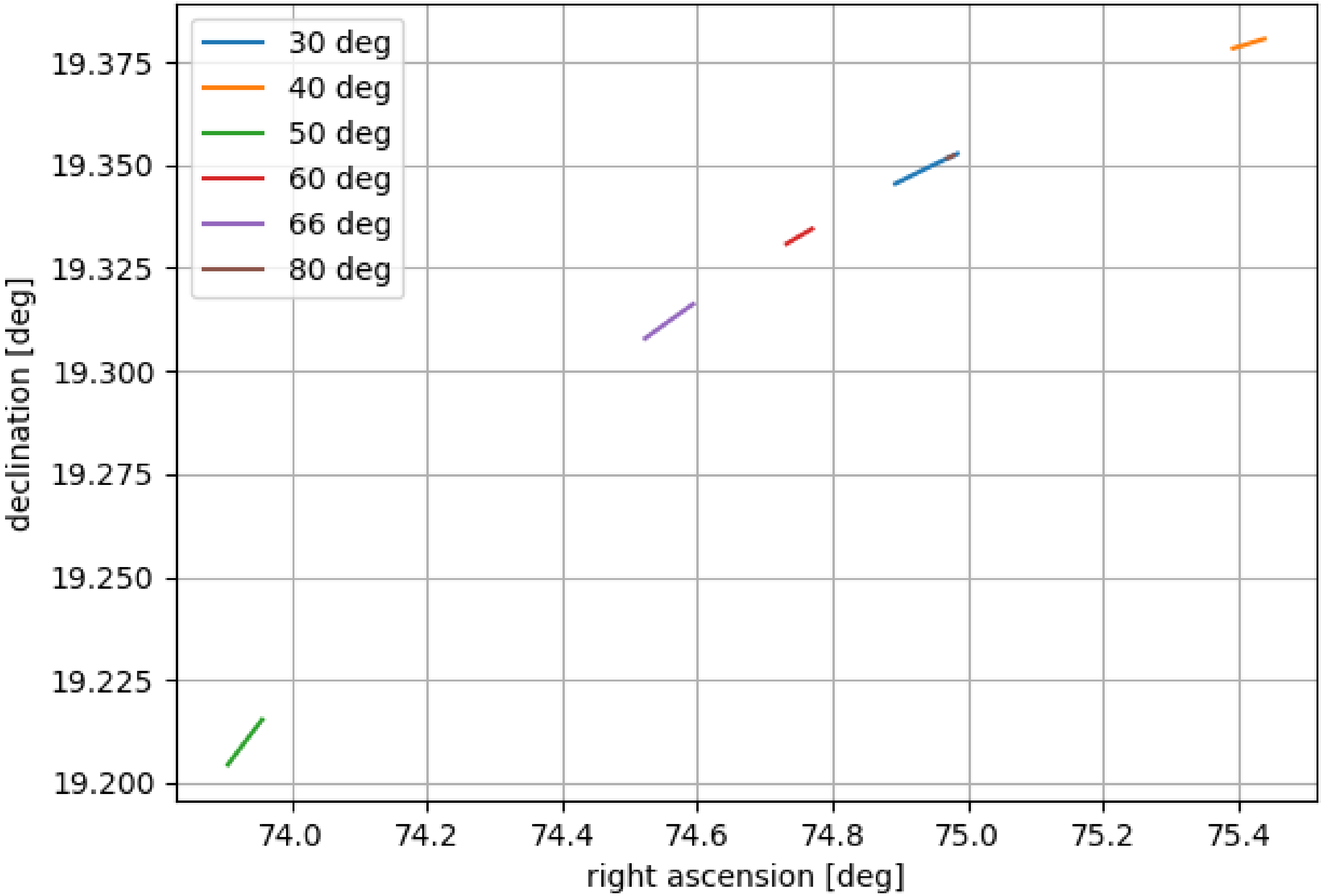


NOW

Telescope : telescope position
Sky : mean values for all pixels
Sky Q1 : position on central pixel

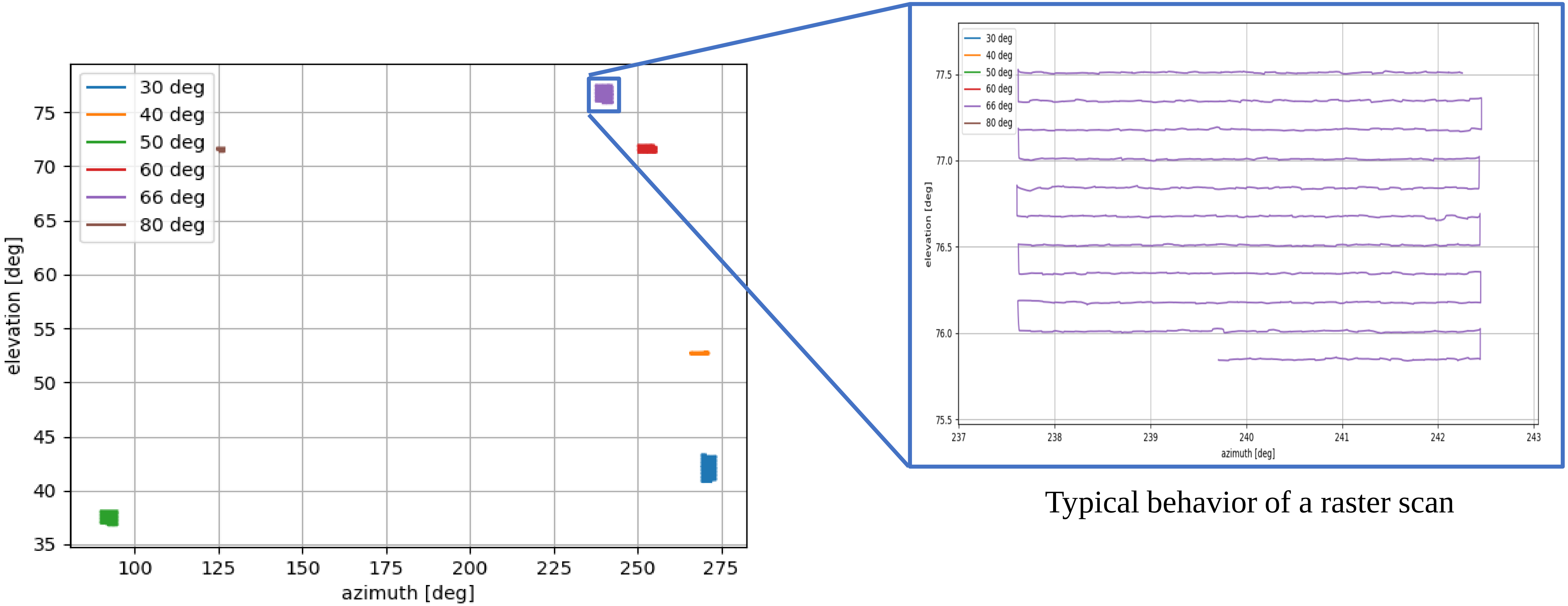
We still need better constraints

Observation of the Moon at different elevations



Different positions on the sky to constraint the parameters

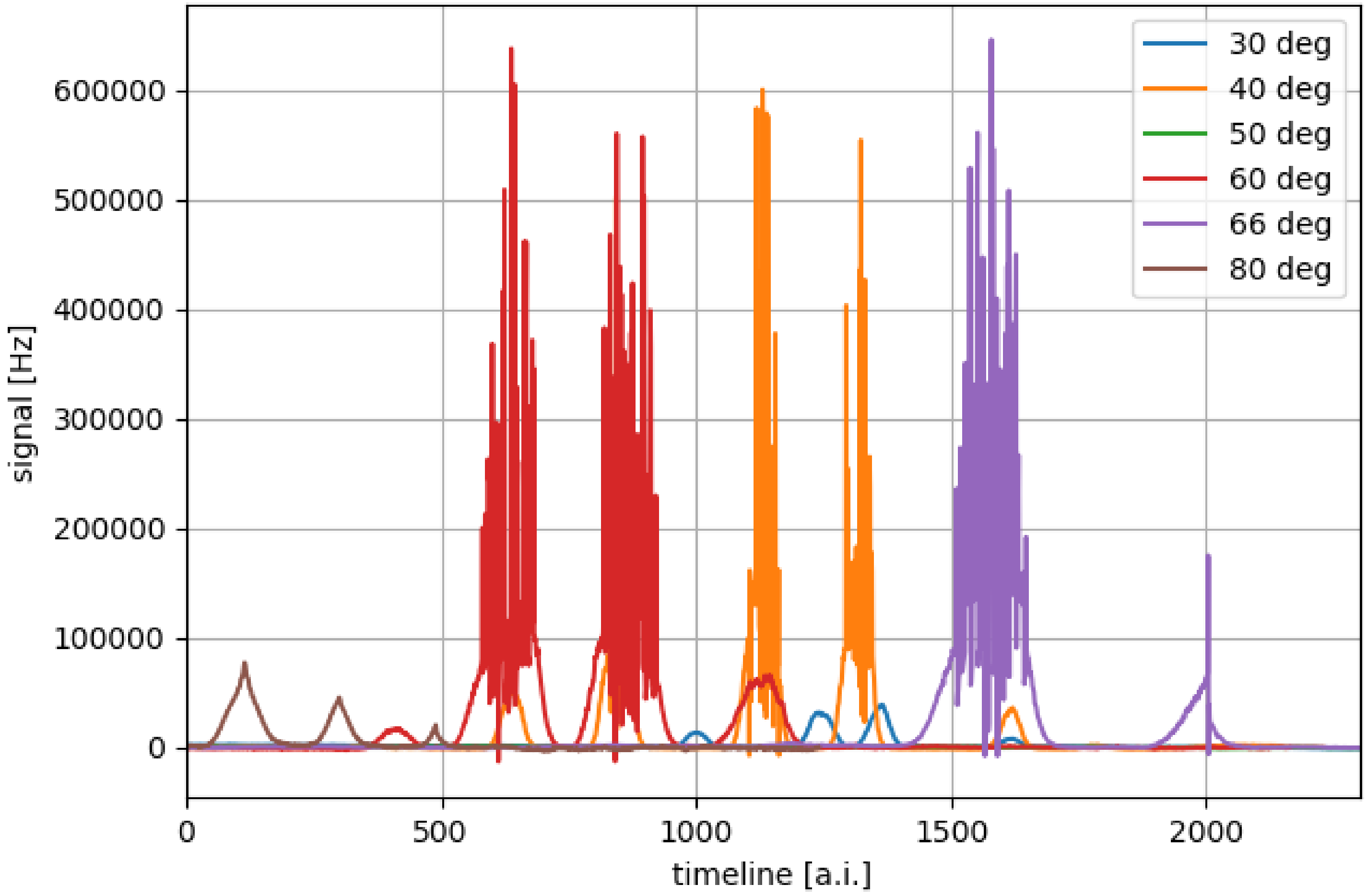
Observations of the Moon at different elevations
Raster Scans



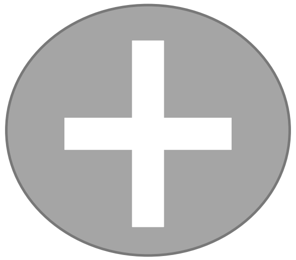
Typical behavior of a raster scan

Observation of the Moon at different elevation

Saturation issue



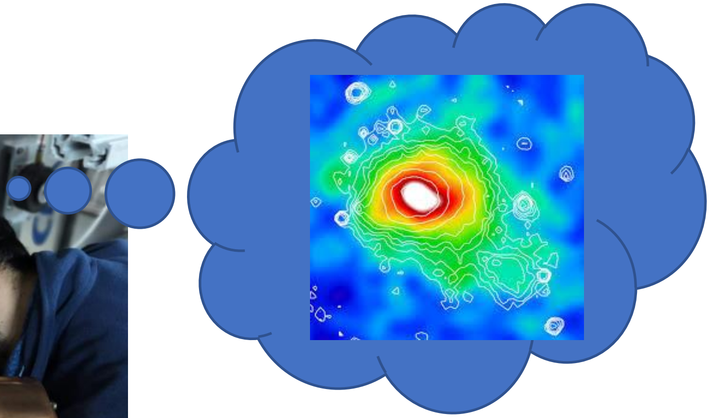
Solutions: diaphragm



We reduce the signal because the Moon is a bright source

Multidisciplinary aspects of the Ph.D.:
- Science
- Instrumentation
- Astronomical observations
- Data analysis

Perspectives for the second half of the Ph.D.:
- Accomplishment of the commissioning phase
- Cluster observation
- Manuscript



EXTRA

EXTRA
Timeline

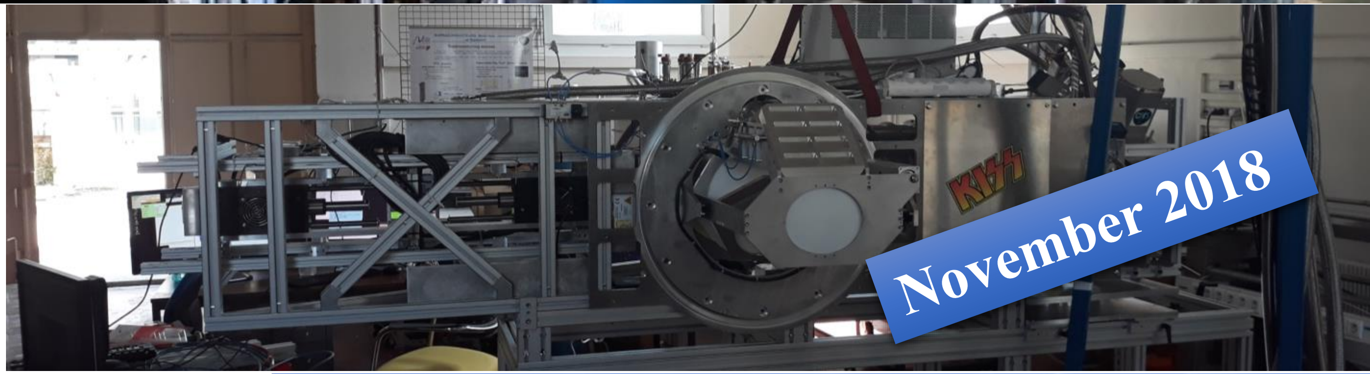
timeline [Ph.D. year]

Duality Ph.D./experiment

I. [past]
R&D, characterization and validation

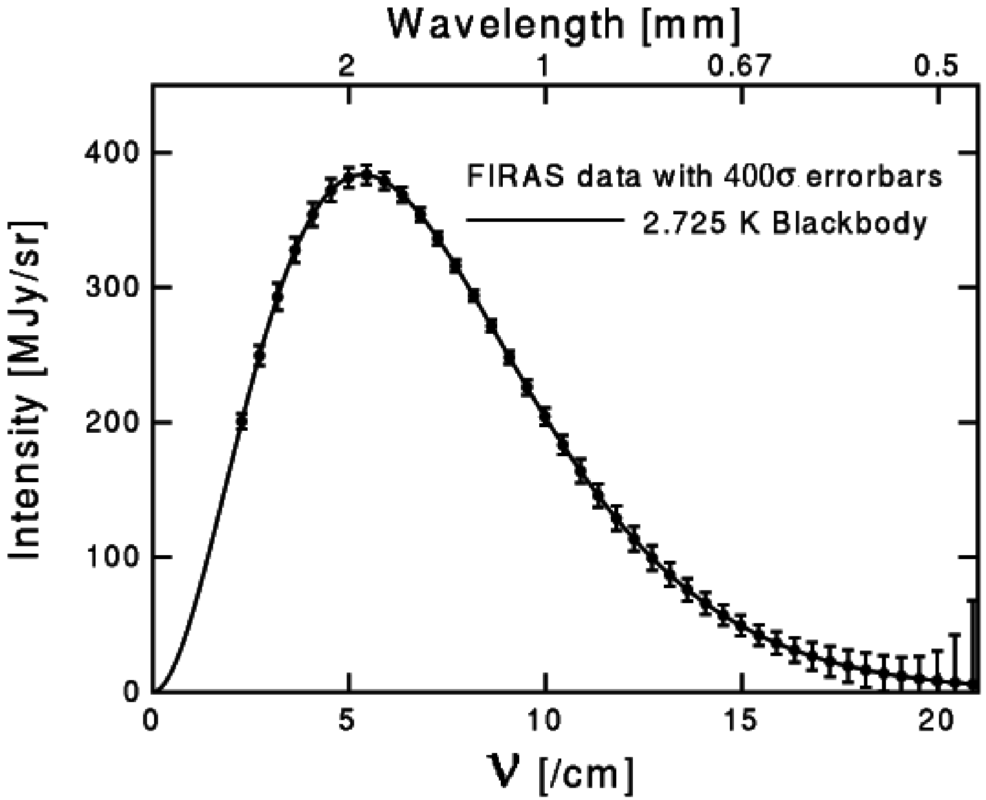
II. [present]
Installation and observations

III. [future]
Data analysis and implementation on Concerto experiment



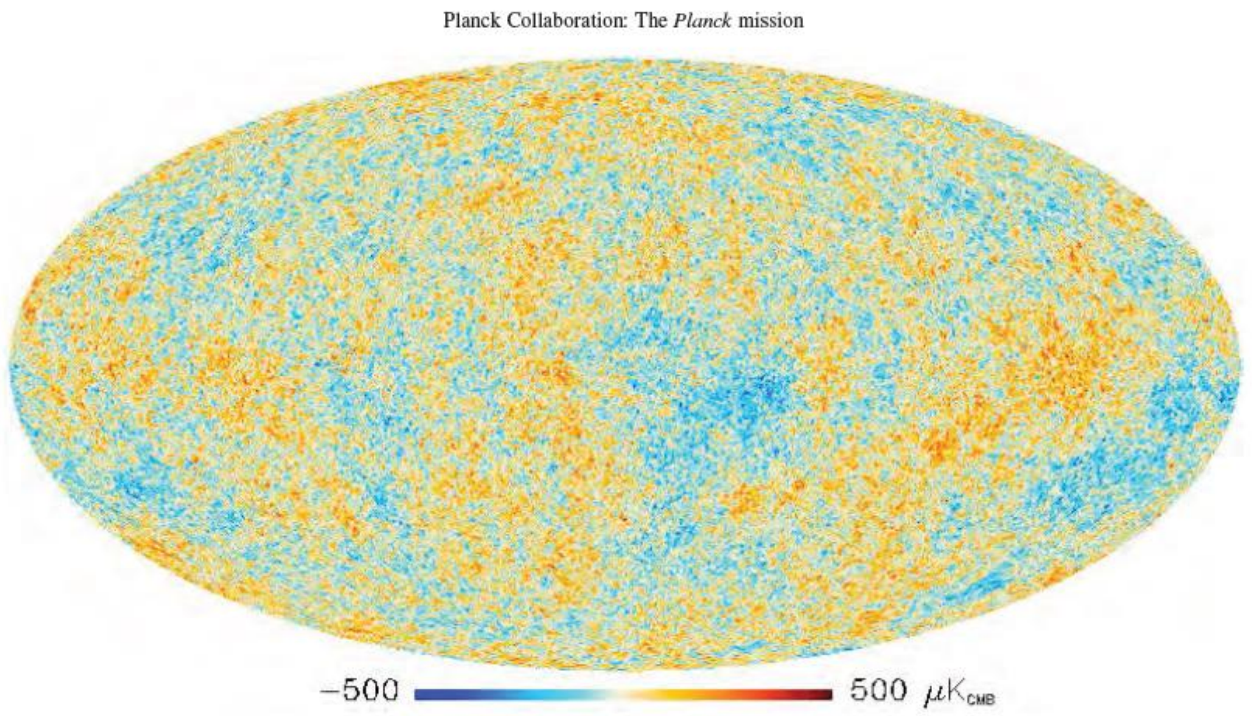
Cosmic Microwave Background

- Formed after the Big-Bang, during the baryogenesis.
- Represents a faithful footprint of the 300’000 years old universe.
- The most perfect Black-Body in the universe.



[COBE-FIRAS science team]

$T_{CMB} = 2.725 \pm 0.002\ K$



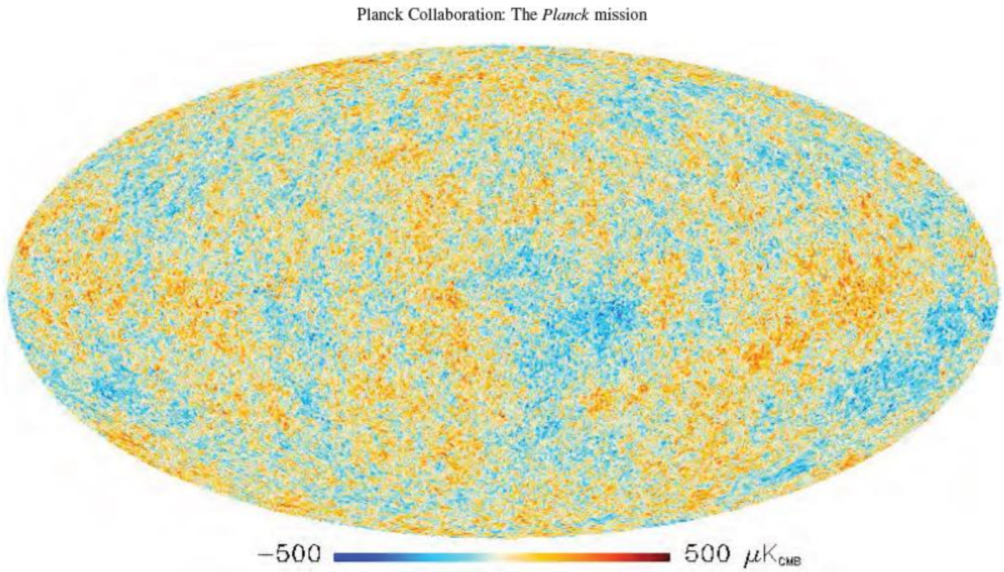
[Planck Collaboration et al.: 2015]

$$\frac{\Delta T_{CMB}}{T_{CMB}} \sim 10^{-5}$$

Extra
CMBR anisotropies

adiabatic perturbation — direct perturbation — redshift

$$\frac{\Delta T_{CMB}}{T_{CMB}} = \frac{1}{3}\frac{\Delta\rho_m}{\rho_m} + \frac{1}{3}\frac{\Delta\phi}{c^2} + \frac{v}{c} \sim 10^{-5}$$



[Planck Collaboration et al.: 2015]

Thermal Effect

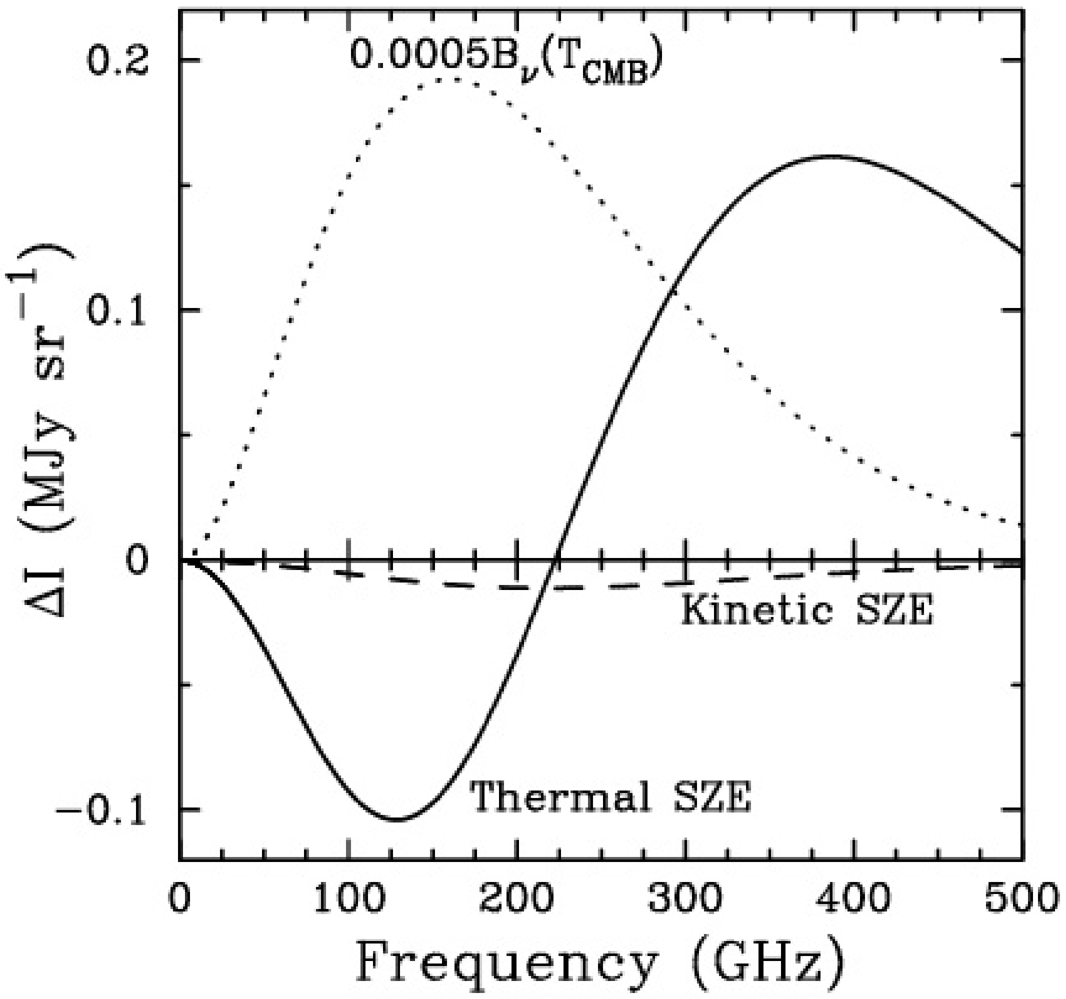
$$\frac{\Delta T_{SZE}}{T_{CMB}} \approx \frac{\Delta \upsilon}{\upsilon} \cdot \tau \approx 10^{-4}$$

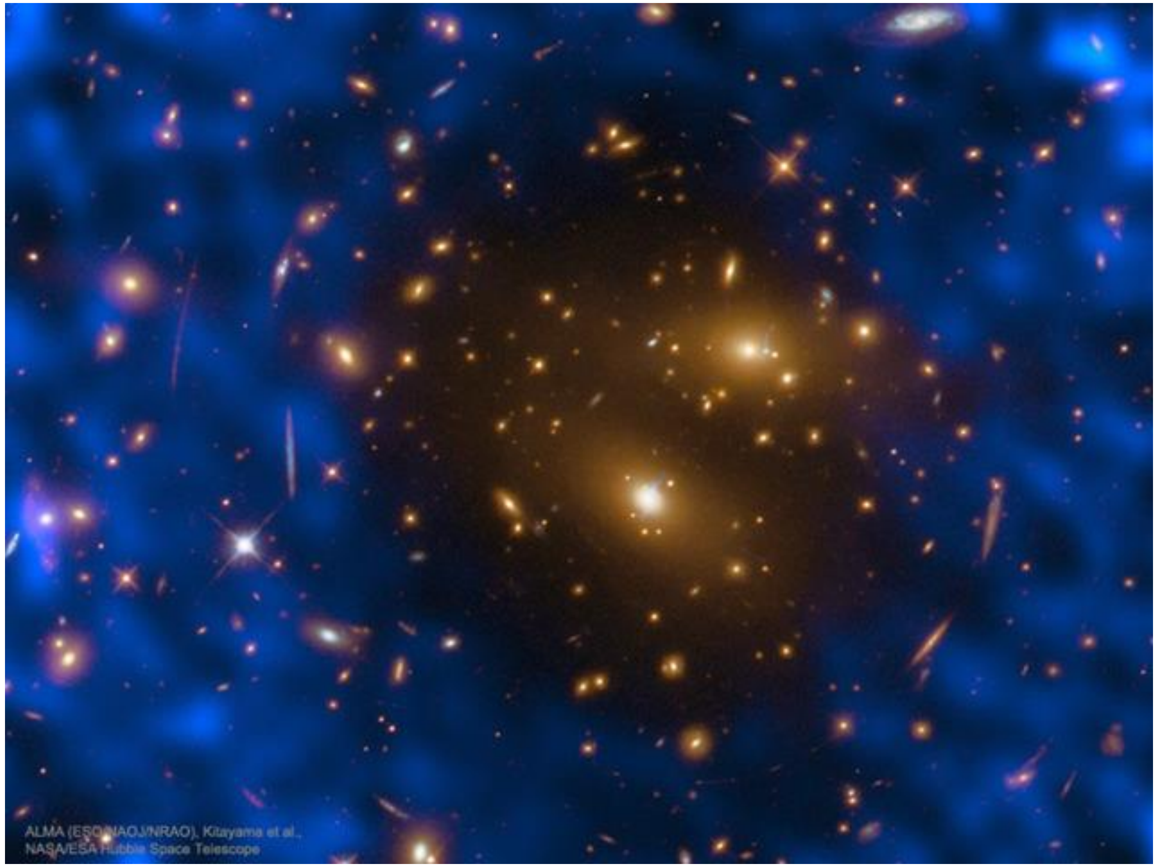
$$\tau = \sigma_T \cdot n_e \cdot l \approx 10^{-2}$$

$$l \approx 10^{25} cm$$
$$\sigma_T \approx 10^{-25}\ cm^2$$
$$n_e \approx 10^{-3} cm^{-3}$$

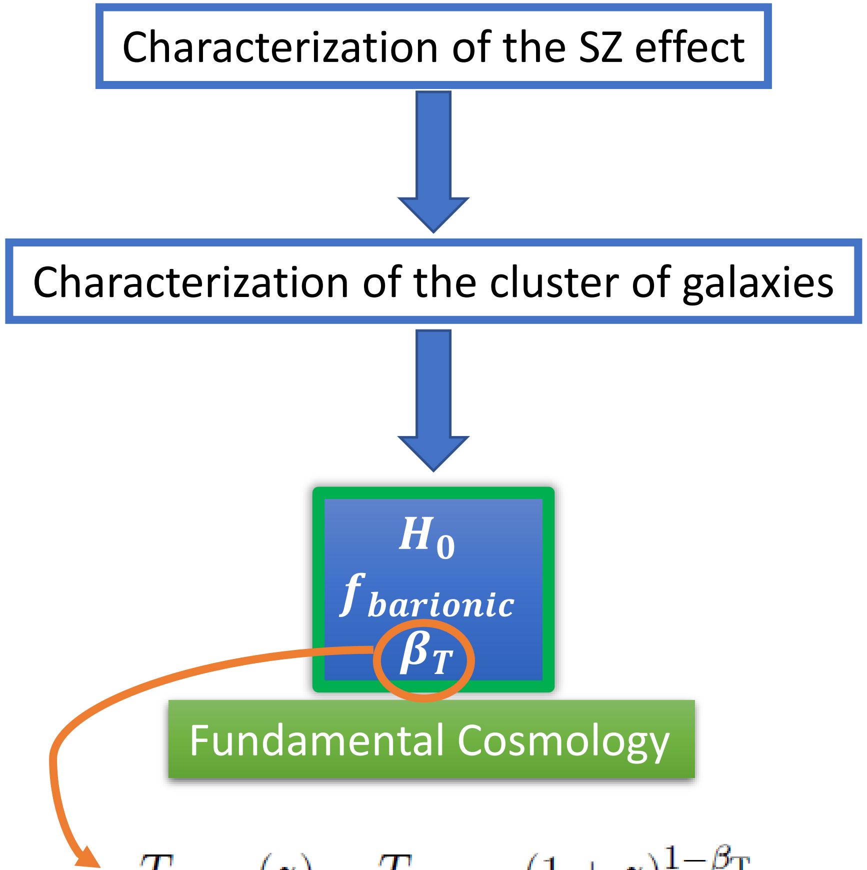
$$\frac{\Delta \upsilon}{\upsilon} = \frac{k_B T_e}{m_e c^2} \cong \frac{0.005\ MeV}{0.511\ MeV} \approx 10^{-2}$$

component	ΔT [μK]
primary anisotropy	10
E modes	1
B modes	0.1
tSZE	100
kSZE	1
rSZE	1-10 (up to 100)





RXJ1347.5 [HST NASA]



$$T_{\mathrm{CMB}}(z) = T_{\mathrm{CMB},0}(1+z)^{1-\beta_{\mathrm{T}}}$$

$$\beta_{\mathrm{T,Planck}} = 0.009 \pm 0.017$$

EXTRA
Kinetic Inductance Detectors

mapping speed

$$v_{map} = \frac{N_{det} \cdot \Omega_{beam}}{NEP^2}$$

APPROVED BY:

why KIDs?

The main features that make KID competitive with the other microwave detectors for astronomy (e.g. TES and bolometers) can be summarized in three points:

- **fabrication** : it consists in just two steps of deposition, a step forward the easiness and the pragmatic approach to the large matrices production;
- **multiplexability** : KIDs are intrinsically multiplexable, with a factor 300-400, they do not require complex readout electronics;
- **recovery speed** : it is defined by the recombination time of the Cooper-pairs,100 μs, gaining a factor 10 with respect to the competitors.

Quality factors

$$Q = 2\pi N = \omega_0 \frac{E_{stored}}{W_{lost}} = \frac{Q_i Q_c}{Q_i + Q_c}$$

Q_c compromise: resonance depth vs high Q
optimised for background

Q_i depends on the number of quasi particles

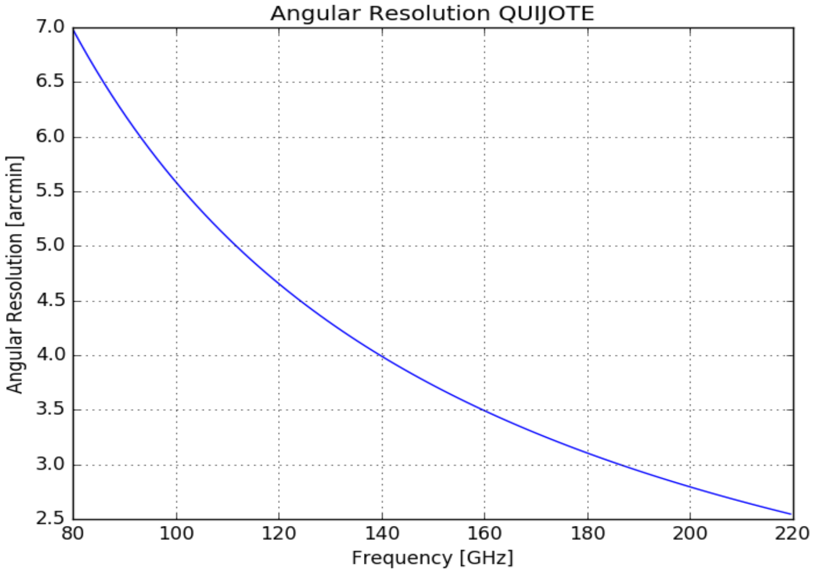
Responsivity

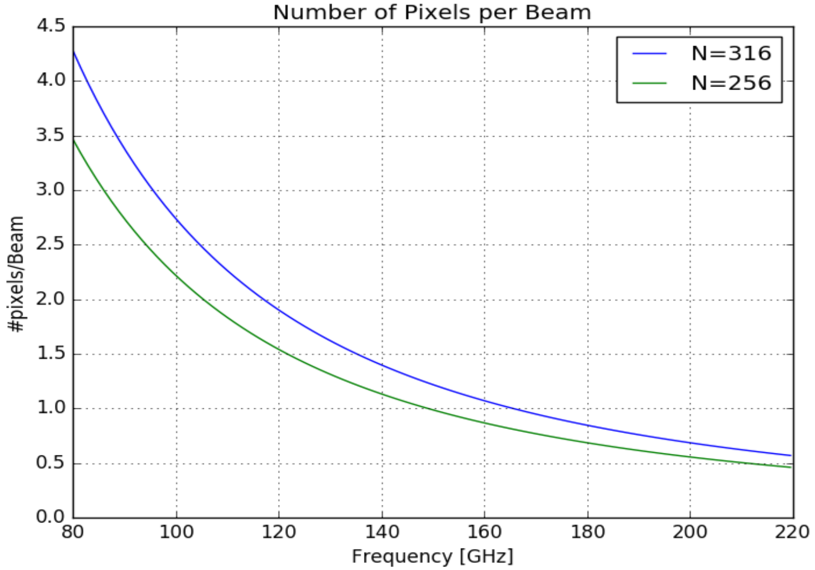
$$\mathcal{R} = \frac{d\varphi}{dN_{qp}} \propto \frac{\alpha Q}{V}$$

$$\alpha \equiv {}^{L_{kin}}/_{L_{tot}}$$

Minimising V
Maximising α and Q

Quijote telescope in Tenerife

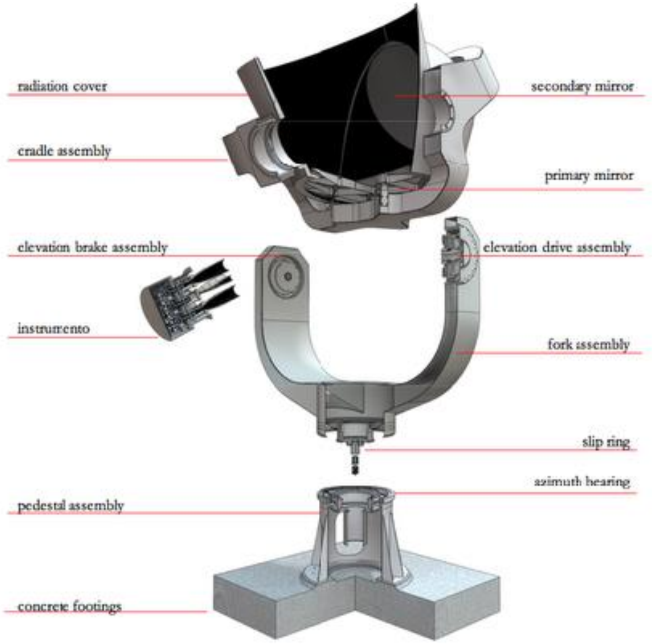




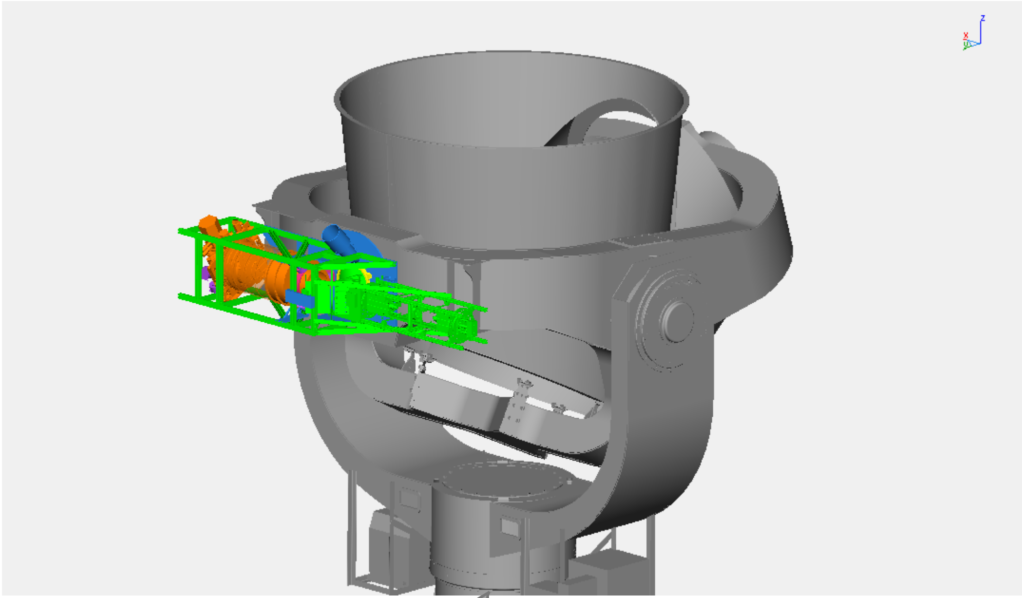
Quijote telescope diameter	^3He-^4He diluition cryostat temperature	FoV [diameter]
2.5 m	150 +- 10 mK 170 mK stable	1°

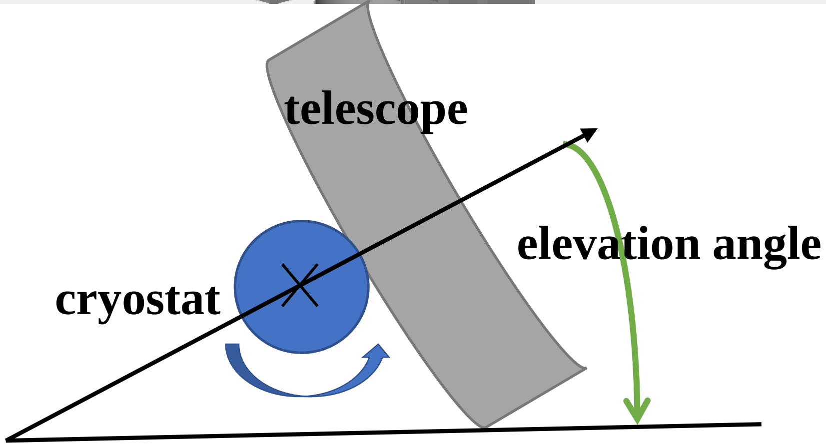
Crossed Dragone

- Primary Mirror = 2.5 m
- Secondary Mirror = 1.85 m
- Surface accuracy < 150 µm
- rms roughness pattern < 1.6 µm
- Telescope aperture = 2-3°



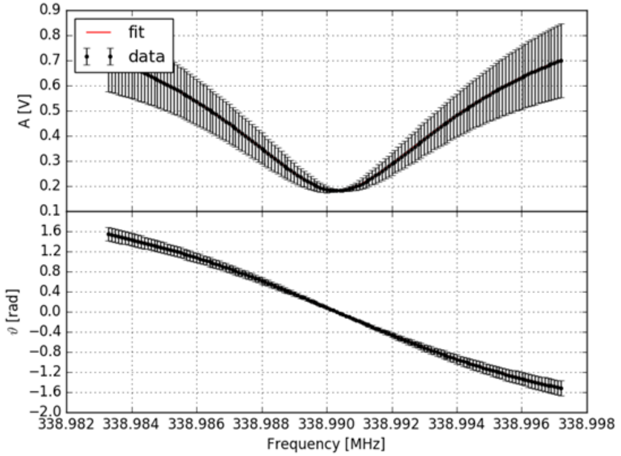
Schematic of KISS coupled to the Quijote telescope.

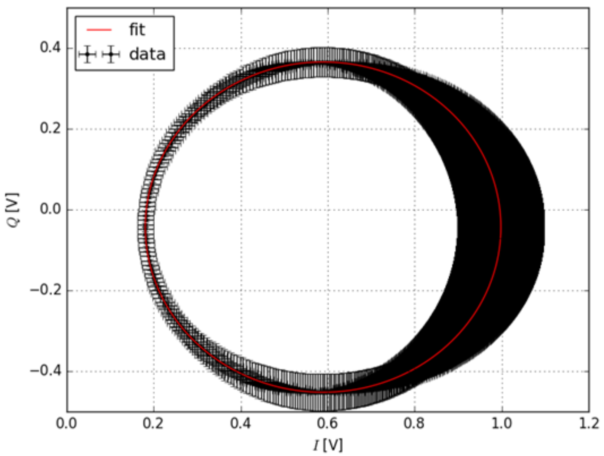


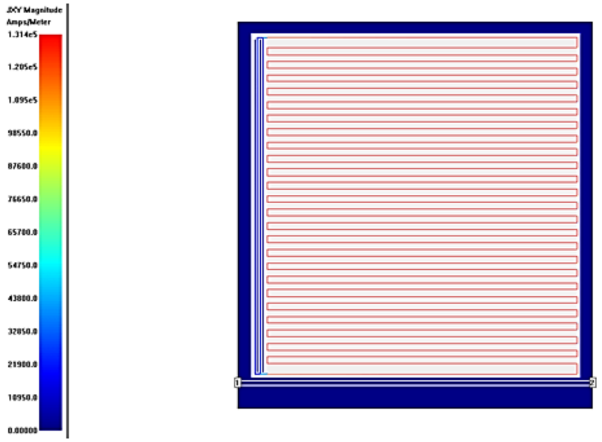


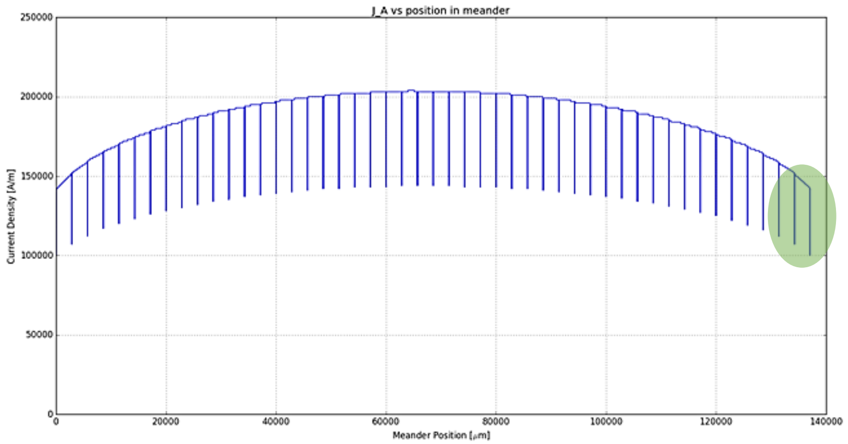
Matrix Name	Material	Optical condition	Backshort
KISS_PB_01	10/25 nm	Back-Illuminated	PIZZA

Electric symulations



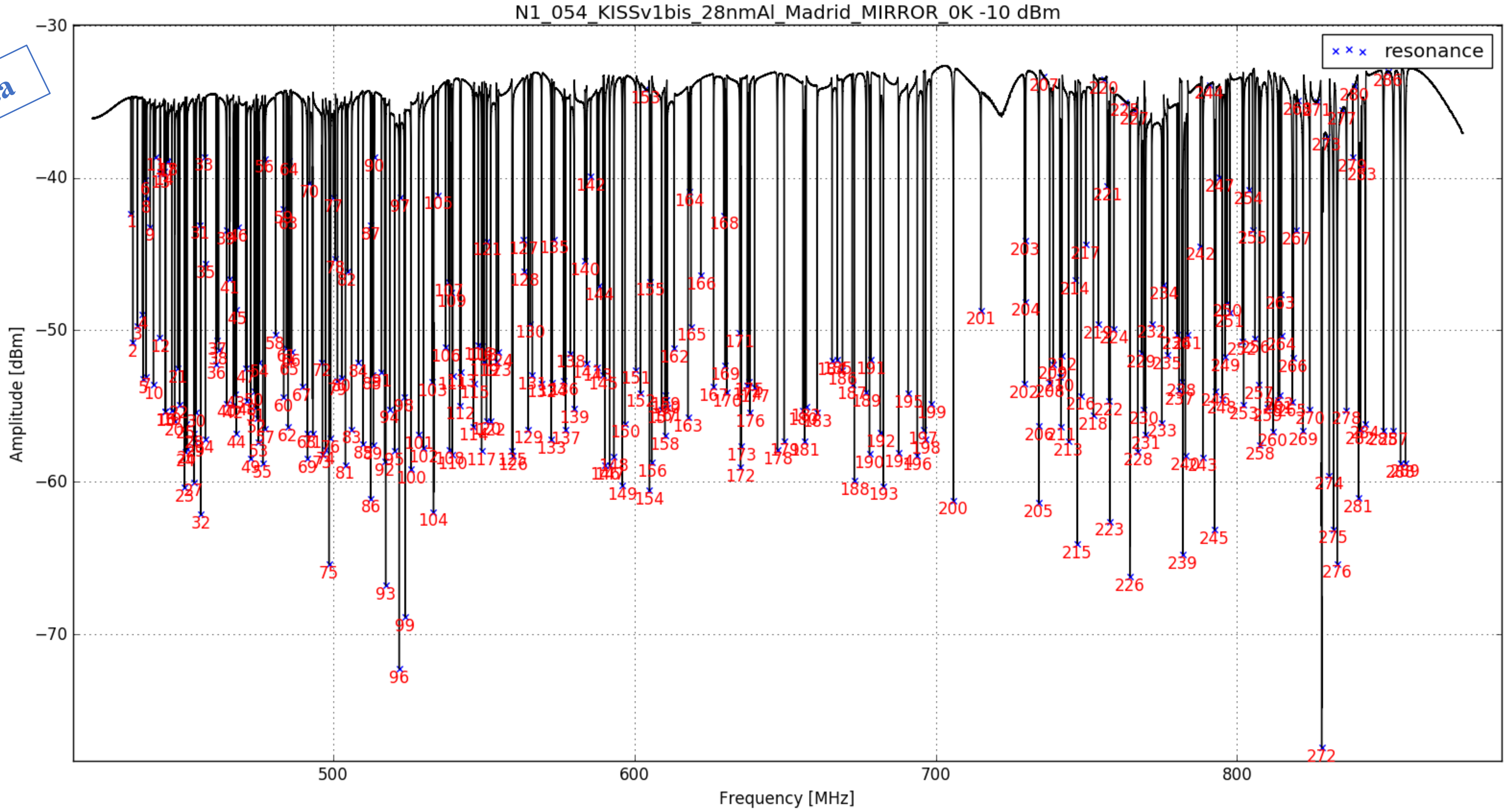






≈ 28%

Real data

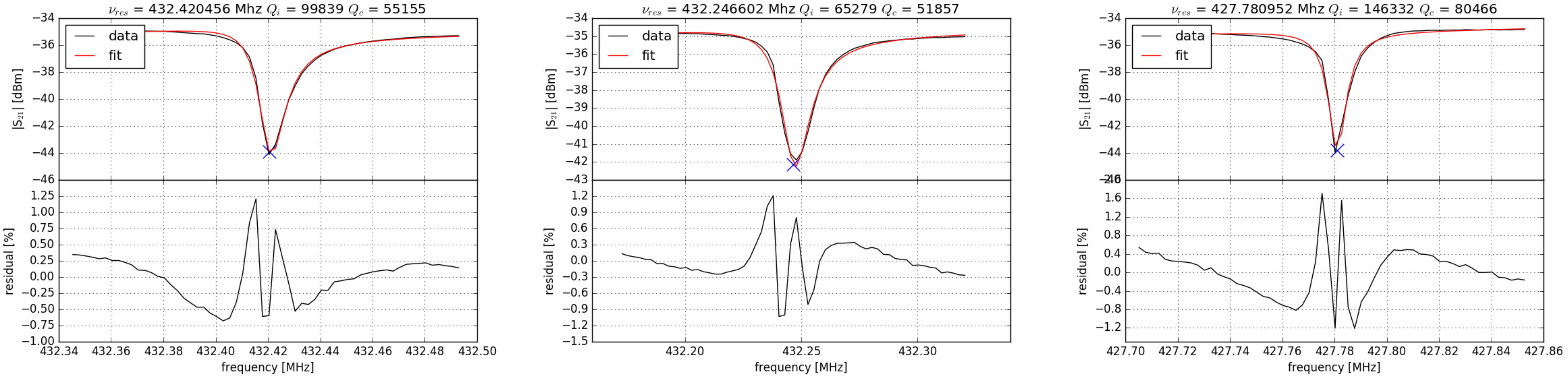


N1_054_KISSv1bis_28nmAl_Madrid_MIRROR_0K -10 dBm
resonance
Amplitude [dBm]
−30
−40
−50
−60
−70
Frequency [MHz]
500
600
700
800

$$S_{21}(\nu;\nu_0,Q_{tot},A,B,C,D) = A + B\cdot(\nu-\nu_0) + \frac{C + D\cdot(\nu-\nu_0)}{1+4Q_{tot}^2\cdot {(\nu-\nu_0)^2}/{\nu_0^2}}$$

Real data

$$Q_i = {Q_{tot}}/{\left|S_{21}^{min}\right|} \qquad Q_c = \left({1}/{Q_{tot}} - {1}/{Q_i}\right)^{-1}$$

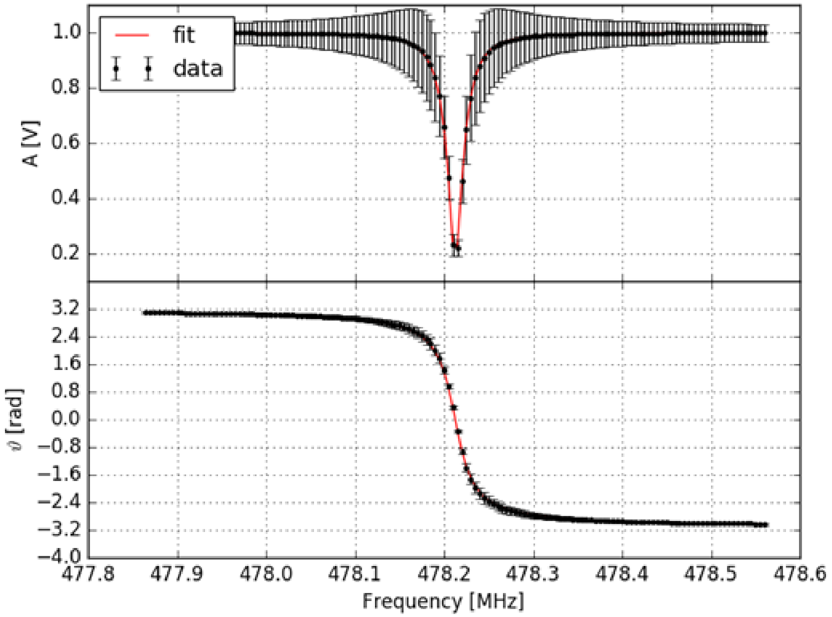


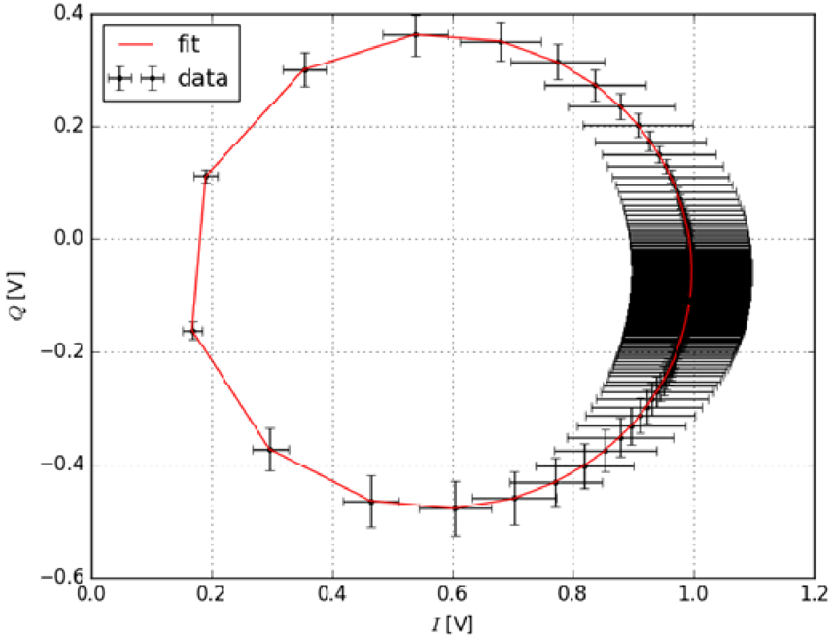
$$S_{21} = ae^{-2\pi j\nu\tau}\left[1 - \frac{\frac{Q_{tot}}{Q_c}e^{j\phi_0}}{1+2jQ_{tot}\left(\frac{\nu-\nu_0}{\nu_0}\right)}\right]$$

$Q_{tot}\ Q_c\ \nu_0$

$$\frac{1}{Q_{tot}} = \frac{1}{Q_c} + \frac{1}{Q_i}$$

Electric symulations





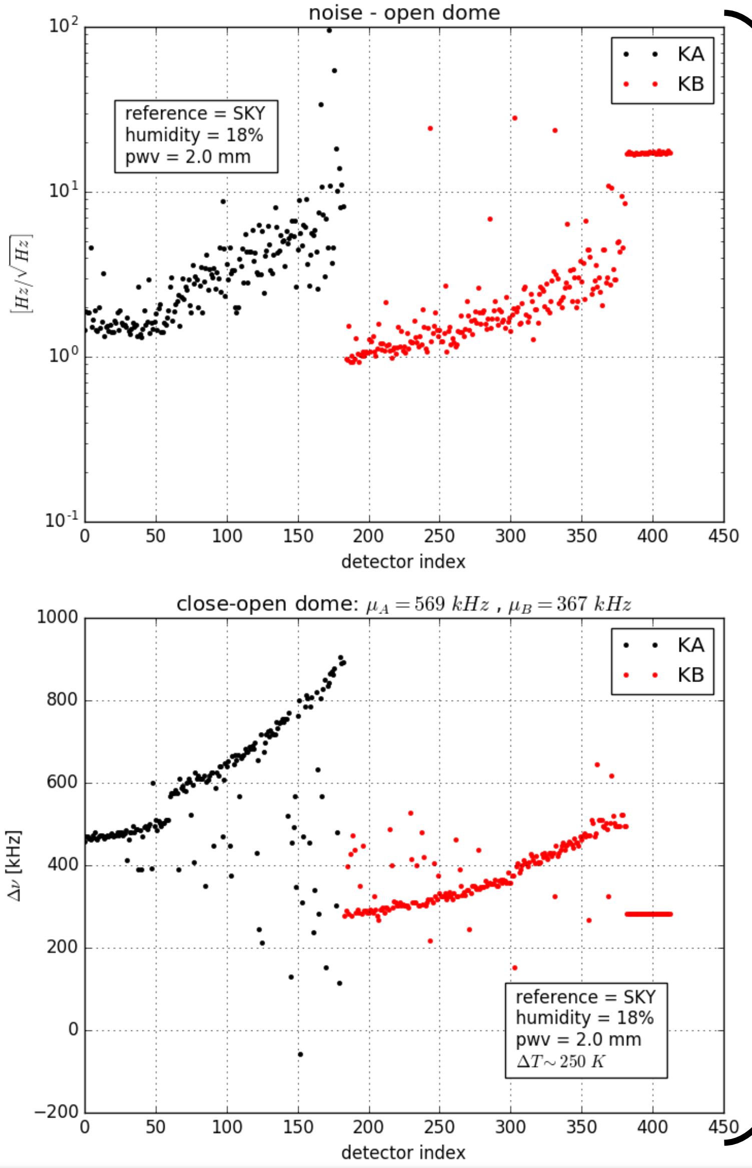
$$\begin{cases} I = A\cos(\varphi) \\ Q = A\sin(\varphi) \end{cases}$$

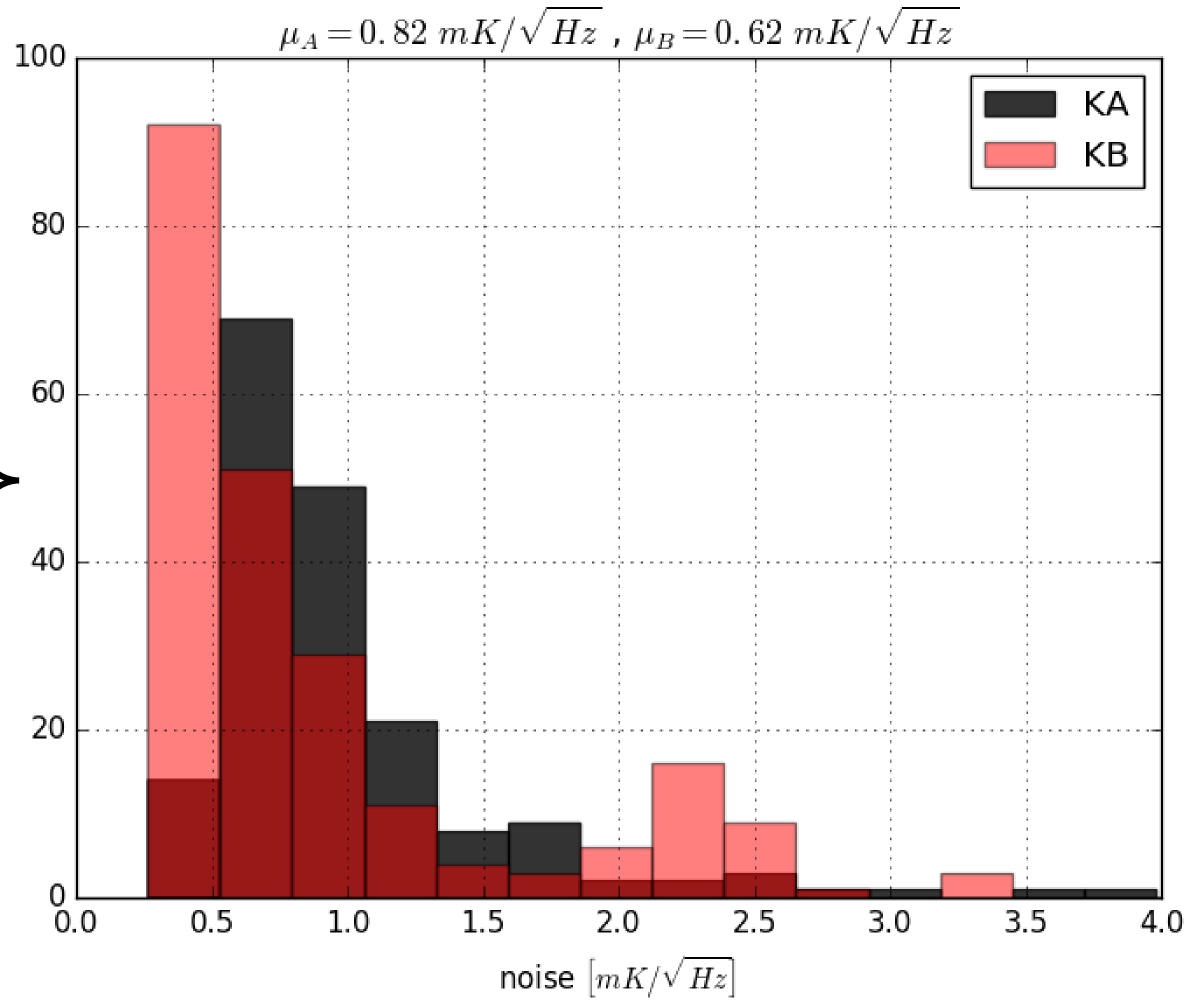
$$S_{21} = I + jQ = Ae^{j\varphi}$$

$$\begin{cases} A = \sqrt{I^2 + Q^2} \\ \varphi = arctan2\left(\frac{Q}{I}\right) \end{cases}$$

EXTRA

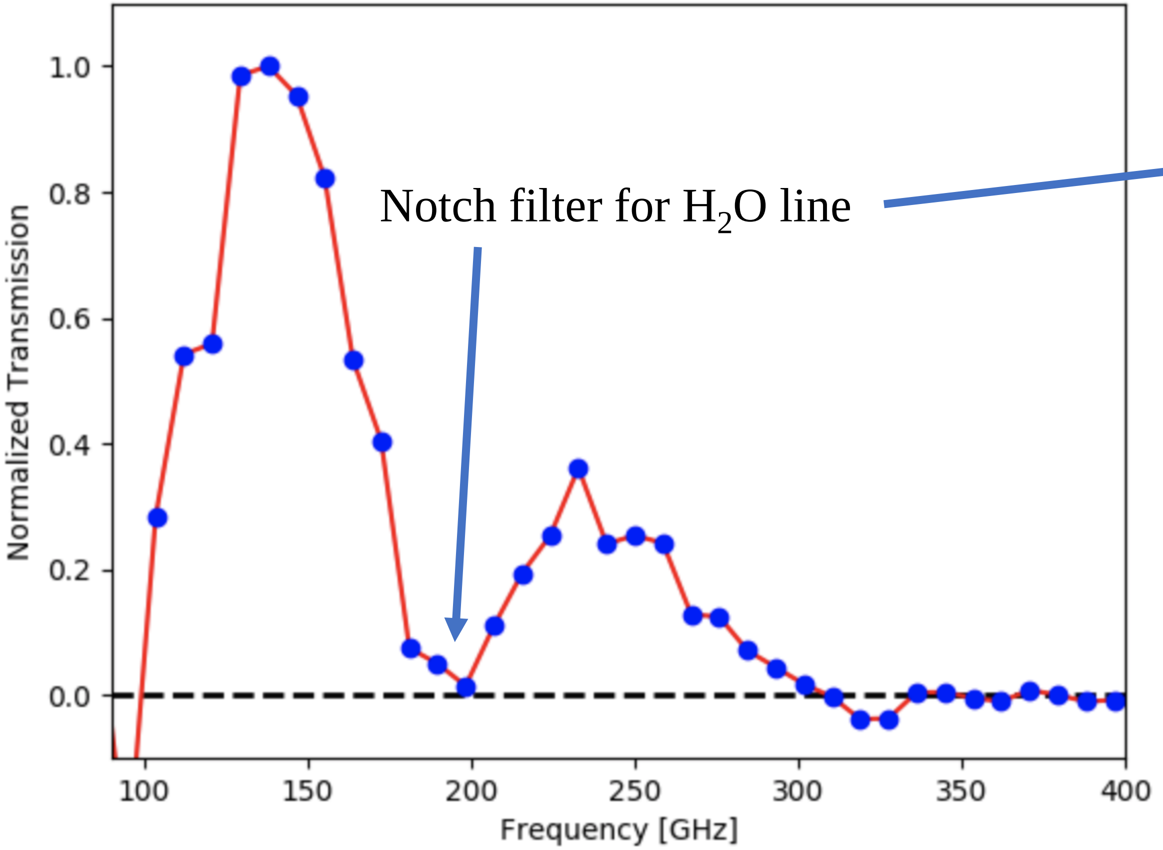
Detectors performances



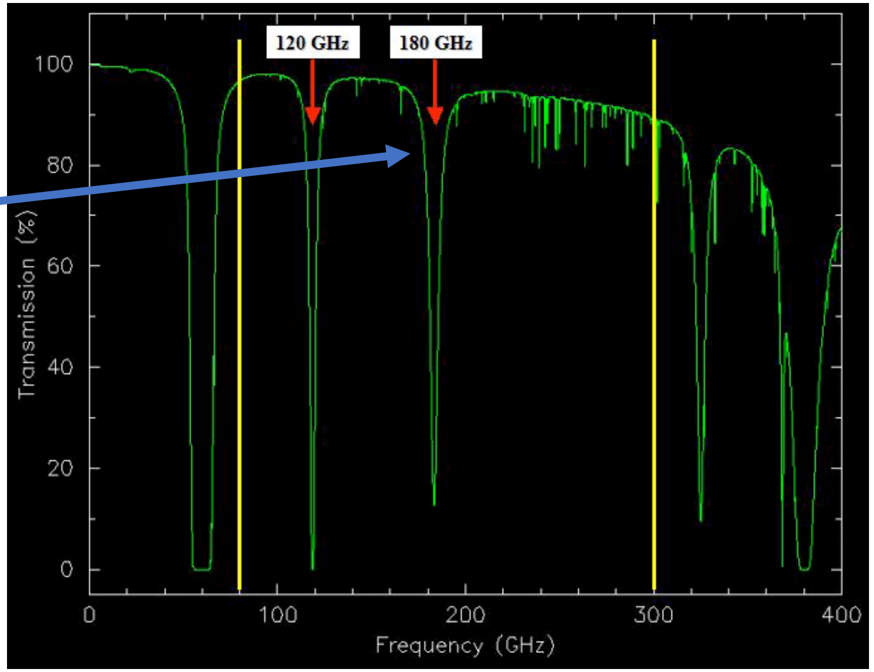


$$S = \Delta\nu / \Re$$

Absorption spectrum of the matrix



Notch filter for H_2O line

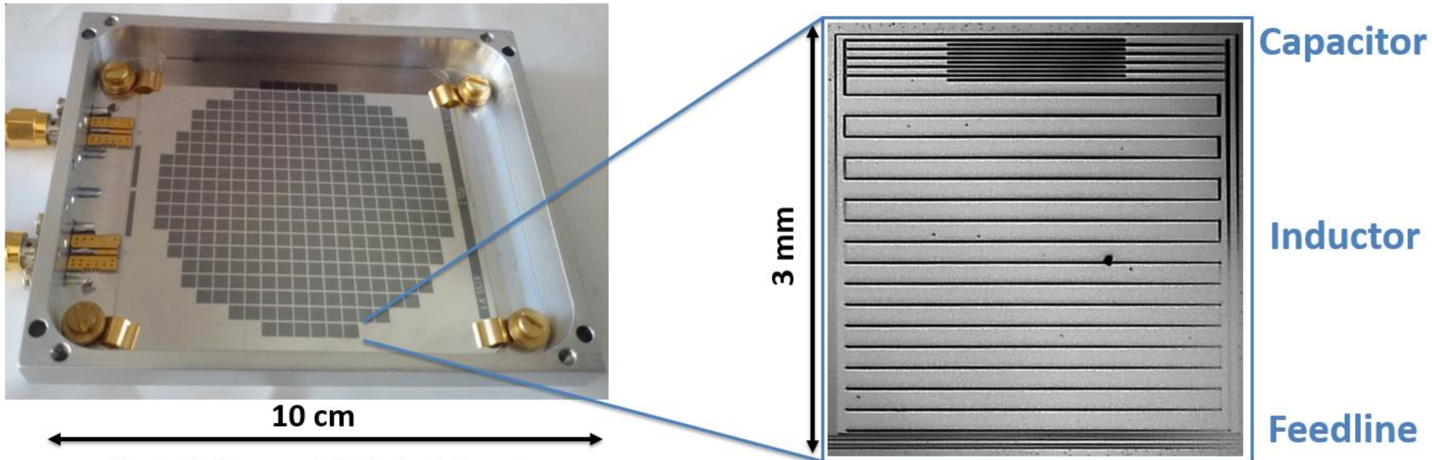


Predicted Atmospheric Transmission
O_2 , H_2O
[Monfardini, A. et al: 2016]

EXTRA
Instrumentation

KIDs reach the intrinsic limitation of sensitivity

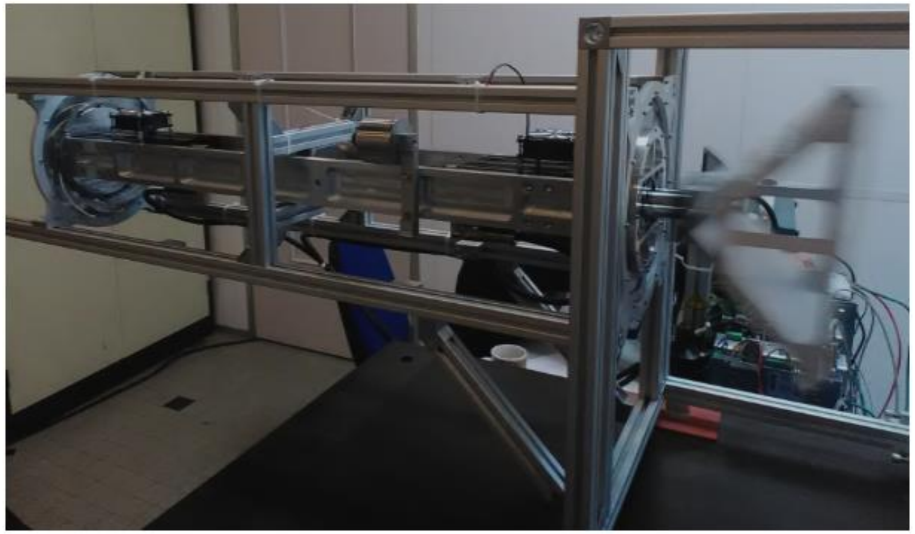
Superconducting LC circuit with high Quality factor



Single KISS array of 316 pixels based on Ti-Al bilayers ($T_C \approx 0.95\ K$) .

One of the 632 pixels within the KISS camera

Closed KISS cryostat: Pulse-Tube/^{3}He-^{4}He dilution.



Martin Puplett Interferometer: fast integration for wide band
5 Hz oscillating mirror on 10 cm total OPD

Quijote telescope in Tenerife

Integration of KISS

GOAL
Low resolution spectroscopy observations of known low redshift galaxies at mm wavelenghts to map cluster physical properties from spectral distortions.

STRATEGY
Compensate relative expected low sensitivity with respect to Planck or photometric ground-based instrument by integrating longer (tens of hours per cluster).

Use spectroscopy to fully separate different components and extract physical information from spectral distortions: pressure, temperature, density, mass, LOS velocity

Multiplex (Felgett) advantage

$$M \doteq (\nu_{max} - \nu_{min})/\delta\nu$$

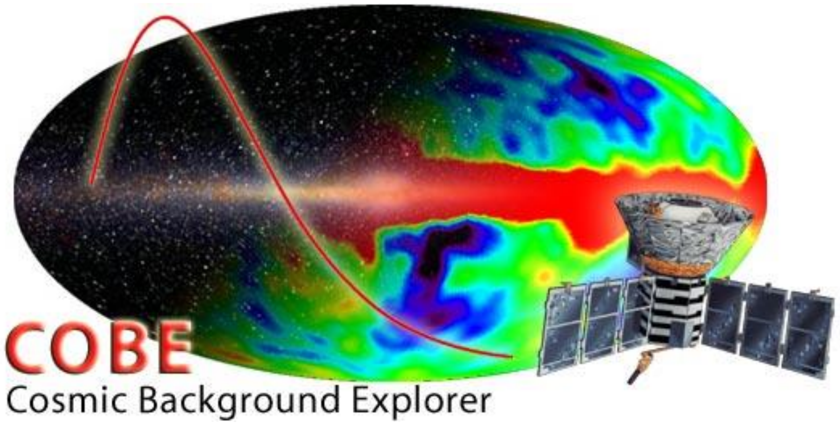
$$\begin{cases} S/N_{disp} = S(\nu)\delta\nu \sqrt{T/M} / NEP \\ S/N_{FTS} = S(\nu)\delta\nu \sqrt{T} / NEP \end{cases}$$

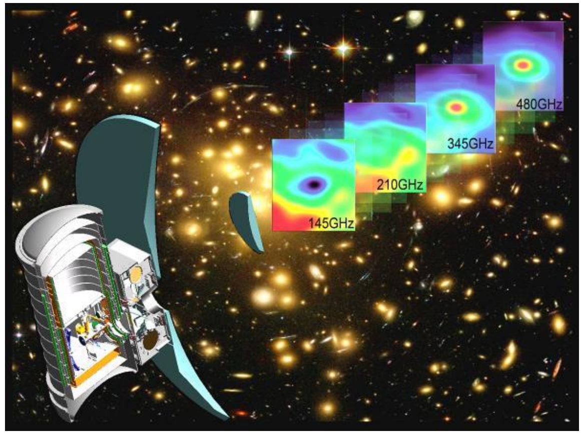
$$(S/N_{FTS}) / (S/N_{disp}) = \sqrt{M}$$

Throughput (Jaquinot) advantage

$$throughput \doteq A\Omega$$

The throughput represents the conservation of energy.
In the case of dispersion spectrometers the necessity of slits in entrance and at the end, limits the diameter of the collimated beam: i.e., the area of the focal plane (A) is limited and it results in a smaller signal.

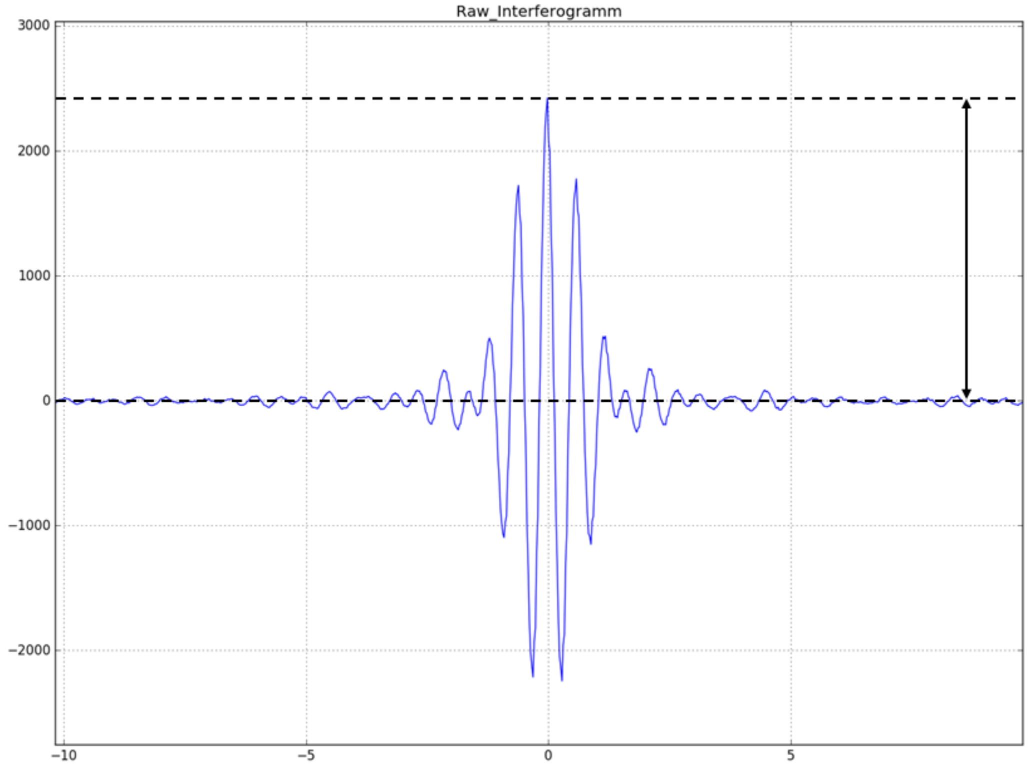




OLIMPO

Extra
MPI output

I output



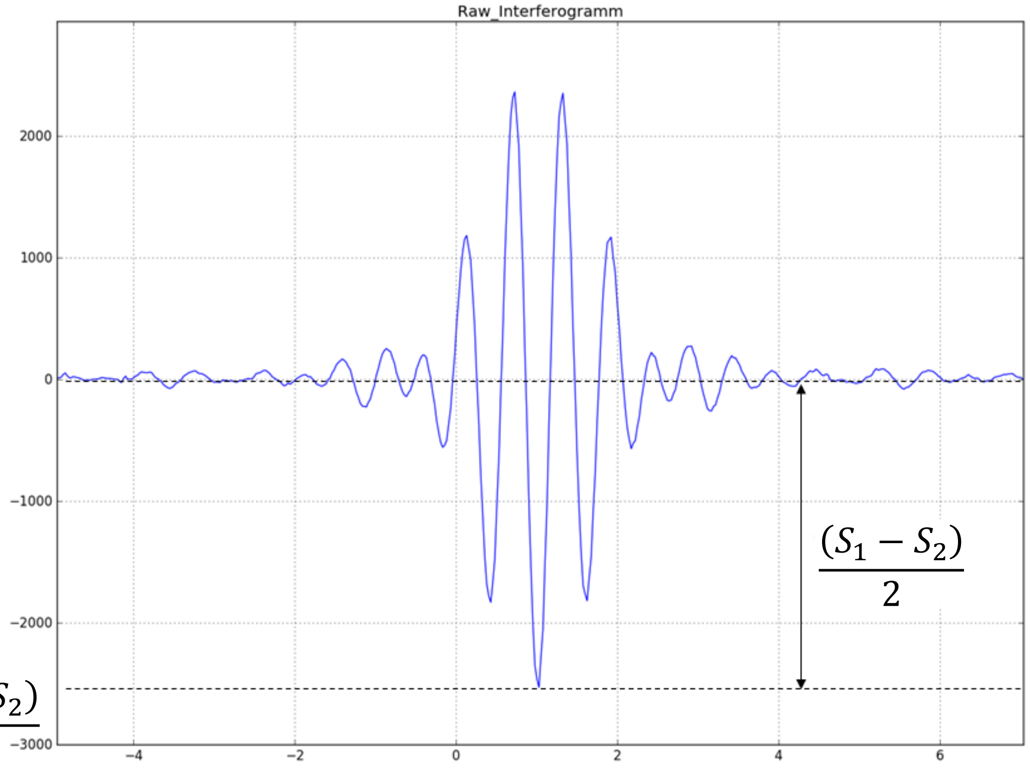
$$\frac{(S_1 + S_2) + (S_1 - S_2)}{2}$$

$$\frac{(S_1 - S_2)}{2}$$

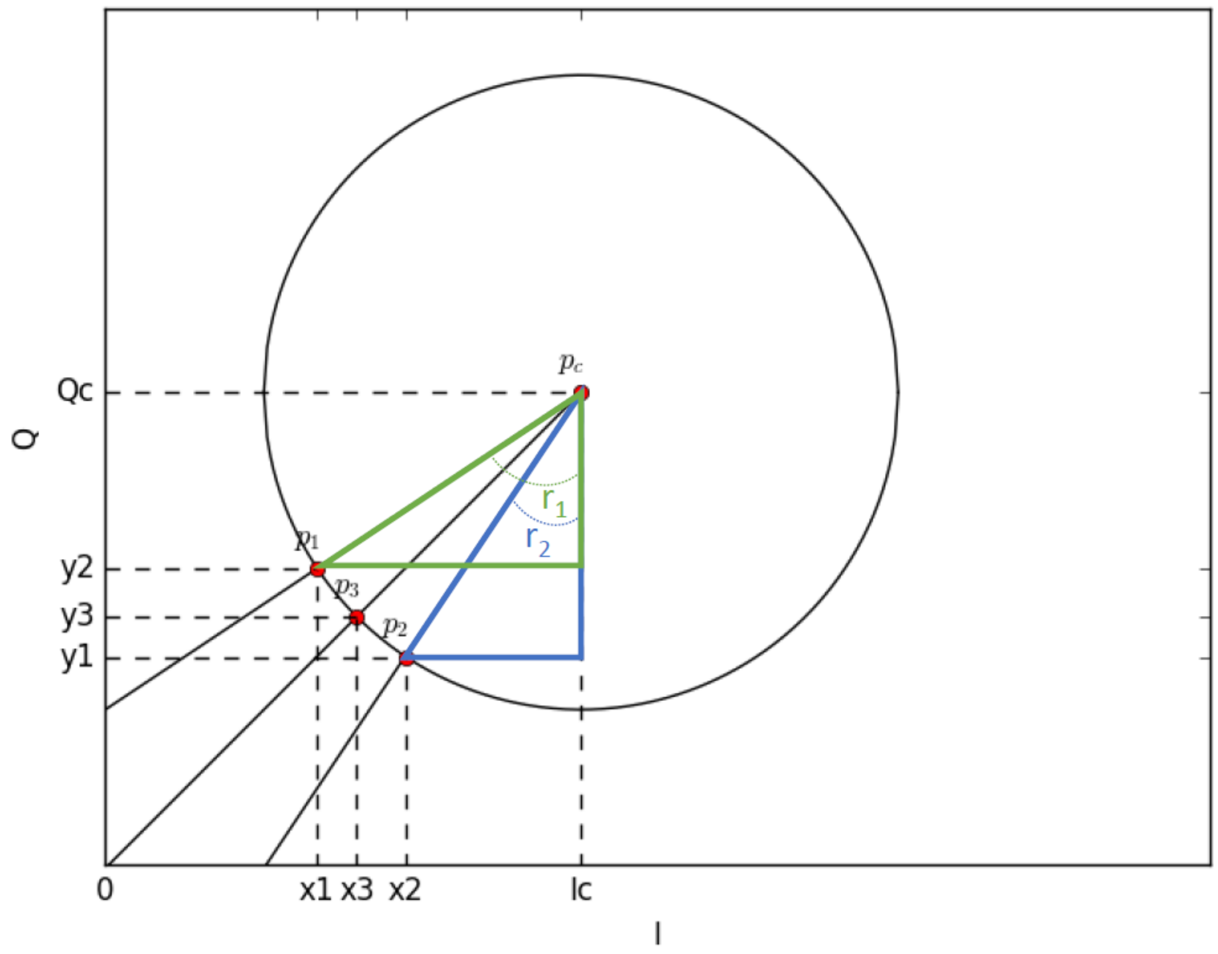
$$\frac{(S_1 + S_2)}{2}$$

$$\frac{(S_1 + S_2) - (S_1 - S_2)}{2}$$

II output



$$\frac{(S_1 - S_2)}{2}$$



Ic,Qc : from circular fit
x1,y1 : from modulation
x2,y2 : from modulation

$$r_1 = \arctan\left(\frac{I_c - x_1}{Q_c - y_1}\right)$$

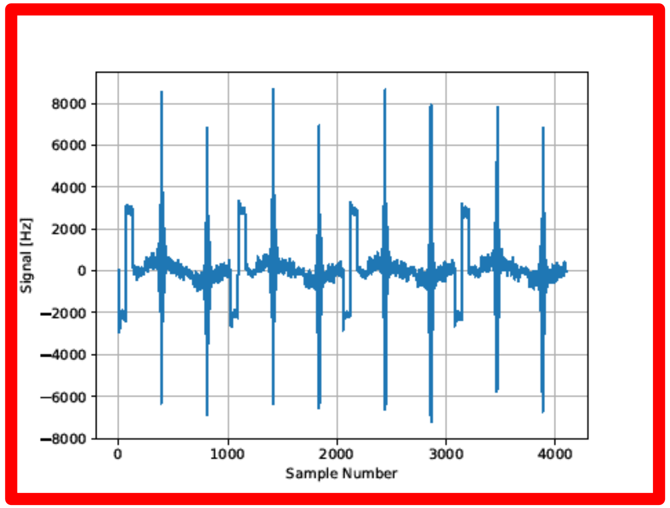
$$r_2 = \arctan\left(\frac{I_c - x_2}{Q_c - y_2}\right)$$

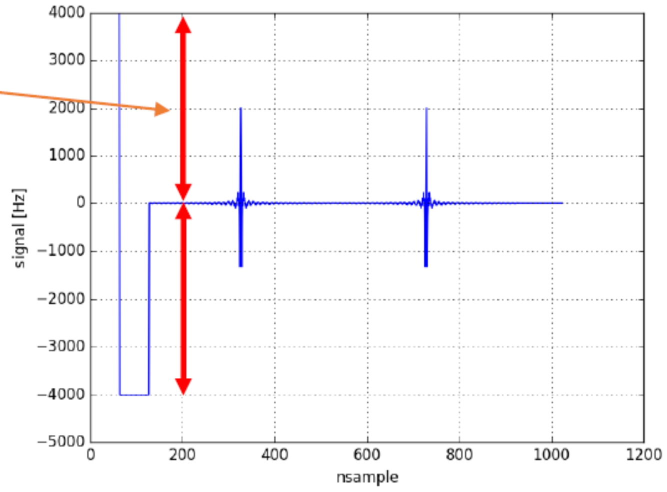
$$\Delta\varphi = r_2 - r_1$$

$C = \Delta\varphi / \Delta\nu$

C: calibration factor [rad/Hz]

Real data

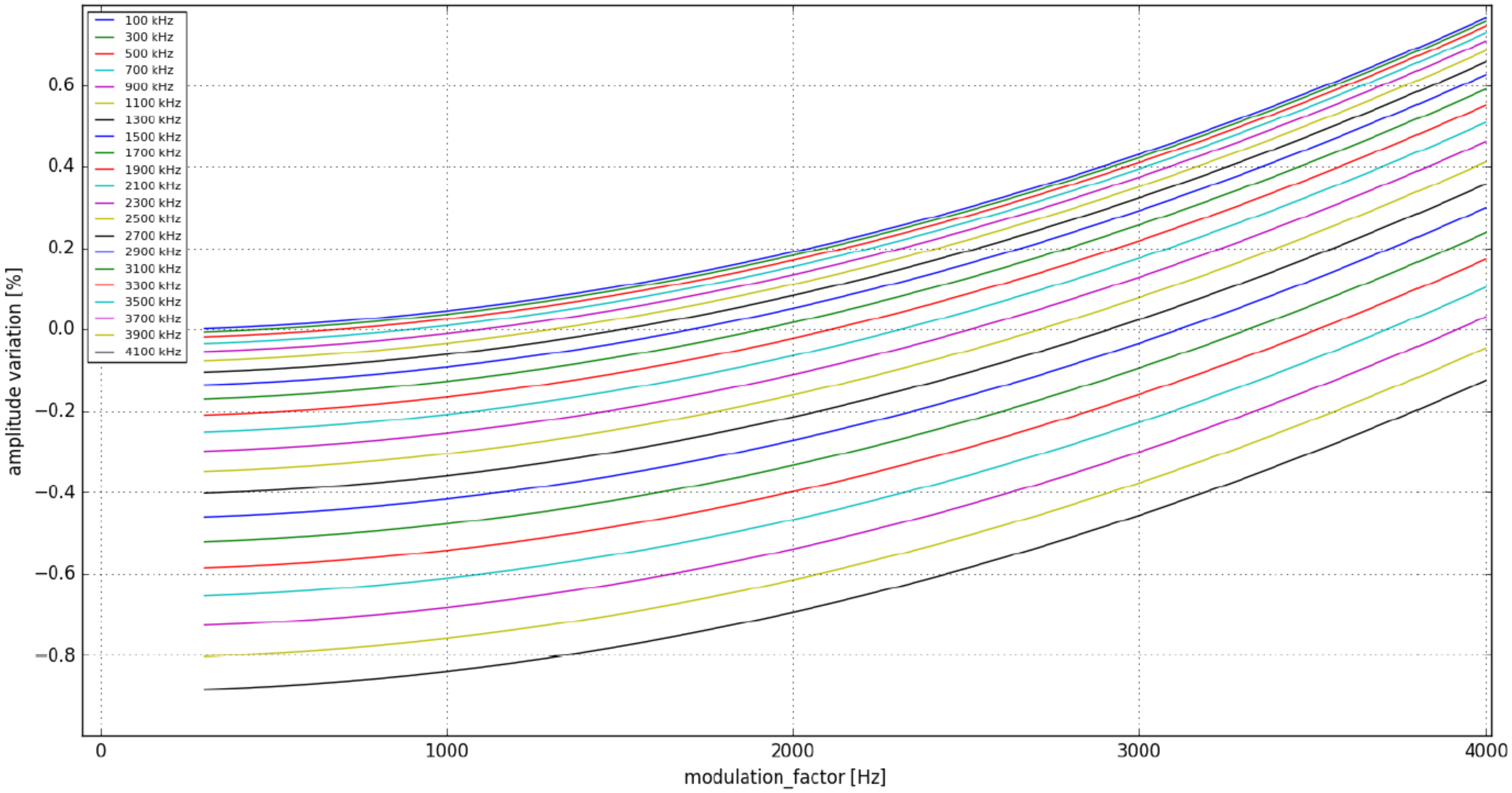




Amplitude criteria for modulation

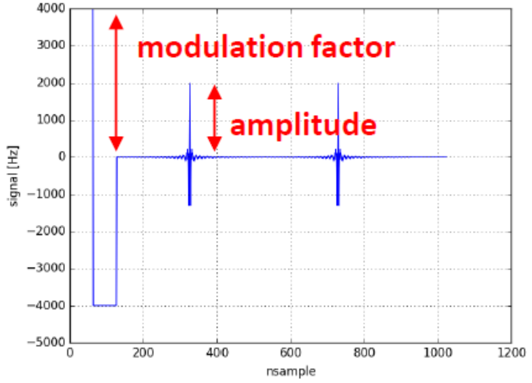
as close as possible to expected signal

fixed background



$$\Delta A = \left(\frac{A_{out} - A_{in}}{A_{in}}\right) \cdot 100$$

legend

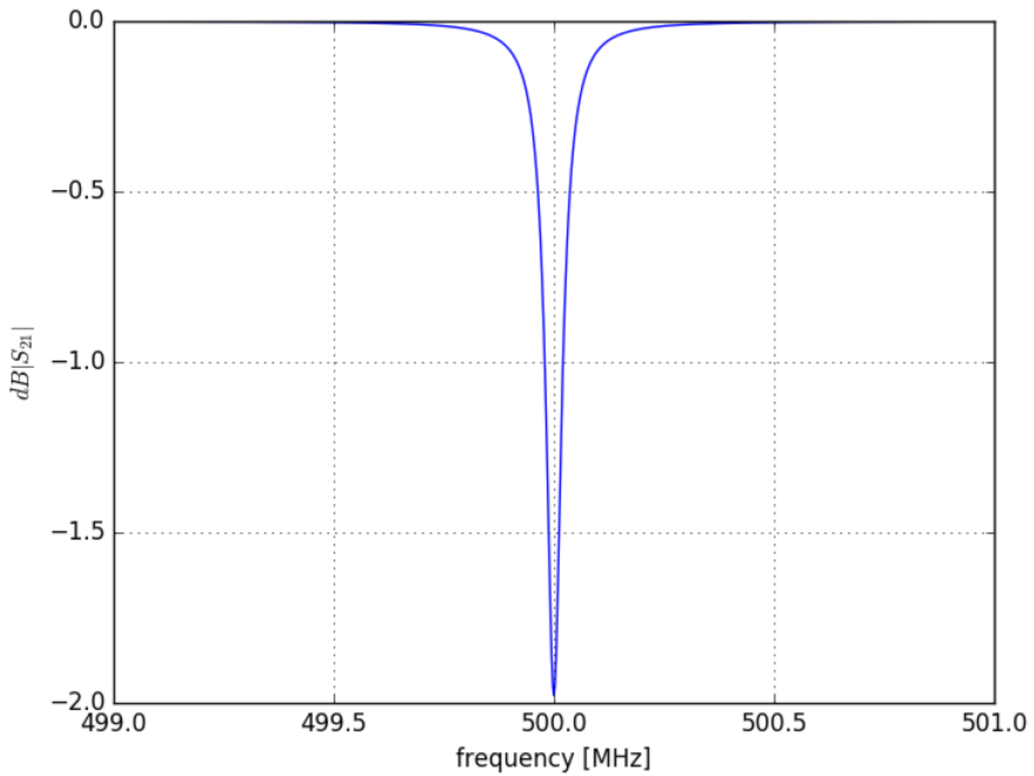


Single pixel simulation

Modulation signal symulation

$$S_{21} = ae^{-2\pi j\upsilon\tau}\left[1 - \frac{\frac{Q_{tot}}{Q_c}e^{j\varphi_0}}{1 + 2jQ_{tot}\left(\frac{\upsilon - \upsilon_0}{\upsilon_0}\right)}\right]$$

τ	= 1
φ_0	= 0
Q_i	= 15’000 with 50 K of background
Q_c	= 26’000
ν_0	= 500 MHz
$\Re$	= 1.5 kHz/K



$$S_{21} = I + jQ = Ae^{j\varphi}$$

$$\begin{cases} I = A\cos(\varphi) \\ Q = A\sin(\varphi) \end{cases}$$

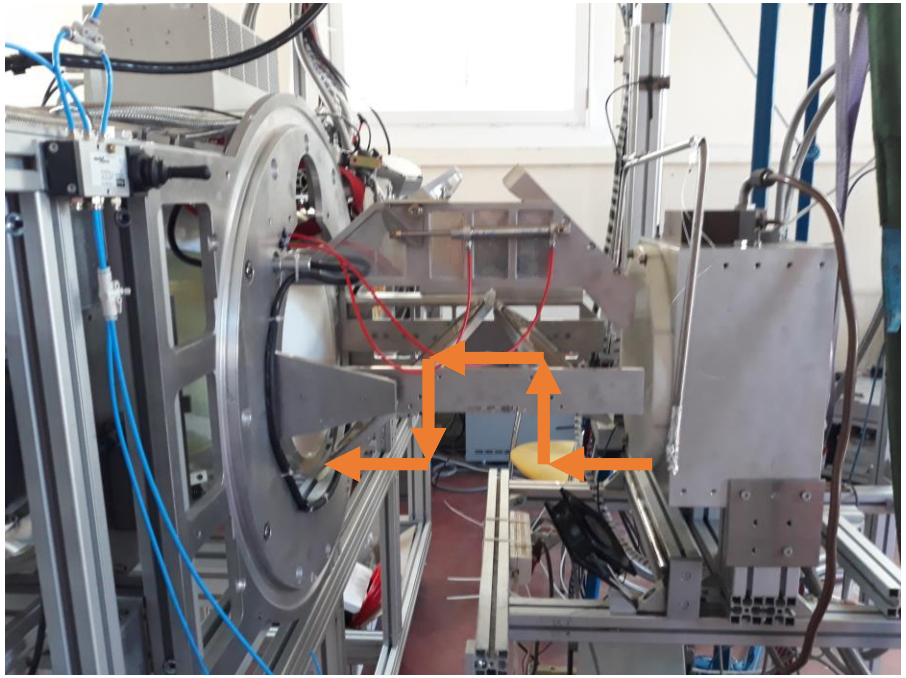
$$\begin{cases} A = \sqrt{I^2 + Q^2} \\ \varphi = arctan2\left(\frac{Q}{I}\right) \end{cases}$$

EXTRA

Second source for KISS

I. Defocused FoV (~30-50 K)

Best for point sources



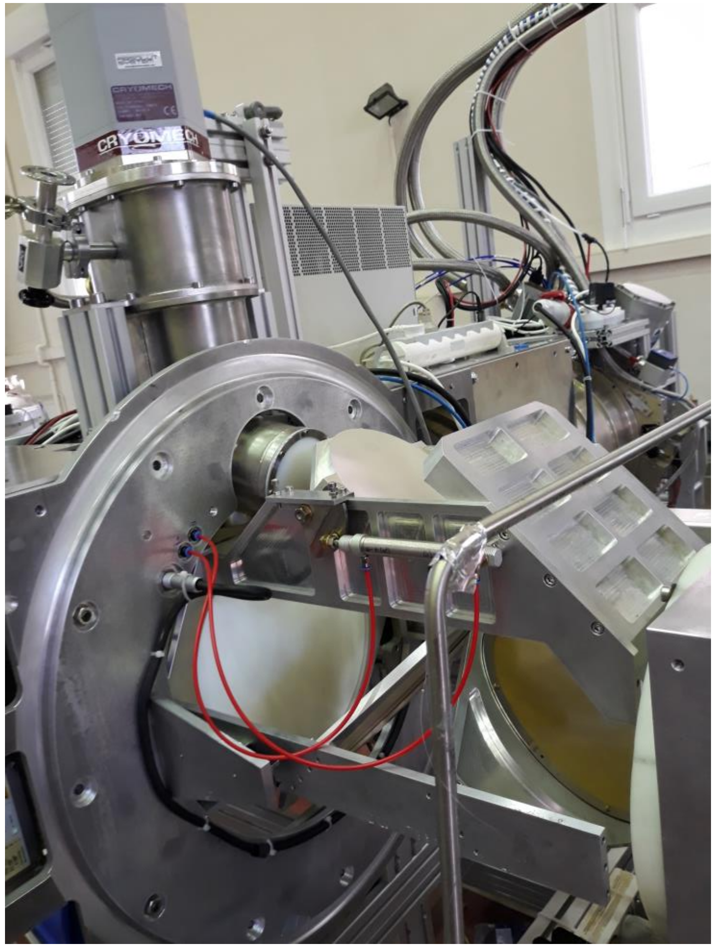
II. Mirror looking inside cryostat (~100 K)

Best for extended sources

III. Pulse-Tube (~15 K)

Best for extended sources

It guarantees stable temperature



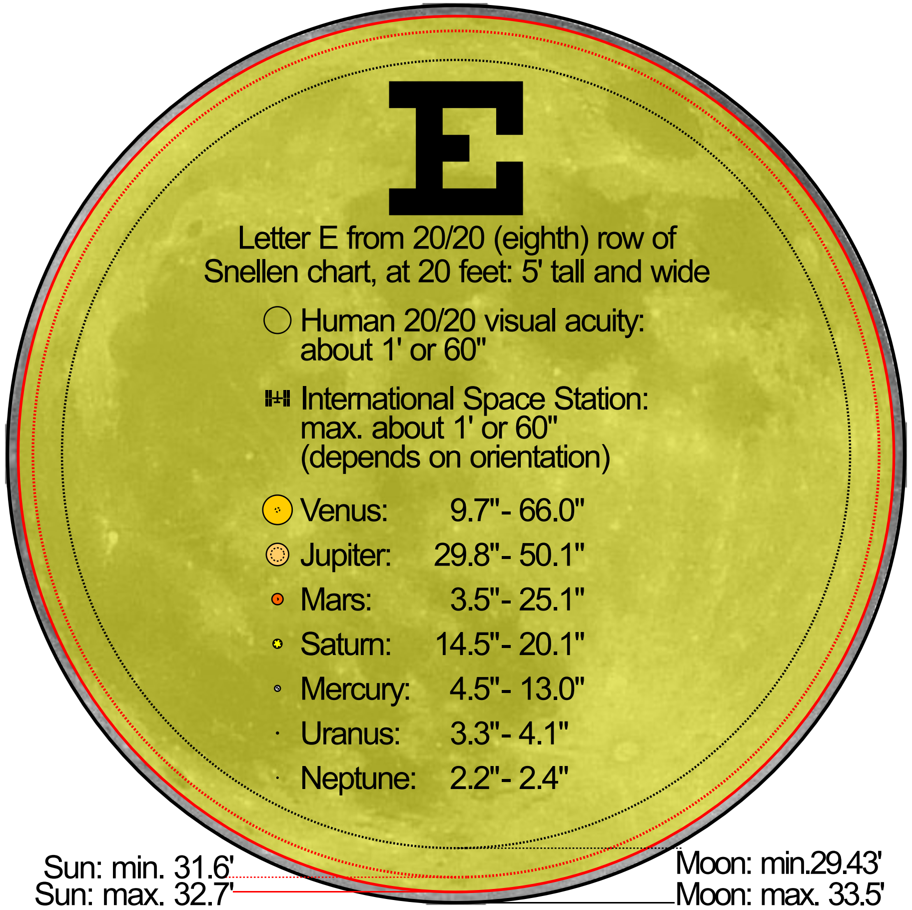
$$NEP^2 = NEP^2_{Johnson} + NEP^2_{phonon} + NEP^2_{gr}$$

$$= \frac{4k_B RT}{\mathcal{R}} + 4k_B GT^2 + \left(\frac{2\Delta}{\eta_{opt}\eta_{pb}}\right)^2 \cdot \frac{\langle N_{qp}\rangle}{\tau_{qp}}$$

$$NEP_{gr} \propto e^{-\Delta_0/k_B T}$$

$$NEP^2_{photon} = \frac{2}{\eta}\int_{\Delta\nu} P_\nu h\nu d\nu + \frac{1}{\eta^2}\int_{\Delta\nu} \frac{P^2_\nu c^2}{A\Omega\nu^2} d\nu$$

$$P_\nu = \epsilon t\eta A\Omega BB(\nu, T)$$



		THERMODYNAMIC TEMPERATURE [K]					
Planet	Freq. [GHz]	Survey 1	Survey 2	Survey 3	Survey 4	Survey 5	Mean
Mars	100	198.4 ± 0.7	186.7 ± 0.7	...	...	197.7 ± 0.7	194.3 ± 0.5 (stat.) ± 0.8 (syst.)
Mars	143	203.3 ± 0.6	188.9 ± 0.5	...	...	203.0 ± 0.5	198.4 ± 0.4 ± 1.1
Mars	217	207.3 ± 0.3	192.1 ± 0.3	...	...	206.2 ± 0.3	201.9 ± 0.2 ± 1.3
Mars	353	215.1 ± 0.5	200.1 ± 0.5	...	...	214.5 ± 0.5	209.9 ± 0.4 ± 1.6
Mars	545	215.0 ± 1.7	199.1 ± 1.5	...	...	213.5 ± 1.5	209.2 ± 1.1 ± 4.0
Mars	857	218.1 ± 1.7	202.6 ± 1.9	...	...	219.9 ± 1.8	213.5 ± 1.3 ± 6.6
Jupiter	100	172.8 ± 0.4	172.1 ± 0.4	173.1 ± 0.4	171.0 ± 0.4	...	172.3 ± 0.4 ± 0.7
Jupiter	143	174.0 ± 0.2	172.5 ± 0.3	174.4 ± 0.2	172.3 ± 0.2	174.7 ± 0.2	173.6 ± 0.2 ± 0.9
Jupiter	217	175.4 ± 0.1	174.7 ± 0.1	174.6 ± 0.1	175.2 ± 0.1	173.8 ± 0.1	174.7 ± 0.1 ± 1.1
Jupiter	353	166.1 ± 0.4	166.0 ± 0.4	166.5 ± 0.4	165.9 ± 0.4	167.1 ± 0.4	166.3 ± 0.4 ± 1.3
Jupiter	545	137.0 ± 0.9	138.2 ± 0.9	136.5 ± 0.9	135.1 ± 1.0	135.7 ± 1.0	136.5 ± 0.9 ± 2.6
Jupiter	857	156.7 ± 1.2	163.8 ± 1.3	160.1 ± 1.3	158.3 ± 1.4	162.3 ± 1.4	160.3 ± 1.3 ± 4.9
Saturn	100	145.2 ± 0.3	148.3 ± 0.3	143.5 ± 0.3	145.9 ± 0.3	...	145.7 ± 0.3 ± 0.6
Saturn	143	146.4 ± 0.2	148.6 ± 0.2	145.4 ± 0.2	147.7 ± 0.2	...	147.0 ± 0.2 ± 0.8
Saturn	217	143.8 ± 0.1	145.4 ± 0.1	144.3 ± 0.1	146.0 ± 0.1	...	144.9 ± 0.1 ± 0.9
Saturn	353	139.9 ± 0.3	140.4 ± 0.3	142.4 ± 0.3	143.1 ± 0.3	...	141.5 ± 0.3 ± 1.1
Saturn	545	100.1 ± 0.6	99.9 ± 0.7	105.0 ± 0.7	104.3 ± 0.7	...	102.4 ± 0.6 ± 2.0
Saturn	857	112.1 ± 0.9	111.0 ± 0.8	120.0 ± 1.1	118.7 ± 1.0	...	115.5 ± 1.0 ± 3.6
Uranus	100	121.1 ± 0.8	118.1 ± 0.8	120.9 ± 0.8	121.6 ± 0.8	120.6 ± 1.0	120.5 ± 0.4 ± 0.5
Uranus	143	107.6 ± 0.2	109.1 ± 0.2	108.5 ± 0.2	108.6 ± 0.2	108.4 ± 0.2	108.4 ± 0.1 ± 0.6
Uranus	217	98.3 ± 0.1	98.5 ± 0.1	98.6 ± 0.1	98.7 ± 0.1	98.5 ± 0.1	98.5 ± 0.1 ± 0.6
Uranus	353	86.5 ± 0.2	86.3 ± 0.2	86.1 ± 0.2	85.9 ± 0.2	86.2 ± 0.2	86.2 ± 0.1 ± 0.7
Uranus	545	74.0 ± 0.5	73.5 ± 0.5	73.2 ± 0.4	73.5 ± 0.5	75.1 ± 0.6	73.9 ± 0.2 ± 1.4
Uranus	857	66.0 ± 0.5	66.2 ± 0.5	66.3 ± 0.5	66.2 ± 0.5	...	66.2 ± 0.2 ± 2.0
Neptune	100	118.2 ± 2.2	117.6 ± 1.9	117.3 ± 1.9	116.6 ± 1.9	...	117.4 ± 1.0 ± 0.5
Neptune	143	105.8 ± 0.5	106.3 ± 0.4	107.0 ± 0.5	106.5 ± 0.4	...	106.4 ± 0.2 ± 0.6
Neptune	217	97.1 ± 0.3	97.7 ± 0.2	97.8 ± 0.3	97.0 ± 0.2	...	97.4 ± 0.1 ± 0.6
Neptune	353	82.2 ± 0.3	82.8 ± 0.3	82.7 ± 0.3	82.6 ± 0.2	...	82.6 ± 0.1 ± 0.6
Neptune	545	72.4 ± 0.5	71.9 ± 0.4	72.4 ± 0.5	72.2 ± 0.4	...	72.3 ± 0.2 ± 1.4
Neptune	857	65.2 ± 0.5	65.5 ± 0.5	65.3 ± 0.4	65.1 ± 0.5	...	65.3 ± 0.2 ± 2.0

[Planck intermediate results. LII. Planet flux densities, 2016]

Hubble Constant

$$D_A \propto \frac{\Delta T_{tSZE}}{S_X}$$

$$D_A(z, H_0, \Omega_k) = \frac{l}{\theta}$$

Baryon Fraction

$$f_b = \frac{\Omega_b}{\Omega_m}$$

$$f_{gas,SZE} \propto D_A$$

$$f_{gas} \sim 80\% \; f_b$$

β_T

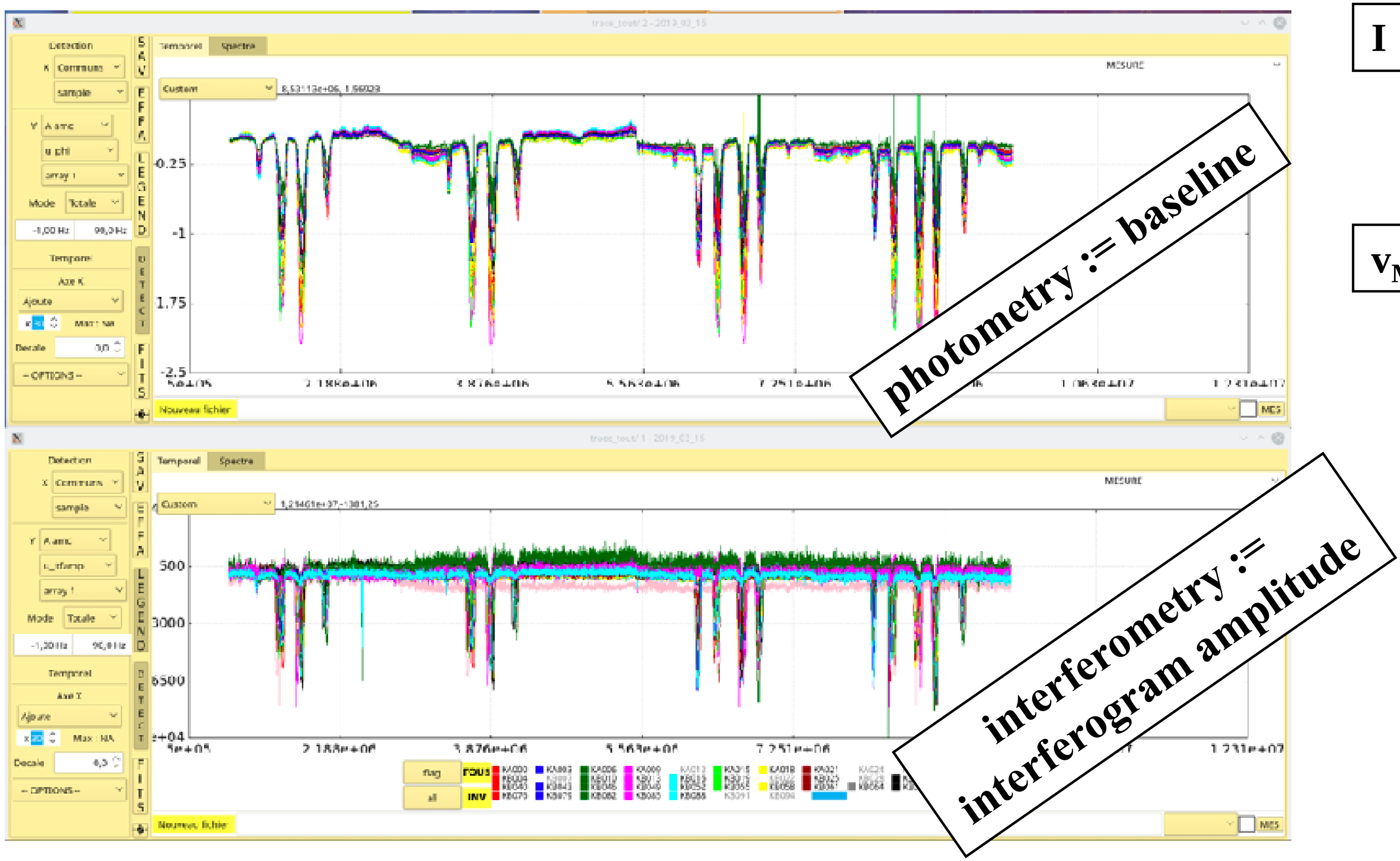
$$T_{CMB} = T_{CMB,0}(1+z)^{1-\beta_T}$$

Study the cluster of galaxy properties

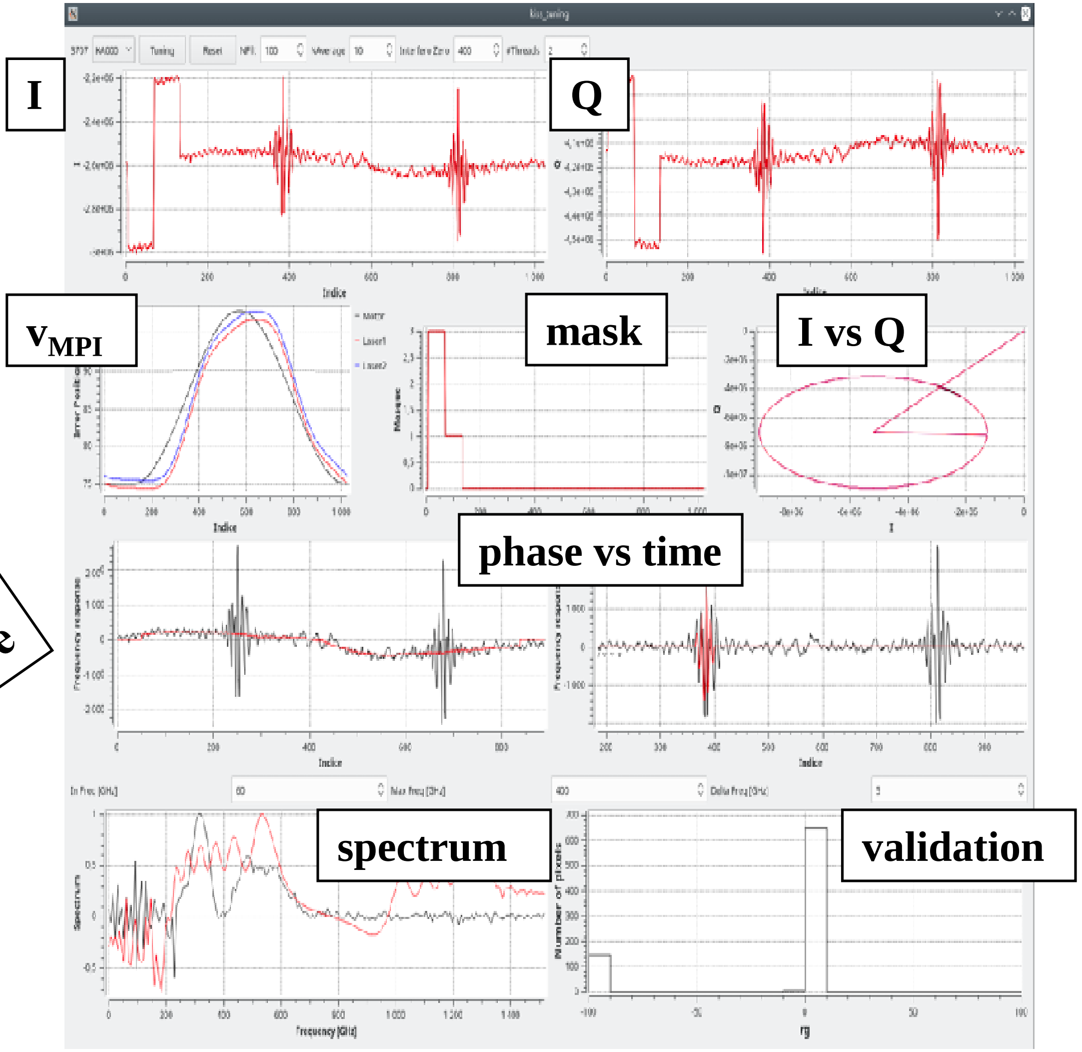
EXTRA

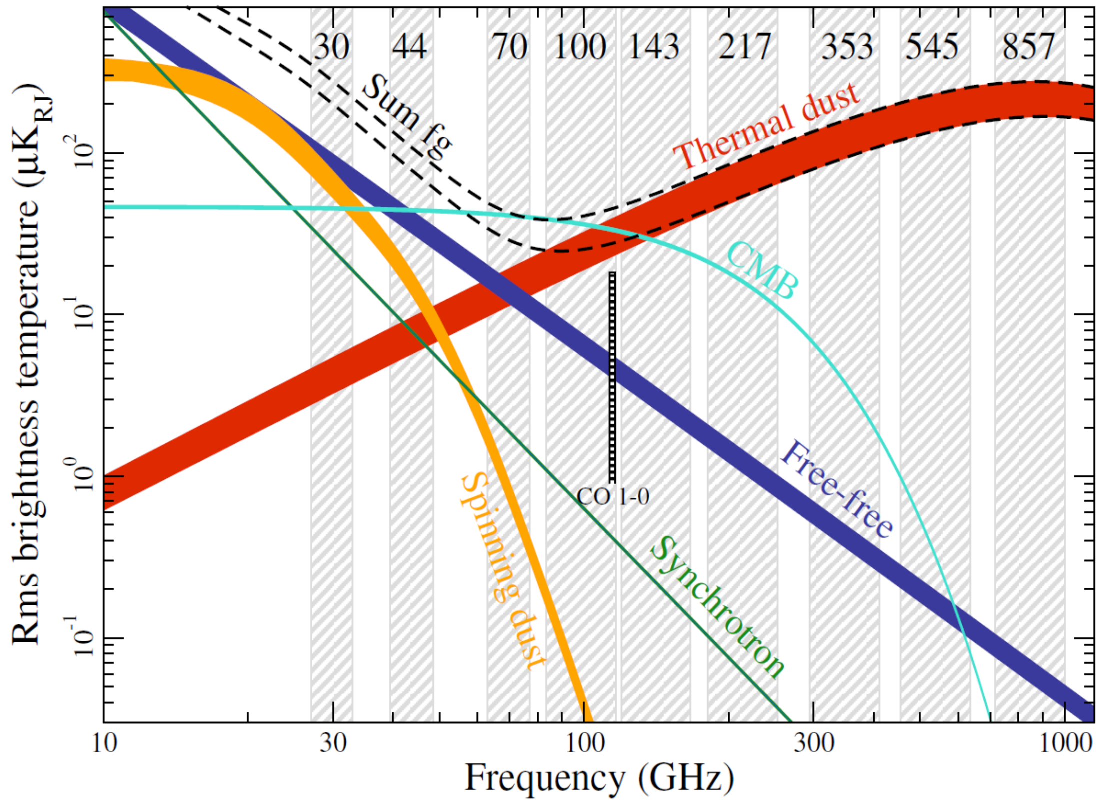
On the fly / real time data

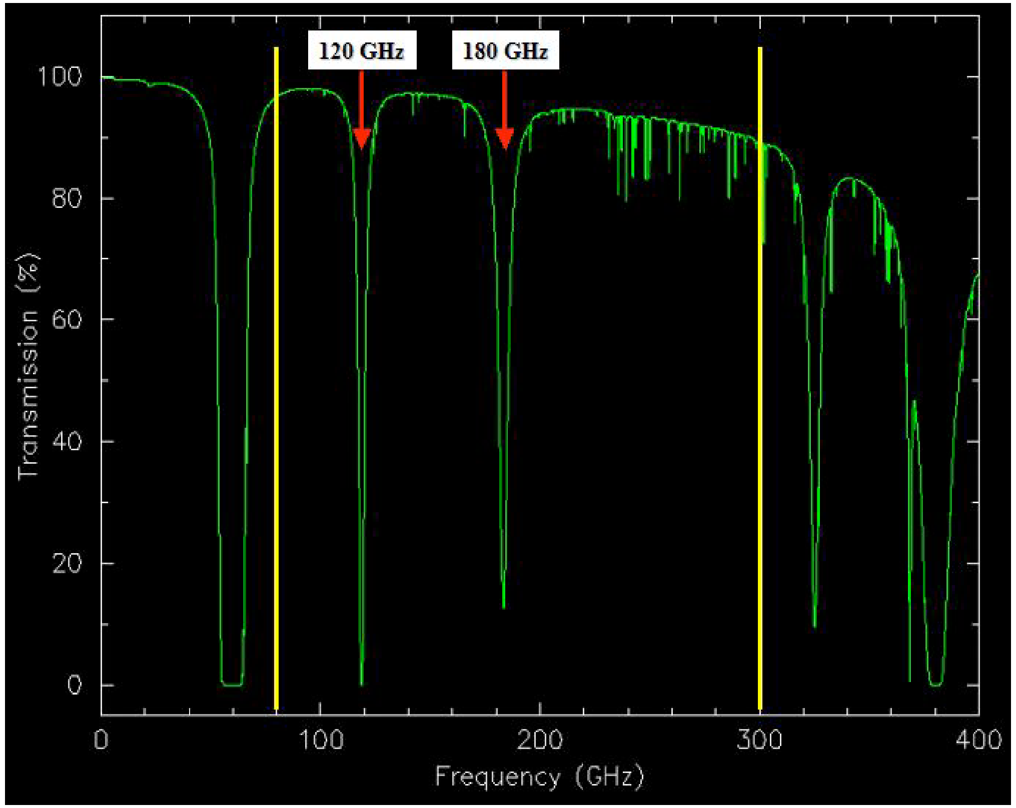
Photometry & Interferometry



and more details…







Predicted Atmospheric Transmission

O_2 , H_2O

[Monfardini, A. et al: 2016]

Quality factors

$$Q = 2\pi N = \omega_0 \frac{E_{stored}}{W_{lost}} = \frac{Q_i Q_c}{Q_i + Q_c}$$

Q_c compromise: resonance depth vs high Q
optimised for background

Q_i depends on the number of quasi particles

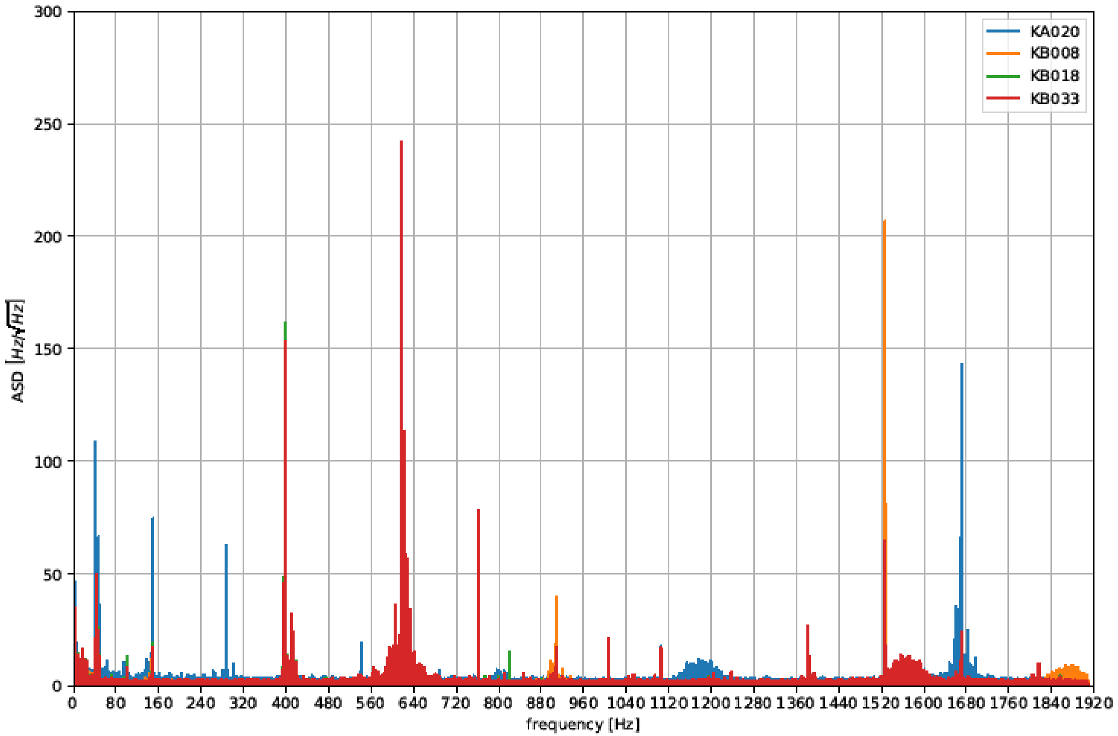
Responsivity

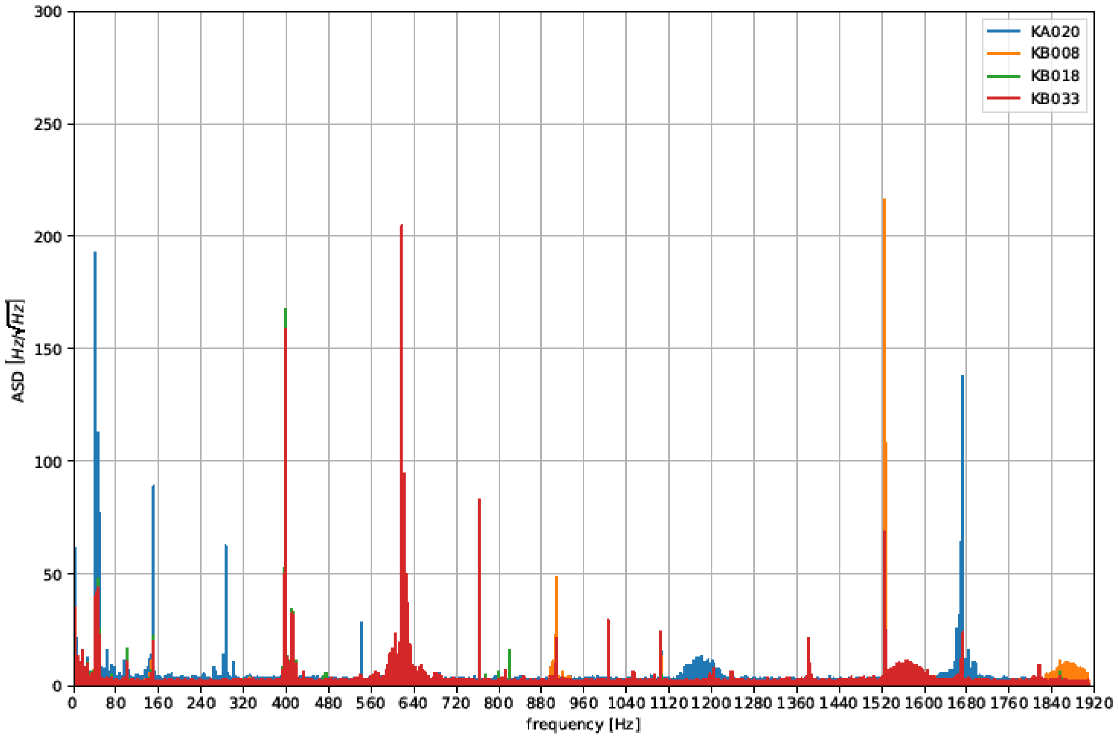
$$\mathcal{R} = \frac{d\varphi}{dN_{qp}} \propto \frac{\alpha Q}{V}$$

$$\alpha \equiv {}^{L_{kin}}/_{L_{tot}}$$

Minimising V
Maximising α and Q

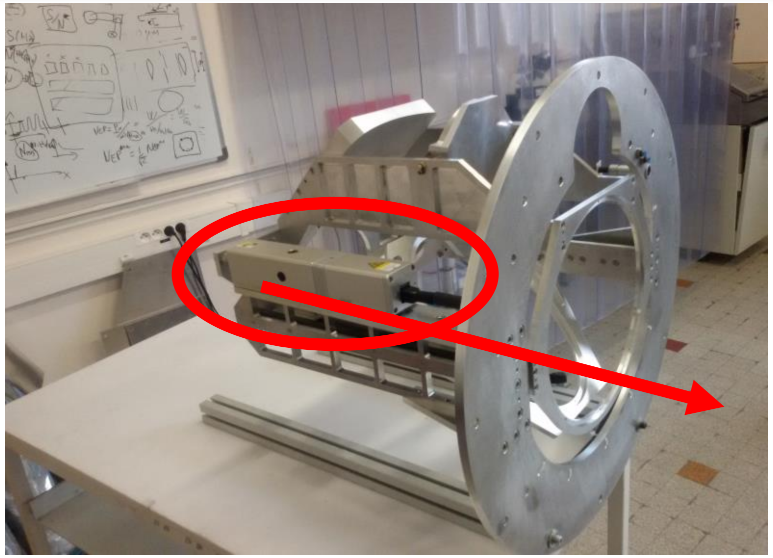
Normal alimentation





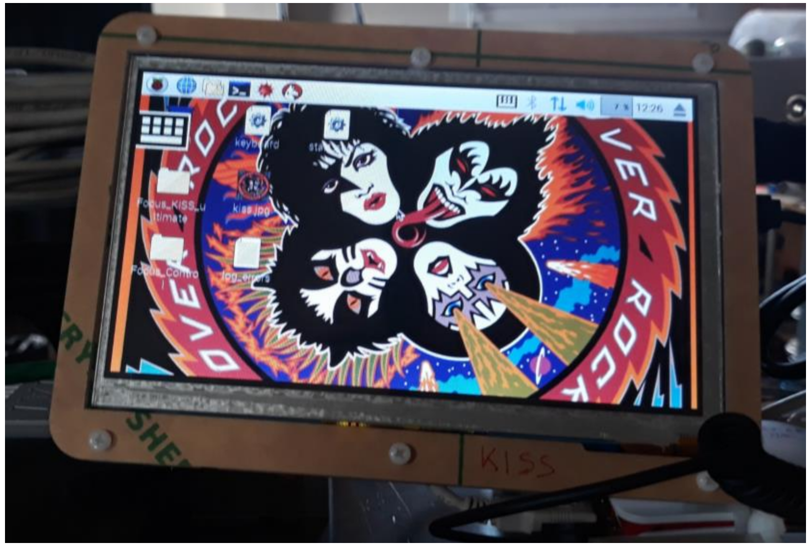
EXTRA

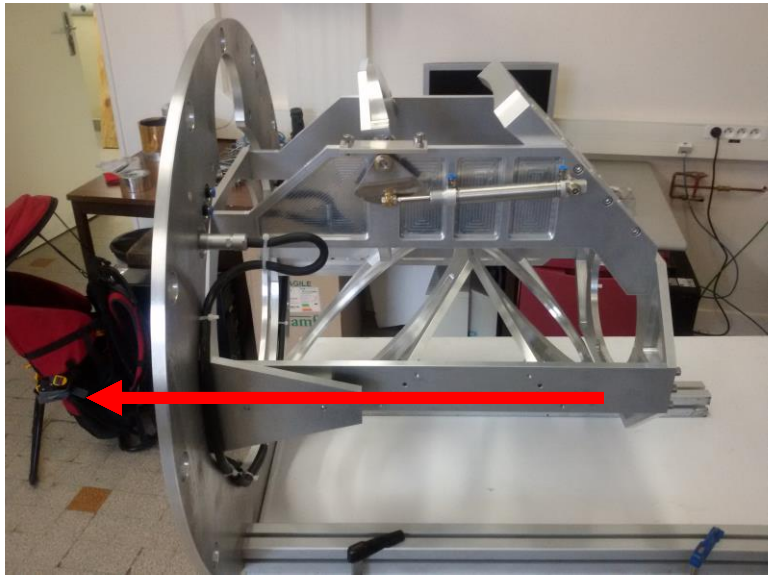
Focus engine

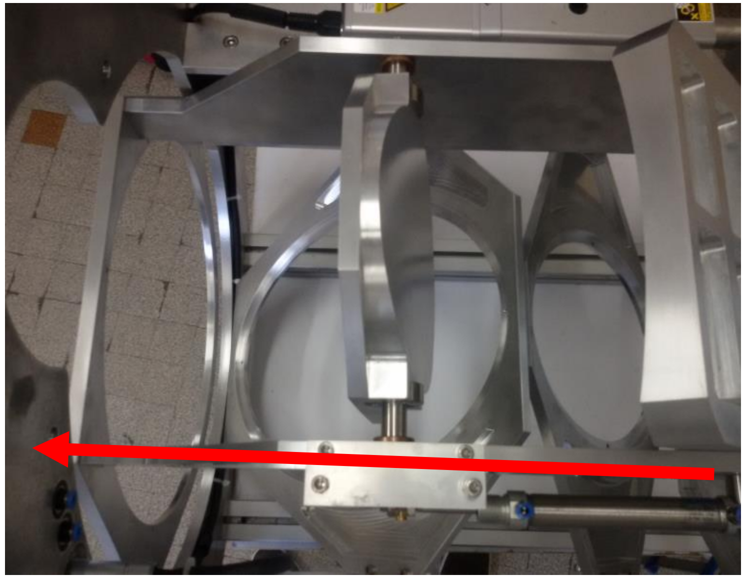


Engine to control KISS' focus

We are observing without the optimized focus at the moment





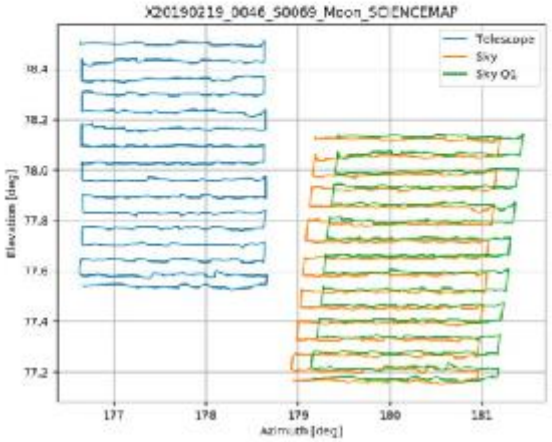


Controlled by RaspberryPi.
Double connection:

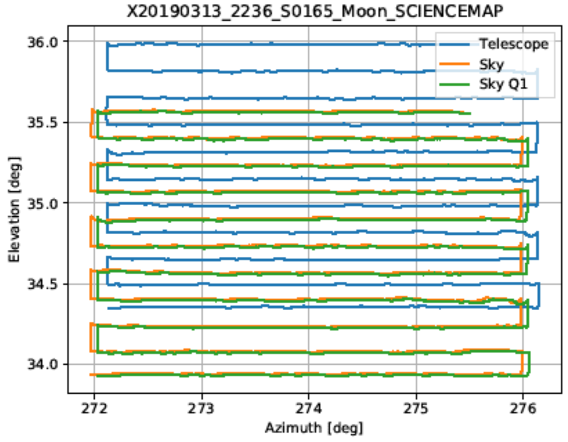
- **Tcp server**
- **Touchscreen interface**

FACTS

- KISS installation lasted from November 2018 to January 2019.
- KISS started observations on February 2019.



1) **Noise**: the 400 Hz noise is still there and it is not still clear where it comes from. Further analysis are required. It is possible that the problem is inside the cryostat: something could be unplugged during the transportation.
2) **Pointing Model:** Pointing correction are of the order of degree especially at higher altituted. Nowadays we are able to observe with more accuracy but still we have to implement the model with the rights parameters.
3) **Calibration sources:** We are acquiring maps of the Moon to set a pointing model accurate enough to allow point source observations. Jupiter and Venus are still under observation. The problem with the Moon is that its flux saturates the pixel. We are studying a solution to reduce the flux.



EXTRA

Status of the pointing model

QUIJOTE1 model parameters

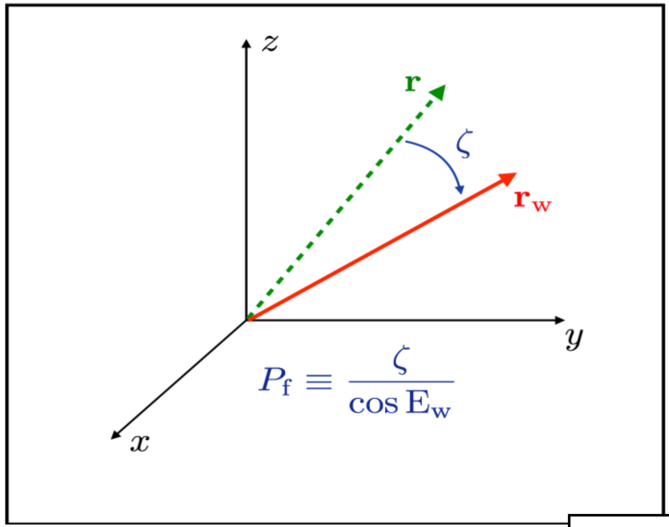
1) vertical flexure **Pf**
2) tilt on azimuth axis **Px, Py**
3) non-perpendicularities **Pc, Pn**
4) encoders errors **Pa, Pb**

Precision up to visible band

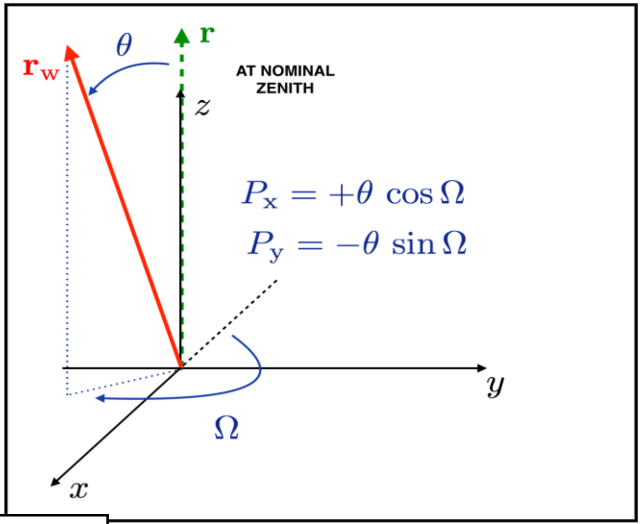
Required data:

[JDate, Azimuth, Elevation, Right Ascension, Declination, signal]

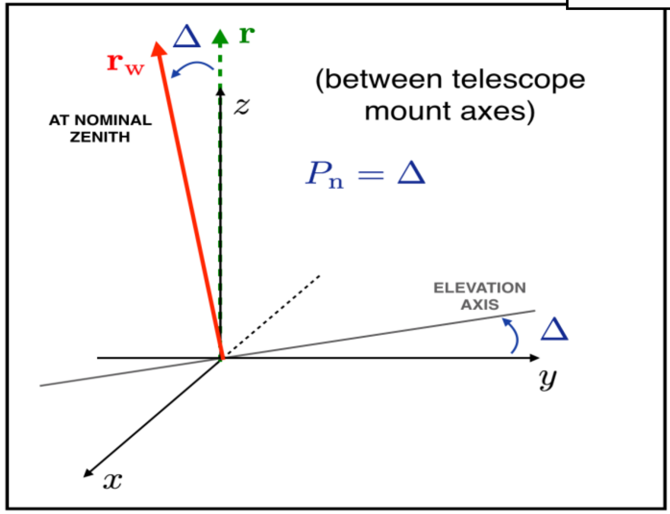
Vertical flexure



Roll axis misalignments

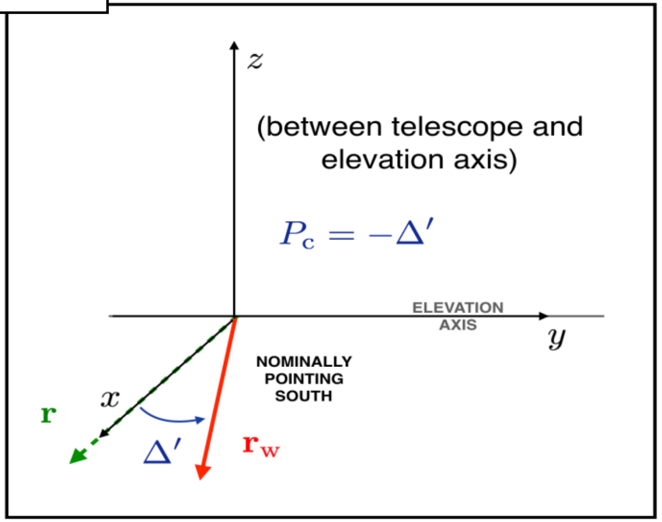


Non-perpendicularity I

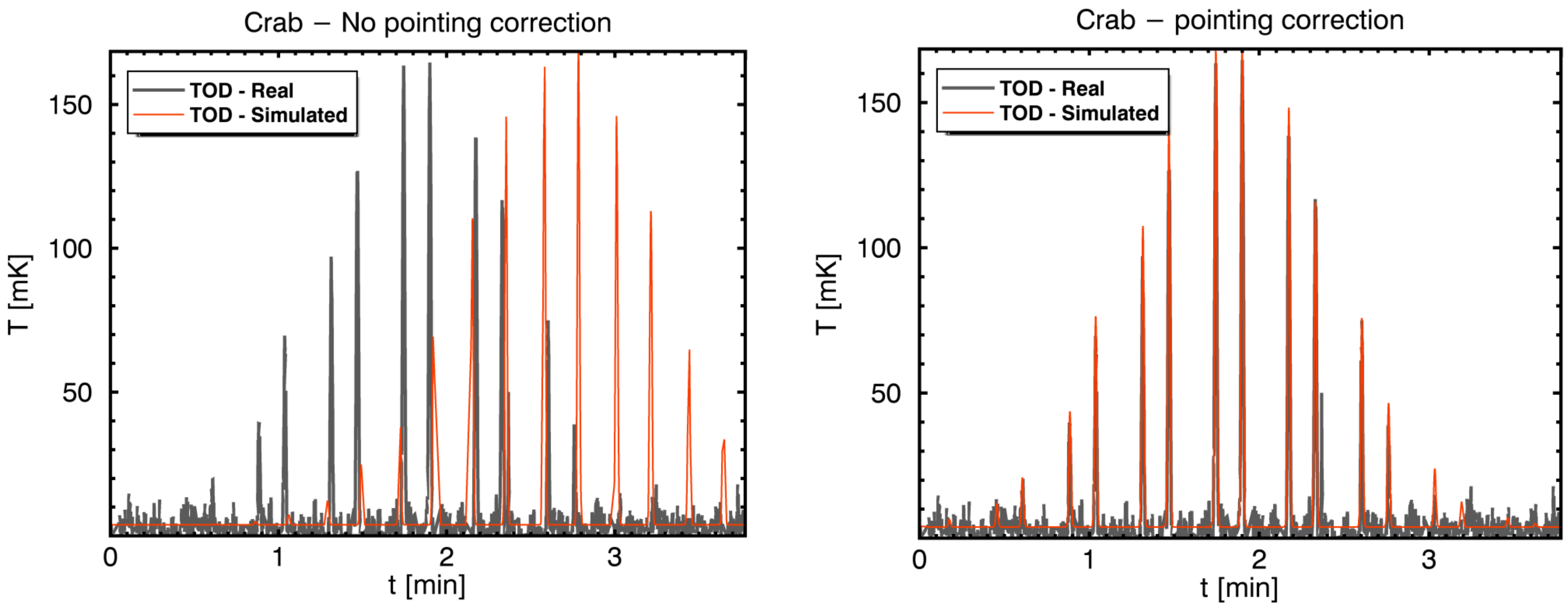


Tramonte, D.

Non-perpendicularity II



MODEL FOR QUIJOTE2



BEFORE → **AFTER**

EXTRA

Testing signal level reduction for Moon observation