

Bands at the 30m MRT, sizes of pixels and arrays for various FOVs, Power load, NEP, NET, and NEFD from the background
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The numbered variables are the free parameters for the optical and photometric calculations

The grey font is used for comments or optional calculations given for information but not used in the optical and photometric calculations

Diffraction size on the 30m, number of beam and pixels per FOV

Speed of light [m/s] c	299792458	Planck RJ approx $P[W]=2A\Omega kT\Delta\nu/\lambda^2$
Boltzman constant [J/K] k	1.381E-23	Flux $F[10^{26}\text{Jy}]=P/(A\Delta\nu)=2\Omega kT/\lambda^2$
Planck constant [J*s] h	6.626E-34	

M1 Diameter [m]	30			
1) Wavelength [mm]	3.25	2.05	1.25	0.87
Frequency [GHz] v	92	146	240	345
Diffraction Pattern FWHM [mrad]	112	70	43	30
Diffraction Pattern FWHM ["]	23	15	9	6

Forward efficiency ξ (empiric fit)	98%	96%	92%	87% <= fit on the best measures with ABCD receivers
Beam efficiency β (Ruze)	78%	72%	58%	39% Ruze (surface deformations): $\beta = 1.2 \cdot \epsilon \cdot \exp(-((4\sigma \cdot R\sigma / \lambda)^2))$
2) Fraction of unvignetted pupil diameter	99%			
Telescope effective area [m ²] A	688			

All the pixels in this document are considered as bare (without horns), except for the MAMBO2 sheet											
FOV diameter [']	Number pixels in FOV discs, rounded at the upper group of 10s										
	1	2	3	4	5	6	7	8	9		
1	10	20	40	80	Total:	30	60	150	300	Total:	8.5
2	30	60	150	300		90	210	570	1170		17.0
3	50	120	320	660		190	480	1270	2620		25.5
4	90	210	570	1170	2040	340	840	2250	4650	8080	34.0
5	130	330	880	1820		520	1310	3520	7260		42.5 3/4 0.87 band
6	190	480	1270	2620		750	1890	5060	10450	18150	51.0 3000 9950
7	260	640	1730	3560	6190	1020	2560	6890	14220	24690	59.5 4000 13450
8	340	840	2250	4650		1340	3350	9000	18570		68.0
9	430	1060	2850	5880		1690	4240	11390	23500		76.4
10	520	1310	3520	7260	12610	2080	5230	14060	29010	50380	84.9
11	630	1590	4260	8780		2520	6330	17010	35100		93.4
12	750	1890	5060	10450		3000	7530	20240	41780		101.9

My simple ATM model

Based on fits on ATM from Astro in Gildas, for the 50-400GHz range, with the error constraint $|\Delta\tau/\tau|<4\%$ at 100kHz resolution in the bands and 1MHz resolution in the atmospheric "walls", built with $T_{atm} = 275$ K, $P_{sea_level} = 1015$ mb, Altitude = Pico Veleta ($\text{Tau} \sim P$ and $\text{Tau} \sim T^3 \Rightarrow wv$ has the strongest effect in the range of possible P and T, so my model ignore dependence in T and P for simplicity)

Continuum

Reference frequency ν_c [GHz]	250							
Water Vapor slope a_c [1/mmwv]	0.071	$\tau_c(\nu, w) = (a_c \cdot w + b_c) \cdot \left(\frac{\nu}{\nu_c} \right)^2$						
Dry continuum at ν_c b_c	0.005							
Kinetic lines								
Central frequency ν_o [GHz]	58.2	60.2	118.7	183.3	325.1	368.5	380.2	$\tau_l(\nu, w) = \sum_l \frac{w^{p_l} \cdot \tau_{o_l}}{1 + \left(\frac{\nu_{o_l}^2 - \nu^2}{\nu_{s_l} \cdot \nu} \right)^2}$
Width ν_s [GHz]	2.5	2	1	2.96	3.47	0.56	3.49	
Central tau τ_o	3.2	11.5	9.4	2.2	2	1	19	
Water power p_l (0 = O2 line, 1 = H2O line)	0	0	0	1	1	0	1	

Gaussians fitting groups of close-packed lines

Central frequency ν_o [GHz]	58.1	62	65.3	440	$\tau_g(\nu, w) = \sum_g w^{p_g} \cdot \tau_{o_g} \cdot \exp \left(- \left(\frac{\nu_{o_g} - \nu}{\nu_{s_g}} \right)^2 \right)$
Width ν_s [GHz]	2.5	2.1	3.1	80	
Central tau τ_o	17.6	20.2	0.2	0.13	
Water power p_l (0 = O2 line, 1 = H2O line)	0	0	0	1	

Simple photometry calculations

(reminder about unit prefixes "a" = atto = 10^{-18} ; $\mu/a = 1/p$)

Remarks 1: the RJ temperatures below are defined so that when used in the RJ approximation formula of the brightness, the result = the unapproximated Planck law

Remarks 2: the Power formula below assumes constant T (brightness) and η (overall efficiency) in the integration over the bandwidth => correct @ <2 % error in the mm atmospheric windows for T>2K
 Remarks 3: the NET and NEFD are given for a chosen observing mode and for one pixel, their value for a standard size (beam of HPBW) is given at the end of the sheet

(Blockage M2 & quadurpod, leackage)	97% <= apparently not included in ξ since it has values > 98%...
4) Cabin optics transmission (M>2)	95% <= transmission of M1 and M2 included in ξ , isn't it ?
5) Cryostat 300K transmission	95% 88% <= total warm parts
6) Cryostat 77K transmission	86%
7) Cryostat 4K transmission	81%
8) Band pass filter transmission	95% 66% <= total cold parts
9) Detector absorption efficiency	90% 52% <= total optical chain
Global optical efficiency η	51% 50% 48% 45% <= total including Feff Maximum bandwidth $\Delta\nu_M$ defined by atmospheric transmission >75% everywhere in the band for the water vapour chosen below:
10) Bandwidth [GHz] $\Delta\nu$	40 40 100 20 wv [mm]: 7 5 4 2 1
Band pass min freq [GHz]	72 126 190 335 $\Delta\nu_M$:
Band pass max freq [GHz]	112 166 290 355 central v [GHz] : 92 146.5 222 249.5 344.5
Band pass min wave [mm]	4.1 2.4 1.58 0.90 central λ [mm] : 3.26 2.05 1.35 1.20 0.87
Band pass max wave [mm]	2.7 1.8 1.03 0.85
Bandwidth [mm]	1.48 0.57 0.54 0.05
11) Degree of polarization	0 (0 = 2 polar = unpolarized, 1 = 1 polar)
Polarization parameter \mathbf{p}	1
Quantic effect of photons bunching on a surface ~ partial coherence factor (C) = covariance of the fluctuations of intensity (= integral of integral of beam pattern for a point source) = 1 / (available number of modes on the surface).	
Asymptotes: (1) monomode or coherent or extended source: $C = 1$; (2) multimode and incoherent point source: $C \sim \lambda^2/A\Omega = 4/(\pi u^2)$ if $u > 3$, $C \sim \exp(-0.6 \cdot u \cdot ((u+2)/(u+1)))$ if $0 < u < 3$ (empirical approx by me). C can't be >1.	
12) Spatial coherence factor \mathbf{C}	1.0 0.5 1.3 1.0 0.8 5.1 (<= multimode pt source approximations for $u < 3$ and $u > 3$ given for information)
13) Observing mode useful time ratio	80% (e.g. 80% for OTF, 45% for On-Off)
Observing mode efficiency γ	1.12 <= includes the "reference+source" *2^0.5 factor and "frequency to time" /2^0.5 factors which cancel each other

NEP to NET = $T/P(T) = Q/\exp(-\tau)$; NEP to NEFD = $F/P(F) = J/\exp(-\tau)$ (Q and J are defined such that they don't depend on the atmospheric conditions)

$Q = p\lambda^2/(2kA\Omega\eta\Delta\nu)$ [K/pW]	2.3	2.3	1.0	5.1	9.0	9.2	3.8	20.3
$J = p\xi/(A\eta\zeta\Delta\nu)$ [Jy/pW]	17	19	10	70	55	60	30	220
T/F: $(Q/J)(\xi/\zeta) = (\lambda^2/2k\Omega) = D^2/2ku^2$ [K/Jy]	0.32	0.32	0.32		1.27	1.27	1.27	
ξ/ζ	2.46	2.61	3.15	4.38	7.72	8.21	9.89	13.76

Atmosphere

14) Atmosphere temperature (Ta) [K]

Black body occupation number at ν	275	62	39	23	16
Brightness for frequencies [fW/m^2/Hz/sr]		0.7	1.8	4.8	9.7
(RJ approx brightness [fW/m^2/Hz/sr])		0.7	1.8	4.9	10.0
Black body RJ temperature T [K]	273	272	269	267	

15) Elevation [deg]

Airmass	60	1.15
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16) Precipitable water vapor (wv) [mm]

Opacity tau meter (225GHz)	1	0.06	<= from IRAM Spain weather page (http://www.iram.es/IRAMES/weather.html), after Nov 16 correction; old was for Atacama ==>	0.05
Opacity tau meter (225GHz)		0.06	<= from the continuum part only (lines negligible at 225Ghz) of my simplified ATM model	

Opacity components for each band:

Atm continuum only	0.010	0.026	0.070	0.145
Atm O2 kinetic lines	0.025	0.008	0.002	0.001
Atm H2O kinetic lines	0.000	0.003	0.004	0.058
Atm O2 gaussian bunch	0.000	0.000	0.000	0.000
Atm H2O gaussian bunch	0.000	0.000	0.000	0.000
Atm total τ (including airmass)	0.04	0.04	0.09	0.235
Emissivity	4%	4%	8%	21%

Spectral radiance of atmosphere [fW/m^2/Hz/sr]

Atmos emission T RJ [K] T	11	11	23	56
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Power [pW] $P=(2A\Omega\eta/p)kT\Delta\nu/\lambda^2$

	4.9	5.0	23.5	11.0	1.2	1.2	5.9	2.8
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$NEP_p = (2hvP)^{0.5}$ [aW/Hz^{0.5}]

$NEP_b = P(pC/\Delta\nu)^{0.5}$ [aW/Hz^{0.5}]

NEP

	25	31	87	71	12	16	43	35
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$NEP_b = P(pC/\Delta\nu)^{0.5}$ [aW/Hz^{0.5}]

NET

	25	25	74	78	6	6	19	19
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$NET = \gamma NEP_p Q / \exp(-\tau)$ [mK*s^{0.5}]

$NET_b = \gamma NEP_b Q / \exp(-\tau)$ [mK*s^{0.5}]

NET

	35	40	114	105	14	17	47	40
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$NEFD_p = \gamma NEP_p J / \exp(-\tau)$ [mJy*s^{0.5}]

$NEFD_b = \gamma NEP_b J / \exp(-\tau)$ [mJy*s^{0.5}]

NEFD

	0.5	0.7	1.0	7.0	0.8	1.1	1.6	11.4
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$NEFD_b = \gamma NEP_b J / \exp(-\tau)$ [mJy*s^{0.5}]

NEFD

	0.5	0.6	0.9	7.7	0.4	0.4	0.7	6.3
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NEFD

	0.7	0.9	1.3	10.4	0.9	1.2	1.7	13.0
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Spillover

Temperature of environment behind M1 [K]

Emissivity	2%	4%	8%	13%
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Spectral radiance of behind M1 [fW/m^2/Hz/sr]

T RJ [K]	5.7	10.9	21.5	34.9
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Power [pW] $P=(2A\Omega\eta/p)kT\Delta v/\lambda^2$	2.6	4.9	24.4	7.9	0.6	1.2	6.1	2.0
NEPp = $(2hvP)^{0.5}$ [aW/Hz ^{0.5}]	18	31	88	60	9	15	44	30
NEPb = $P(pC/\Delta v)^{0.5}$ [aW/Hz ^{0.5}]	13	25	77	56	3	6	19	14
NEP	22	40	117	82	9	17	48	33
NETp = γ NEPpQ/exp(- τ) [mK*s ^{0.5}]	0.05	0.08	0.10	0.43	0.09	0.17	0.21	0.86
NETb = γ NEPbQ/exp(- τ) [mK*s ^{0.5}]	0.03	0.07	0.09	0.40	0.03	0.07	0.09	0.40
NET	0.06	0.11	0.14	0.59	0.10	0.18	0.23	0.95
NEFDp = γ NEPpJ/exp(- τ) [mJy*s ^{0.5}]	0.4	0.7	1.0	6.0	0.6	1.1	1.6	9.4
NEFDb = γ NEPbJ/exp(- τ) [mJy*s ^{0.5}]	0.3	0.5	0.9	5.5	0.2	0.4	0.7	4.3
NEFD	0.4	0.9	1.4	8.1	0.6	1.2	1.8	10.3

300K optics

(17) Mean surface temperature [K]	280							
Black body occupation number at v	63	39	24	16				
Black body RJ temperature T [K]	278	277	274	272				
Emissivity mirrors / cryostat	4.9%	5.0%						
Spectral radiance of mirrors [fW/m ² /Hz/sr]	0.04	0.09	0.24	0.49				
Spectral radiance of warm optics [fW/m ² /Hz/sr]	0.04	0.09	0.24	0.50				
T RJ for mirrors [K]	13.6	13.6	13.4	13.3				
T RJ for cryostat warm optics [K]	13.9	13.8	13.7	13.6				
For P: apply ξ to mirrors (<u>correct or not ?</u>) but not to cryostat 300K								
Power [pW] $P=(2A\Omega\eta/p)kT\Delta v/\lambda^2$	13.7	13.6	33.3	6.5	3.4	3.4	8.3	1.6
NEPp = $(2hvP)^{0.5}$ [aW/Hz ^{0.5}]	41	51	103	54	20	26	51	27
NEPb = $P(pC/\Delta v)^{0.5}$ [aW/Hz ^{0.5}]	69	68	105	46	17	17	26	11
NEP	80	85	147	71	27	31	58	30
NETp = γ NEPpQ/exp(- τ) [mK*s ^{0.5}]	0.11	0.14	0.12	0.39	0.22	0.28	0.24	0.78
NETb = γ NEPbQ/exp(- τ) [mK*s ^{0.5}]	0.18	0.18	0.12	0.33	0.18	0.18	0.12	0.33
NET	0.21	0.23	0.17	0.51	0.28	0.33	0.27	0.85
NEFDp = γ NEPpJ/exp(- τ) [mJy*s ^{0.5}]	0.8	1.1	1.2	5.4	1.3	1.8	1.9	8.5
NEFDb = γ NEPbJ/exp(- τ) [mJy*s ^{0.5}]	1.4	1.5	1.2	4.6	1.1	1.2	1.0	3.6
NEFD	1.6	1.9	1.7	7.1	1.7	2.1	2.1	9.2

77K stage

Temperature cryostat optics on N2 stage [K]	77							
Black body occupation number at v	17	10	6	4				
Black body RJ temperature T [K]	75	74	71	69				
Emissivity	14%							
Spectral radiance of N2 stage [fW/m ² /Hz/sr]	0.03	0.07	0.18	0.36				
T RJ for [K]	10.7	10.5	10.2	9.8				
Power [pW] $P=(2A\Omega\eta/p)kT\Delta v/\lambda^2$	6.4	6.3	15.3	3.0	1.6	1.6	3.8	0.7

NEPp = $(2hvP)^{0.5}$ [aW/Hz $^{0.5}$]	28	35	70	37	14	18	35	18
NEPb = $P(pC/\Delta v)^{0.5}$ [aW/Hz $^{0.5}$]	32	32	48	21	8	8	12	5
NEP	43	47	85	42	16	19	37	19
NETp = $\gamma NEPpQ/\exp(-\tau)$ [mK*s $^{0.5}$]	0.07	0.09	0.08	0.26	0.15	0.19	0.16	0.53
NETb = $\gamma NEPbQ/\exp(-\tau)$ [mK*s $^{0.5}$]	0.08	0.08	0.06	0.15	0.08	0.08	0.06	0.15
NET	0.11	0.13	0.10	0.30	0.17	0.21	0.17	0.55
NEFDp = $\gamma NEPpJ/\exp(-\tau)$ [mJy*s $^{0.5}$]	0.6	0.8	0.8	3.7	0.9	1.2	1.3	5.7
NEFDb = $\gamma NEPbJ/\exp(-\tau)$ [mJy*s $^{0.5}$]	0.7	0.7	0.6	2.1	0.5	0.5	0.4	1.6
NEFD	0.9	1.0	1.0	4.2	1.0	1.3	1.3	6.0

TOTAL BACKGROUD

Power [pW]	28	30	97	28	7	7	24	7
NEPp = $(2hvP)^{0.5}$ [aW/Hz $^{0.5}$]	58	76	175	114	29	38	88	57
NEPb = $P(pC/\Delta v)^{0.5}$ [aW/Hz $^{0.5}$]	138	149	305	200	35	37	76	50
NEP [aW/Hz$^{0.5}$]	150	167	352	231	45	53	116	76
NETp = $\gamma NEPpQ/\exp(-\tau)$ [mK*s $^{0.5}$]	0.15	0.20	0.21	0.82	0.31	0.41	0.41	1.64
NETb = $\gamma NEPbQ/\exp(-\tau)$ [mK*s $^{0.5}$]	0.36	0.40	0.36	1.44	0.36	0.40	0.36	1.44
NET [mK*s$^{0.5}$]	0.39	0.45	0.41	1.66	0.48	0.57	0.54	2.18
NEFDp = $\gamma NEPpJ/\exp(-\tau)$ [mJy*s $^{0.5}$]	1.2	1.7	2.0	11.3	1.9	2.6	3.2	17.7
NEFDb = $\gamma NEPbJ/\exp(-\tau)$ [mJy*s $^{0.5}$]	2.8	3.3	3.5	19.9	2.2	2.6	2.8	15.6
NEFD [mJy*s$^{0.5}$]	3.1	3.7	4.1	22.9	2.9	3.7	4.2	23.6

0.95 1.00 1.04 1.03

TOTAL BACKGROUD for a standard elementary size

(18) Standard elementary size us [Fλ]	1.1 Comon standard sizes: "beam" = $2 \cdot 1.22 = 1$ st dark ring of the Airy diffraction pattern ≈ 2 ; "HPBW" = "FWHM" = $1.03 \approx 1$							
(19) spatial coherence factor Cs	1 (\leq extended source) 0.5 1.1 (\leq incoherent point source case given for information, note that NEPb becomes poissonian like NEPp only when $C = \lambda^2/A\Omega !$)							
Diffractive gaussian efficiency ζ_s	45% 42% 33% 23%							
ζ_s/ζ	1.1 1.1 1.1 1.1 3.6 3.6 3.6 3.6							
T/F [K/Jy]	0.26 F/T 3.81							
P ~ (us/u)2 [pW]	33	36	117	34	33	36	117	34
!! In case of incoherent signal $C \sim 1/u^2 \Rightarrow$ the NEXb behave like the NEExp ; they become Poissonian !!								
NEPp ~ (us/u)	64	84	193	125	64	84	193	125
NEPb ~ (us/u) 2 (Cs/C) $^{0.5}$	167	181	369	243	167	181	369	243
NEP [aW/Hz$^{0.5}$]	179	199	417	273	179	199	417	273
NETp ~ 1/(us/u)	0.14	0.19	0.19	0.74	0.14	0.19	0.19	0.74
NETb ~ (Cs/C) $^{0.5}$	0.36	0.40	0.36	1.44	0.36	0.40	0.36	1.44
NET [mK*s$^{0.5}$]	0.39	0.44	0.40	1.62	0.39	0.44	0.40	1.62
NEFDp ~ (us/u)/(ζ_s/ζ)	1.1	1.6	2.0	10.9	1.1	1.6	2.0	10.9
NEFDb ~ (us/u) 2 (Cs/C) $^{0.5}/(\zeta_s/\zeta)$	3.0	3.5	3.8	21.2	3.0	3.5	3.8	21.2

NEFD [mJy*s^0.5]	3.2	3.9	4.3	23.8	3.2	3.9	4.3	23.8
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Power from a source in a pixel

T RJ of the source seen by the pixel [K]	50				5	5	13	2
Power [pW] $P = (2A\Omega^{-1}\eta/p)kT\Delta v/\lambda^2$	21	21	48	8	5	5	13	2
total TRJ + Tbkg [pW]	49	51	144	36	12	13	37	9
Flux of the source [Jy]	500				9	8	15	2
Power [pW] $P = (FAe^{-\tau}\eta\zeta/\xi p)\Delta v$	27	25	48	6	9	8	15	2
Dynamic: Pmax/Pmin	2.8	3.4	3.4	2.6				