ALMA Sensitivity Calculator

	Common Parameter	rs										
			Dec		00:00:00.000							
			Polarization		Dual			-				
			Observing Frequency		345.00000		GHz			-		
			Bandwidth per Polarization		0.00000		GHz	GHz		-		
Project - Alma Observing Tool Elle Edit Iool Search Options Help			Water Vapour		Automatic Choice O Manual Choice				e			
			Column Density		0.913mm (3rd Octile)							
Project Structure	Editors Field Setup				tau=0.158, Tsky=44.400 K			-				
Project Project Project Project Project	Input the source you wish to look at and your mappi					13Ky=44.400 K			-			
Science Coal ()	Alternatively you may define this with the Visual Edit		Tsys 157.02			57.027 K						
Field Setup Spectral Setup	ngr253	Individual Paramete	rs					_	_			
- 🗋 Control Parameters			12m Array 7m Array			Total Power A	rray					
Calibration Setup Parameters	Source Name ngc253 Non Sidercal Motion Solar Se	Number of Antennas	s 34		9			2				
	Ephemeris	Resolution	0.00000	arcsec			5.974554 arcsec		17.923662 arcsec			
	Proper Motion RA 0.00000	Resolution	0.00000	arcsec			J.374JJ4 al		_		il coet	
	Proper Motion Dec 0.00000	Sensitivity(rms)	0.00000	Jy		-	0.00000	Jy	-	0.00000	Jy	-
	Source Coordinates System RA	(equivalent to)	Infinity	К		-	0.00000	К	-	0.00000	К	-
	Dec Source Velacity 244.0	Integration Time	0.00000	s	-	-	0.00000	s	-	0.00000	s	-
	Parallax 0.00000			1	Integ	urot	ion Time Unit	Ontic		utomotio		
	Target Type 🛞 Single R	integration time one option Adconatio										
	- Field Center Coordinates Coordinates Type .		Calculate Integra	ation Time	Calcu	ılat	e Sensitivity	1		lose		
	Dffset[RA] 0.0000		salealare integre		Calec	incit	o benoleway	1				
Overview Phase-I Phase-II	0ffset[Dec]0.00000	clegrees 📼										
▲ ▼ Feedback	UnsetDecto.00000	clegrees 💌										
Description Suggestion Resource	Add	Delete										
Log Problems Information	Spectral Spatial Forms Catalog											

German ALMA Community Days 2017 Bonn, 27-28 March *Yurii Pidopryhora, AlfA*



EUROPEAN ARC ALMA Regional Centre || Germany

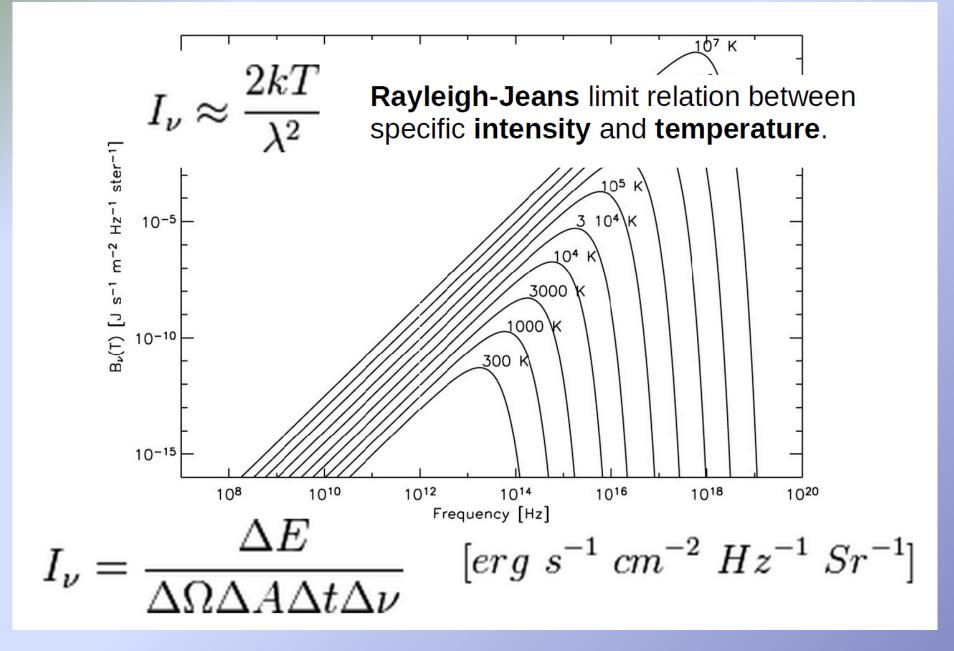
- Two versions of ALMA Sensitivity Calculator (ASC): integrated into the OT and stand-alone, available online at the ALMA Science Portal
- They are *almost* identical and use the same algorithms
- But when the integration times are estimated for your project using the OT ASC, it knows a little bit more about your project (e.g. the correlation modes) and always assumes the default values for some parameters (number of antennas and PWV)

 Some theoretical background Refer to Ch. 9 of the ALMA Cycle 5 Technical Handbook for more details

Doc 5.3, ver. 1.0 | March 21, 2017

ALMA Cycle 5 Technical Handbook





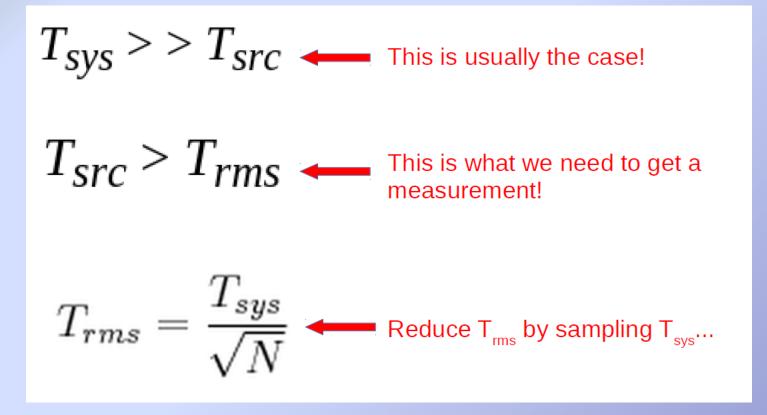
$$P_{\nu} = I_{\nu} dA d\Omega$$
$$= \frac{2kT_{src}}{\lambda^2} dA d\Omega$$
$$= 2kT_{src}$$

RJ limit means: power ~ specific intensity ~ (brightness) temperature

 $T_{sys} = T_{sky} + T_{Rx}$ Something we don't need!

$$T_{sys} > > T_{src}$$

We need $T_{src}!$ What to do?



the sky component

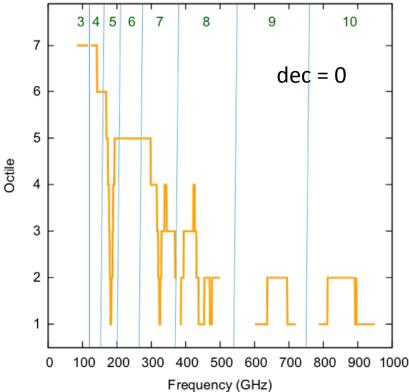
$$T_{\rm sky}(z) = T_{\rm sky}(z=0) \frac{(1-e^{-\tau_0 \sec z})}{(1-e^{-\tau_0})}$$

- z zenith angle
- T_{sky}(z=0) and the atmospheric zenith opacity τ₀ are determined by the Atmospheric Transmission at Microwaves (ATM) code (Pardo et al. 2001) based on experimental measurements
- It includes the CMB as well as the Planck correction

Octile	PWV (mm)
1	0.472
2	0.658
3	0.913
4	1.262
5	1.796
6	2.748
7	5.186

Table 9.1: Octiles of PWV measured at the ALMA site from years of monitoring data and used in the ASC. The first octile corresponds to the best weather conditions and shows that 12.5% of the time, PWV values at least as good as 0.472 mm can be expected. Subsequent octiles give the corresponding value for 25%, 37.5%. etc.

- Automatic choice of the PWV octile: the worst, for which the int. time needed is still less than twice the previous one
- Generally higher freq. requires better weather
- But some lines are prominent (like e. g. 183 GHz water line in band 5)
- Source declination determines the elevation, in assumption of transit, so *extreme cases also need better PWV*
- You can play with PWV during the preparation, but for the final calculation of int. time OT will force the automatic choice!



the Rx component

ALMA Band	Receiver Type	$T_{\rm rx,spec}$ (K)	$T_{\rm rx,ASC}$ (K)
1	SSB	17	17
2	\mathbf{SSB}	30	30
3	2SB	37	45
4	2SB	51	51
5	2SB	65	55
6	2SB	83	55
7	2SB	147	75
8	2SB	196	150
9	DSB	175	110
10	DSB	230	230

Table 9.2: Receiver temperatures (and their specifications) assumed in the ASC as a function of ALMA band. For most of the bands it is currently assumed the ALMA specification for the receiver temperature that should be achieved across 80% of the band, $T_{\rm rx,spec}$. In practice, the receivers actually outperform the specification and for Bands 3, 6, 7, 8 and 9 the ASC uses "typical temperatures measured in the laboratory" (highlighted in bold text).

- at the moment no freq. dependence across the band and the actually measured values included only for some bands (specification for the others)
- note that usually ALMA receivers *outperform* the specification!

the spillover component

- assumes the typical T_{amb}=270K ambient temperature (which still results in frequency dependence due to the Planck correction)
- assumes the fixed coupling factor or forward efficiency η_{eff} = 0.95, i. e. 5% spillover

the total Tsys

$$T_{\rm sys,ndsb} = \frac{1}{\eta_{\rm eff} e^{-\tau_0 \sec z}} \Big(T_{\rm rx} + \eta_{\rm eff} T_{\rm sky,s} + (1 - \eta_{\rm eff}) \times T_{\rm amb,s} \Big)$$

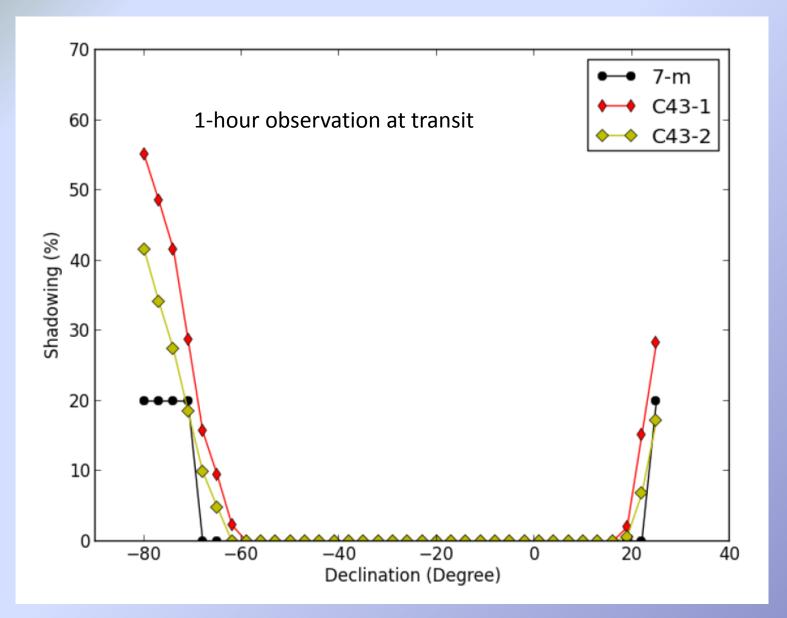
- This expression is for non-DSB receivers, i. e. single sideband (SSB) in bands 1-2 or sideband-separating (2SB) in bands 3-8.
- For bands 9-10 and their double sideband (DSB) receivers see the handbook for some complications!

the final sensitivity expression (point-source sensitivity in Jy)

$$\sigma_{\rm S} = \frac{w_r \, 2 \, k \, T_{\rm sys}}{\eta_{\rm q} \eta_{\rm c} A_{\rm eff} (1 - f_s) \sqrt{N(N - 1) \, n_{\rm p} \, \Delta \nu \, t_{\rm int}}}$$

- slightly simpler for the total power array, refer to the handbook for details
- includes a few factors close to 1: ω_r =1.1 (robust weighting factor, assuming Briggs weighting 0.5); η_q = 0.96 (3-bit quantization efficiency), η_c = 0.88 (correlator efficiency assuming 64-input mode)
- $n_p = 1$ for single pol and 2 for dual/full pol sometimes $n_p \Delta v$ is called "effective bandwidth"

• f_s – shadowing fraction



• $A_{\rm eff}$ – the effective area

Band	Frequency (GHz)	$\eta_{\rm ap,12\ m}$ (%)	$\eta_{\rm ap,7\ m}\ (\%)$
3	100	71	71
4	145	70	71
6	230	68	69
7	345	63	66
8	405	60	64
9	690	43	52
10	870	31	42

Table 9.3: Aperture efficiencies at typical continuum frequencies for both the 12 and 7 m antennas. The effective area, A_{eff} , is equal to η_{ap} multiplied by the physical area of the dish i.e. 113.1 m² and 38.5 m² for the 12 and 7 m antennas respectively.

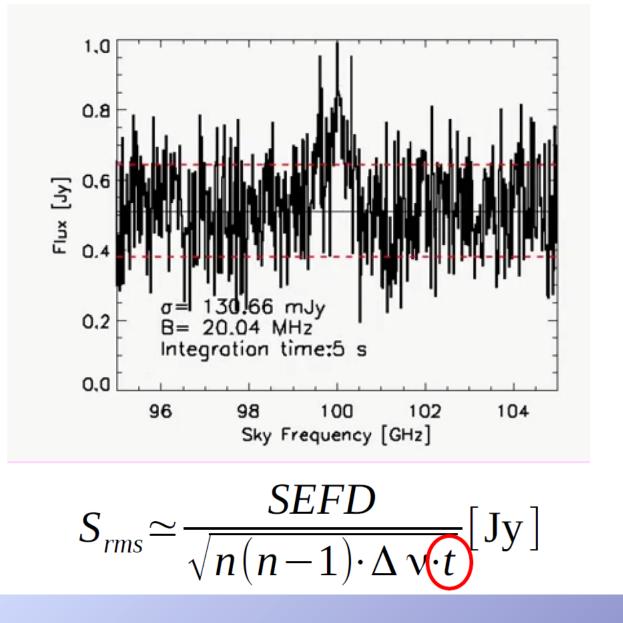
a simpler version

System Equivalent Flux Density

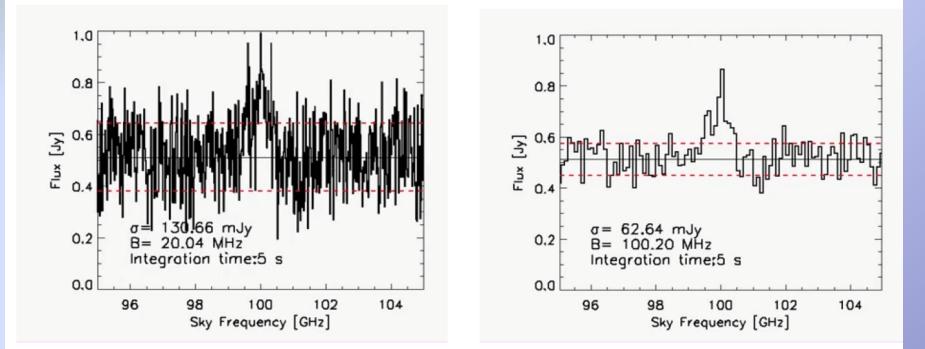
$$S_{rms} \simeq \frac{SEFD}{\sqrt{n(n-1)} \cdot \Delta v \cdot t} [Jy]$$

n(n-1) = number of baselines, n is the number of antennas $<math>\Delta v =$ frequency range (bandwidth) in Hz t = exposure time (on source time) in seconds

Effects of time on source



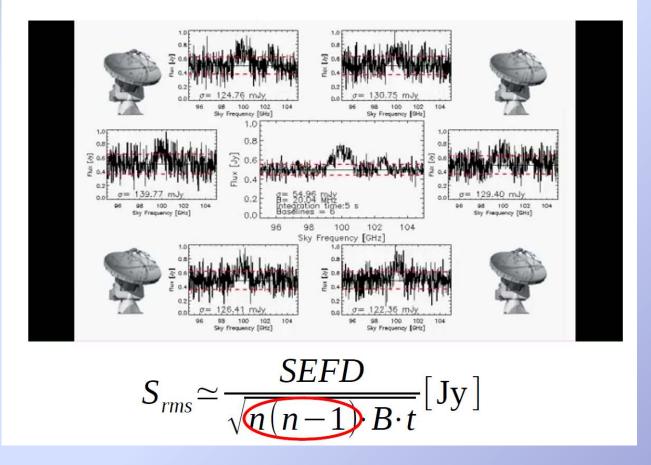
Effects of Resolution



Note: 7.5 GHz = 4 x 1.875 GHz should be used for "continuum bandwidth"

$$S_{rms} \simeq \frac{SEFD}{\sqrt{n(n-1)\cdot B}t} [Jy]$$

Adding More Antennas...



Note: for the final sensitivity calculation the OT will always use a "standard" number of antennas for this cycle: 43 for the 12-m array and 10 for the 7-m array!

$$\sigma_{\rm T} = \frac{\sigma_{\rm S} \lambda^2}{2k \ \Omega}$$

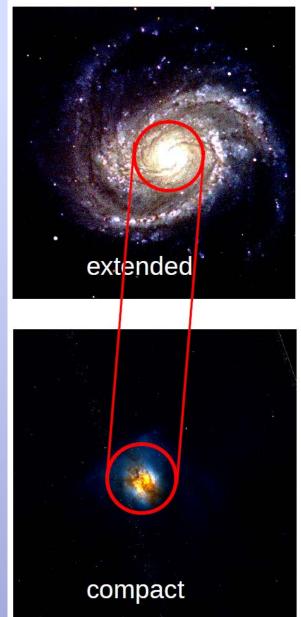
 σ_{T} – surface brightness sensitivity in K as related the point-source sensitivity in Jy (σ_{s})

$$\Omega = \frac{\pi \theta^2}{4\ln 2}.$$

A circular Gaussian beam related to the half-power beam width θ (the ASC input parameter)

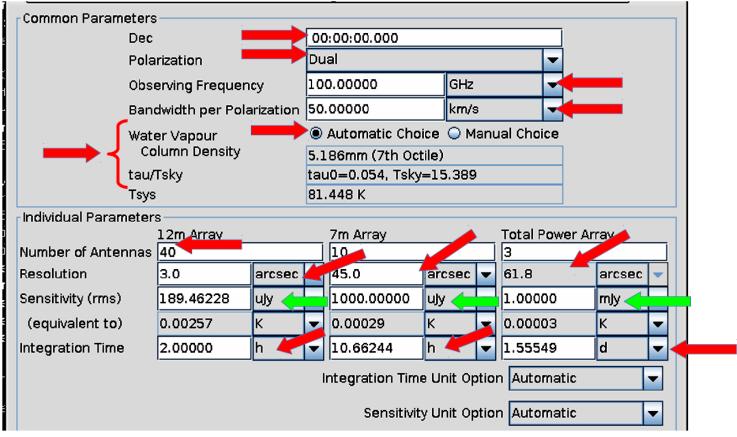
The ASC calculates both σ_{T} and σ_{s} !

Source size:



Inputs to calculator:

- declination (for elevation)
- frequency (e.g. for atmospheric absorbtion etc.)
- weather (optional)
- number of antennas (gives number of baselines)
- resolution (gives the Δv)
- integration time (gives the value of t)



Output:

- Sensitivity reached

Inputs to calculator:

- declination (for elevation)
- frequency (e.g. for atmospheric absorbtion etc.)
- weather (optional)
- number of antennas (gives number of baselines)
- resolution (gives the Δv)
- desired sensitivity (gives the value of S_{rms} or T_{rms})

Common Parameters 00:00:00.000 Dec Polarization Dual **Observing Frequency** 100.00000 GHz Bandwidth per Polarization 50.00000 km/s Automatic Choice O Manual Choice Water Vapour Column Density 5.186mm (7th Octile) tau/Tsky tau0=0.054, Tsky=15.389 Tsys 81.448 K Individual Parameters Total Power Array 12m Array 7m Array Number of Antennas 40 10 3 arcsec 45.0 61.8 Resolution 3.0 arcsec arcsec Sensitivity (rms) 1000.00000 1.00000 189.46228 uly uly mjy i 0.00029 (equivalent to) 0.00257 0.00003 К К к 2.00000 10.66244 1.55549 Integration Time h. h d -Integration Time Unit Option Automatic Sensitivity Unit Option Automatic •

Output:

- Integration time required

Not magic!

- The ASC does not know about certain things (e. g. some telescope and software limitations) and makes some ideal assumptions
- The most important one: ALL time is assumed to be the onsource integration time. It is YOUR responsibility to allow the overhead for calibration etc. and check the OT's final estimate!

