

ALMA 感度計算のまとめ

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お急ぎの方は **Results** をご参照ください。

内容が煩雑かもしれません。

ご不明な点は、容赦なく田村までお問い合わせください。

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Cycle 1 Capabilities

- ❖ From “Pre-announcement for Cycle 1” (<http://almascience.nao.ac.jp/call-for-proposals/news/pre-announcement-for-cycle-1>)
- ❖ The ALMA Early Science Cycle 1 anticipated capabilities will comprise:
 - ❖ **Thirty two 12-m antennas in the main array**, and nine 7-m antennas (for short baselines) and two 12-m antennas (for making single-dish maps) in the Atacama Compact Array (ACA)
 - ❖ ==> $\sqrt{4.13} = 2.03$ times more sensitive than Cycle 0 (for fixed integ. time)
 - ❖ **Receiver bands 3, 6, 7 & 9 (wavelengths of about 3, 1.3, 0.8 and 0.45 mm)**
 - ❖ ==> same as Cycle 0
 - ❖ **Baselines up to 1km**
 - ❖ ==> 4 times higher resolution than Cycle 0 (for a fixed observing band)
 - ❖ Both **single field interferometry** and **mosaics**
 - ❖ (==> but, # of FoVs will be limited.)
 - ❖ Mixed correlator modes (both high and low frequency resolution in the same observation)
 - ❖ Use of the ACA for short baseline interferometry and single-dish observations will only be offered to complement observations with the main array, and not as a stand-alone capability. Single dish use will be limited to spectral line observations. More details will be provided in the Call for Proposals.

Sensitivity calculation

- ❖ The sensitivity calculations are based on the “ALMA Sensitivity Calculator”, which is available at the ALMA User Portal (<http://almascience.nao.ac.jp/call-for-proposals/sensitivity-calculator>).

The screenshot shows the "Sensitivity Calculator — Welcome to the Science Portal at NAOJ" page. The left sidebar has a "User Services at ARCs" section with links for Helpdesk, EU ARC, NA ARC, and EA ARC. The main content area is titled "Sensitivity Calculator" and includes a brief description of the tool's purpose and usage. It features two sections: "Common Parameters" and "Individual Parameters".

Common Parameters:

Dec	00:00:00.000
Polarization	Dual
Observing Frequency	107.6 GHz
Bandwidth per Polarization	300.0 km/s
Water Vapour Column Density	Calculator Chooses
tau/Tsky	tau=0.046, Tsky=14.506 K
Tsys	78.170 K

Individual Parameters:

	12m Array	7m Array	Total Power Array
Number of Antennas	32	0	0
Resolution	0.00000 arcsec	19.156330 arcsec	47.890825 arcsec
Sensitivity(rms)	0.18555 mJy	Infinity Jy	Infinity Jy
(equivalent to)	Infinity K	Infinity K	Infinity K
Integration Time	26.6667 min	0.00000 s	0.00000 s

At the bottom are two buttons: "Calculate Integration Time" and "Calculate Sensitivity".

Continuum observations

-- L_{FIR} , M_{dust} and SFR of a galaxy which is detected in 10 min

❖ Assumptions

- ❖ 1 component of gray body
- ❖ **Dust temperature $T_{\text{dust}} = 35 \text{ K}$ (typical in LIRGs)**
- ❖ **Emissivity index $\beta = 1.5$ (typical in LIRGs)**
- ❖ Emissivity $\kappa(850\text{um}) = 0.15 \text{ m}^2 \text{ kg}^{-1}$ (Hildebrand 1983)

❖ Parameters used in the calculation

- ❖ **Thirty-two 12-m antennas**
- ❖ **Bandwidth per polarization 7.5 GHz, num. of polarization = 2**
- ❖ “Calculator Choose” for an atmospheric condition

❖ Formulae

$$M_{\text{dust}} = \frac{S_{\text{obs}} D_{\text{L}}^2}{(1+z) \kappa_d(\nu_{\text{rest}}) B_{\nu}(\nu_{\text{rest}}, T_{\text{dust}})}$$

$$L_{\text{FIR}} = 4\pi M_{\text{dust}} \int_0^{\infty} \kappa_d B_{\nu}(\nu_{\text{rest}}, T_{\text{dust}}) d\nu \quad L_{\text{FIR}} = \frac{8\pi h}{c^2} \frac{\lambda_{\text{rest}}^{\beta} \kappa_d(\lambda_{\text{rest}})}{c^{\beta}} \left(\frac{k T_{\text{dust}}}{h} \right)^{\beta+4} \Gamma[\beta+4] \zeta[\beta+4] M_{\text{dust}}$$

- ❖ $S\text{FR} = 200 \times (L_{\text{FIR}} / 10^{12} L_{\odot}) \text{ M}_{\odot} \text{ yr}^{-1}$ (Kennicutt 1998)

Results

Continuum observations

-- L_{FIR} , M_{dust} and SFR of a galaxy which is detected in 10 min

- ❖ The FIR luminosities, dust masses, and SFRs of galaxies at $z = 1.5$ to 6.5 which Cycle-1 ALMA will detect at 5 sigma. Note that the values depend largely on dust temperature.

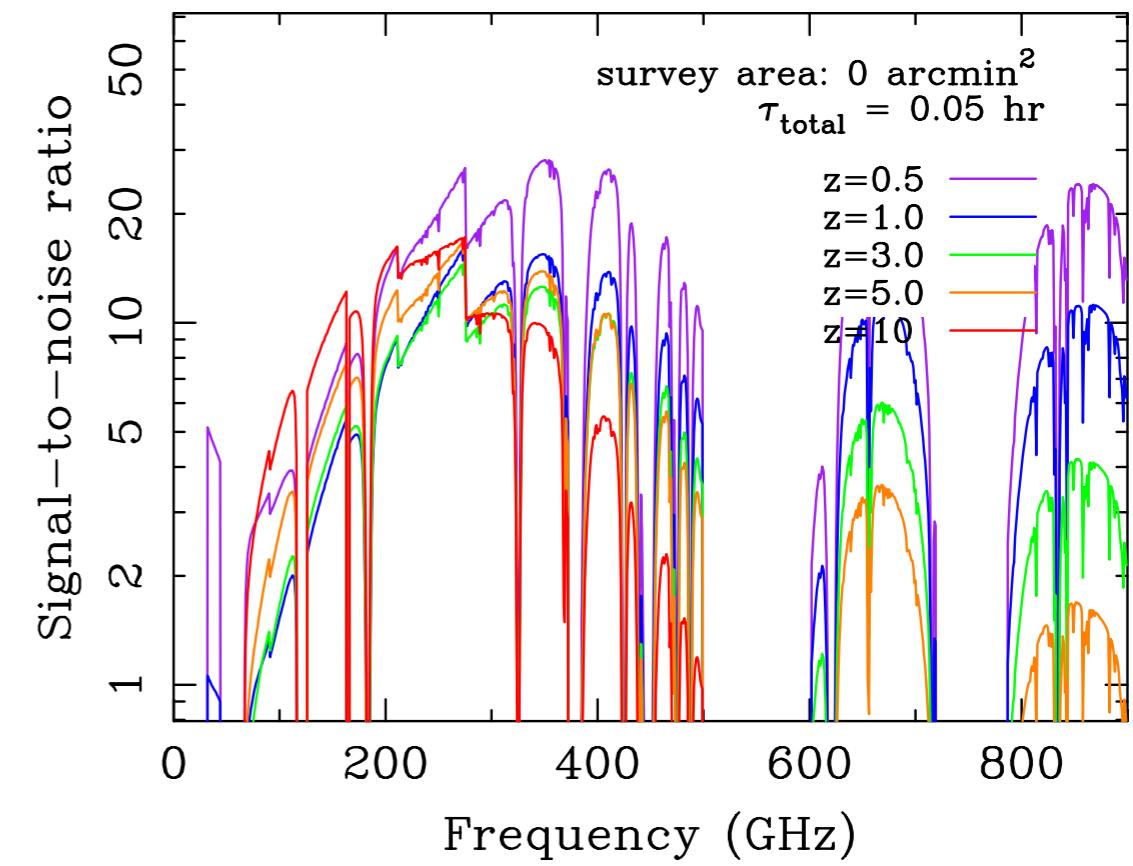
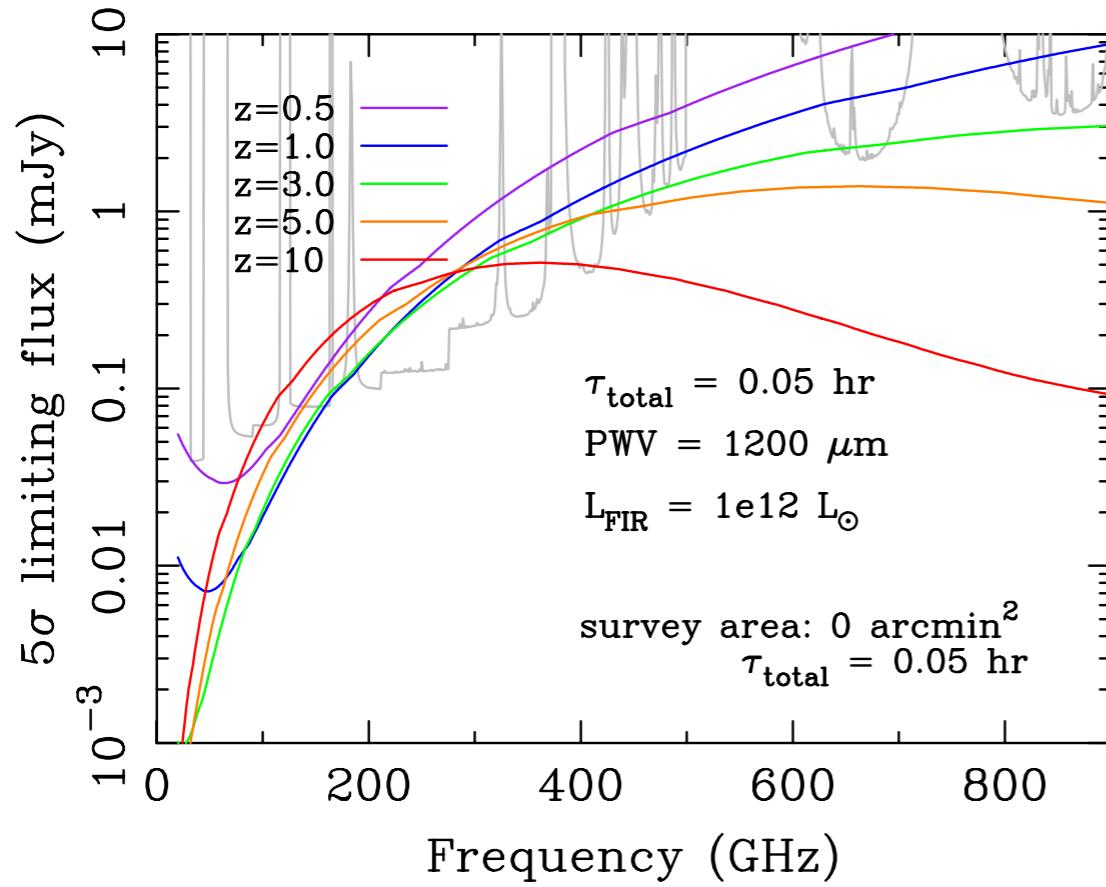
N_antenna = 32 (Early Science, Cycle 1)							
wave-length (um)	5-sigma lim.flux (mJy)	z=1.5			z=2.5		
		L_{FIR} (Lsun)	/ M_{dust} (Msun)	/ SFR (Msun/yr)	L_{FIR} (Lsun)	/ M_{dust} (Msun)	/ SFR (Msun/yr)
3000	0.179	5.3e+12	/ 8.1e+08	/ 1e+03	4.3e+12	/ 6.7e+08	/ 8e+02
1100	0.289	3.5e+11	/ 5.4e+07	/ 7e+01	3.4e+11	/ 5.2e+07	/ 7e+01
850	0.484	2.8e+11	/ 4.3e+07	/ 6e+01	2.9e+11	/ 4.5e+07	/ 6e+01
450	4.982	6.2e+11	/ 9.5e+07	/ 1e+02	9.1e+11	/ 1.4e+08	/ 2e+02
wave-length (um)	5-sigma lim.flux (mJy)	z=3.5			z=4.5		
		L_{FIR} (Lsun)	/ M_{dust} (Msun)	/ SFR (Msun/yr)	L_{FIR} (Lsun)	/ M_{dust} (Msun)	/ SFR (Msun/yr)
3000	0.179	3.4e+12	/ 5.2e+08	/ 7e+02	2.7e+12	/ 4.2e+08	/ 5e+02
1100	0.289	3.1e+11	/ 4.8e+07	/ 6e+01	2.9e+11	/ 4.5e+07	/ 6e+01
850	0.484	2.9e+11	/ 4.5e+07	/ 6e+01	3.0e+11	/ 4.6e+07	/ 6e+01
450	4.982	1.3e+12	/ 2.0e+08	/ 3e+02	3.1e+12	/ 3.1e+08	/ 6e+02
wave-length (um)	5-sigma lim.flux (mJy)	z=5.5			z=6.5		
		L_{FIR} (Lsun)	/ M_{dust} (Msun)	/ SFR (Msun/yr)	L_{FIR} (Lsun)	/ M_{dust} (Msun)	/ SFR (Msun/yr)
3000	0.179	2.2e+12	/ 3.4e+08	/ 4e+02	1.9e+12	/ 2.9e+08	/ 4e+02
1100	0.289	2.8e+11	/ 4.3e+07	/ 6e+01	2.8e+11	/ 4.3e+07	/ 6e+01
850	0.484	3.2e+11	/ 4.9e+07	/ 6e+01	3.5e+11	/ 5.4e+07	/ 7e+01
450	4.982	3.2e+12	/ 4.9e+08	/ 6e+02	5.3e+12	/ 8.2e+08	/ 1e+03

Results

Continuum observations

-- Arp 220 versus 5-sigma limiting flux (32 ant., 3 min integ.)

- ❖ (Left) Comparison between SEDs of a $L_{\text{FIR}} = 1.0 \times 10^{12} L_{\odot}$ galaxy at $z = 0.5$ to 10 (color curves) and the 5-sigma limiting flux achieved in 3 minutes with Cycle-1 ALMA (grey curve).
- ❖ (Right) The signal-to-noise ratio of a $L_{\text{FIR}} = 1.0 \times 10^{12} L_{\odot}$ galaxy at $z = 0.5$ to 10, as a function of observing frequency.

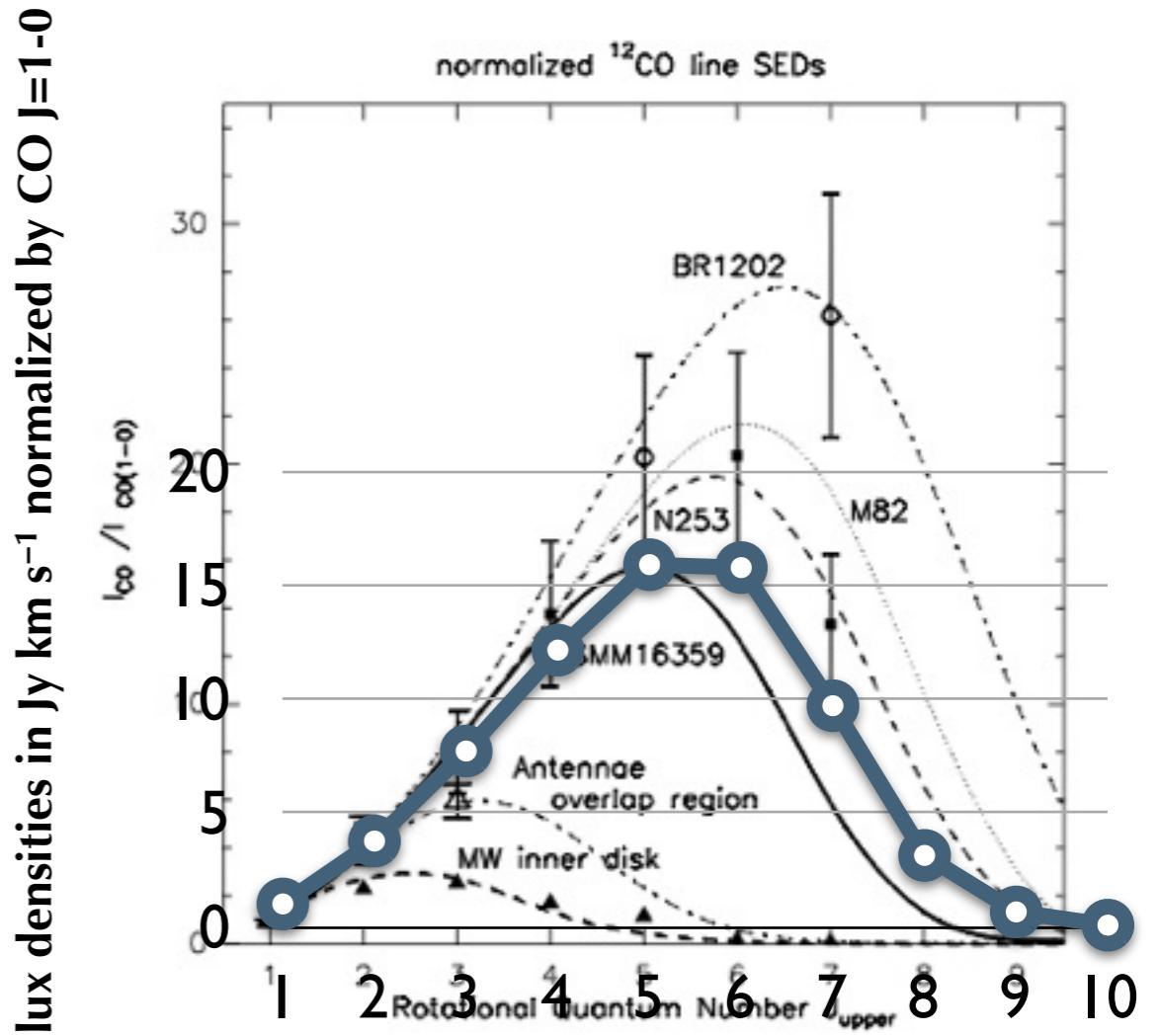


CO line observations

-- M(H₂) of a galaxy which is detected in 1.0 hr

❖ Assumptions

- ❖ CO excitation is estimated with RADEX (van der Tak+07)
- ❖ CO photons come from a big collection of small cloudlets, each of which is a uniform sphere with...
 - ❖ $\Delta v = 1$ km/s.
 - ❖ **Temperature = 40 K**
 - ❖ Hydrogen molecule density $3e+3$ cm⁻³
 - ❖ a photon that leaves a cloudlet will not be absorbed by another cloudlet.
- ❖ **The line FWHM = 300 km/s**
- ❖ Parameters used in the calculation
 - ❖ **Thirty-two 12-m antennas**
 - ❖ **Bandwidth per polarization: 300 km/s**
 - ❖ “Calculator Choose” for an atmospheric conditions
 - ❖ **The L'co-to-M(H₂) conversion factor X_{co} = 0.8 M_{Sun} / (K km/s pc²)**



The CO SED estimated with RADEX (thick curve) and those of high-z and nearby starbursts, and the Milky Way from Weiss et al. (2005).

Results

CO line observations

-- M(H₂) of a galaxy which is detected in 1.0 hr

- ❖ The H₂ molecular masses of a galaxy at z = 1.5 to 6.5, which 1.0-hr integration with Cycle-1 ALMA will detect at 5 sigma. Note that observing CO at *lower transitions* in Band 3 is recommended because CO intensities at J = 5-4 or higher transitions strongly depend on physical conditions of molecular gas and thus are very uncertain.

N_antenna = 32 (Early Science, Cycle 1)

Trans-	nu_obs (GHz)	/ 5-sigma limiting	S _{CO} *dV (Jy km/s)	/ H₂ mass (Msun)
ition	z=1.5	z=2.5	z=3.5	
J=1-0	...	/ ... / ...	...	... / ... / ...
J=2-1	92.2	/ 0.19 / 4.6e+09	...	... / ... / ...
J=3-2	...	/ ... / ...	98.8 / 0.18 / 5.5e+09	... / ... / ...
J=4-3	...	/ ... / ...	...	102.5 / 0.18 / 6.1e+09
J=5-4	230.5	/ 0.18 / 1.0e+09	...	... / ... / ...
J=6-5	276.6	/ 0.21 / 1.2e+09	...	... / ... / ...
J=7-6	...	/ ... / ...	230.5 / 0.18 / 4.3e+09	... / ... / ...
J=8-7	...	/ ... / ...	263.5 / 0.19 / 1.4e+10	... / ... / ...

Trans-	nu_obs (GHz)	/ 5-sigma limiting	S _{CO} *dV (Jy km/s)	/ H ₂ mass (Msun)
ition	z=4.5	z=5.5	z=6.5	
J=1-0	...	/ ... / ...	...	... / ... / ...
J=2-1	...	/ ... / ...	...	... / ... / ...
J=3-2	...	/ ... / ...	...	... / ... / ...
J=4-3	83.8	/ 0.16 / 7.8e+09	...	... / ... / ...
J=5-4	104.8	/ 0.18 / 6.9e+09	88.7 / 0.19 / 9.8e+09	... / ... / ...
J=6-5	...	/ ... / ...	106.4 / 0.18 / 9.5e+09	92.2 / 0.19 / 1.2e+10
J=7-6	...	/ ... / ...	...	107.6 / 0.19 / 2.0e+10
J=8-7	...	/ ... / ...	...	... / ... / ...