

# Feasibility Check

calculation for expected flux density

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- ▶ Before we start ... Tips for T.J.
- ▶ Where do we start
- ▶ Flux density
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Before we start ...

Check lists: To achieve the Science Goal,

- ▶ Is the target best?
  - ▶ nearest, brightest, first
- ▶ Is the largest beam size?
- ▶ Is the shortest integration time?
- ▶ Is the band best?
  - ▶ Optically thin, efficient spectral setup,,

# ALMA Sensitivity calculator / Observing Tool

almascience.nao.ac.jp/proposing/sensitivity-calculator

**Common Parameters**

Declination: 00:00:00.00 ✓

Polarisation: Dual ▾

Observing Frequency: 345 GHz ▾

Observing Band: ALMA\_RB\_07 ▾

Bandwidth per Polarization: 0.1 km/s ▾

Water Vapour:  Automatic Choice  Manual Choice

Column Density: 0.913mm (3rd Octile) ▾

Trx, tau, Tsky: 72 K, 0.158, 39.538 K

Tsys: 153.278 K

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**Individual Parameters**

	12 m Array	7 m Array	Total Power Array
Number of Antennas	43 ✓	10 ✓	3 ✓
Resolution	0.3 arcsec ✓	0 arcsec ✓	9.5 arcsec ✓
Sensitivity (rms)	1 K ✓	2.4826852653365648 mJy ✓	4.85010668201959 mJy ✓
Equivalent to	8.761179 mJy	Unknown K	0.174 mK
Integration Time	31.61216 min ✓	43.12316 d ✓	34.99973 d ✓

Integration Time Unit Option: Automatic ▾

Sensitivity Unit Option: Automatic ▾

Calculate Integration Time    Calculate Sensitivity

ALMA Observing Tool (Cycle 11 (Phase 2 Patch 1)) - Project

File Edit View Tool Search Help

Project Structure    Editors

Proposal    Program    Spectral    Spatial    Control and Performance

Unsubmitted Proposal

- Project
  - Proposal
    - Planned Observing
      - Science Goal (Science Goal)
        - General
          - Field Setup
          - Spectral Setup
          - Calibration Setup
          - Control and Performance
          - Technical Justification

These parameters are used to control various aspects of the observations, including the required antenna configurations and integration times.

Configuration Information

Antenna Beamsize (1.13 \* A / D)    12m    17.615 arcsec    7m    30.197 arcsec

Number of Antennas    12m    43    7m    10    TP    3

Longest baseline    0.049 km    0.161 km    16.197 km

Synthesized beamsize    3.800 arcsec    0.981 arcsec    0.016 arcsec

Shortest baseline    0.009 km    0.015 km    0.256 km

Maximum recoverable scale    20.279 arcsec    8.777 arcsec    0.151 arcsec

Desired Performance

Desired Angular Resolution (Synthesized Beam)     Single  Range  Any  Standalone ACA

0.15000 arcsec ▾

Largest Angular Structure in source    0.30000 arcsec ▾

Desired sensitivity per pointing    7.07 mJy    equivalent to    3.5157 K

Bandwidth used for Sensitivity    RepWindowEffectiveChannelWidth ▾    Frequency Width    0.097656 MHz

Override OT's sensitivity-based time estimate (must be justified)     Yes  No

Science Goal Breakdown: time estimate, clustering, beam and configurations    [Planning and Time Estimate](#)

Simultaneous 12-m and ACA observations     Yes  No

Are the observations time-constrained?     Yes  No

**Feedback**

Validation    Validation History    Log

**Planning and Time Estimate**

Note: The time in brackets is that required to reach the sensitivity. Operational requirements often mean that the actual observed time is longer, especially for mosaics. Please see the User Manual for more details.

**Input Parameters**

Requested sensitivity    7.070 mJy

Bandwidth used for sensitivity    0.098 MHz

Representative frequency (sky, first source)    330.574 GHz

**Estimated Total time for Science Goal    4.46 h**

Cluster 1

Source Name	RA	Dec	Velocity
TW Hya	11:01:51.9053	-34:42:17.033	12.335 km/s

**Possible Configuration Combinations**

12-m (1)	12-m (2)	7-m	TP
C-6	None	No	No

**Input Parameters**

Precipitable water vapour (all sources)    0.913mm (3rd Octile)

**Time required for 12m (1) [C-6]**

Time on source per pointing (first source)    1.41 h [1.41 h]

Total number of pointings (all sources)    1

Number of tunings    1

Total time on source    1.41 h [1.41 h]

Total calibration time    2.90 h

Other overheads    9.20 min

Total time for 1 SB execution    1.49 h

Number of SB executions    3

Total time to complete SB    4.46 h

**Calibration Breakdown per SB execution**

4 x Pointing    8.00 min

1 x Amplitude/bandpass    10.00 min

19 x Phase    5.70 min

4 x Check-Source    2.00 min

2 x DGC    8.00 min

10 x Atmospheric    6.67 min

1 x DGC Bandpass    5.00 min

Close

# Integration time table for CO with rms of 1 K

CO transition	Freq. (GHz)	ALMA Band	RMS (mJy) @0.3" w/ 1K	Integration time (0.1km/s)	ALMA configuration
1-0	115.271	3	0.98	3.7d/ 2.68 d/ 9.2 d	C-7 (0.092 km/s)
2-1	230.538	6	3.9	1.47h/1.13h/3.59 h	C-5 ( 0.092 km/s)
<b>3-2</b>	<b>345.796</b>	<b>7</b>	<b>8.8</b>	<b>31.5m/23.7m/ 1.36h</b>	<b>C-5 (0.122 km/s)</b>
4-3	461.041	8	15.6	76.9 min/55.4m/2.75h	C-4 (0.092km/s)
5-4	576.267	X			
6-5	691.473	9	35.2	2.93h/1.58h/5.22h	C-3 (0.122 km/s)
7-6	806.652	10	47.8	3.85h/2.48h/7.37h	C-3 (0.105km/s)
8-7	921.7997	10	62.5	30.7h/16.35h/1.96d (A/ B/ C)	C-2 (0.092km/s)

## Integration time:

A: on-source time using sensitivity calculator

B: on-source time using OT

C: total observing time (B + time for calibration + etc)

# Which band should be chosen?

- ▶ CO transitions can be covered in the Bands 3, 6, and 7. You should describe why the band is chosen.
  - ▶ For a given integration time, band 7 provides the highest SNR.
  - ▶ Other lines of interest can be covered within 1 S.G.s.
  - ▶ A relation use the CO 1-0 line..
  - ▶ Optically thin line is located only in Band 3.
  - ▶ When considering of interstellar extinction (optical depth of continuum emission), the line in Band # can trace the midplane of target ...

Requested RMS over  is

**A** For a peak flux density of , the S/N is

Achieved RMS over the total  bandwidth is

For a continuum flux density of , the achieved S/N is

For a peak line flux of  **B**, the achieved S/N over 1/3 of the source line width (  / 3 =  ) is

Line width / bandwidth used for sensitivity (  /  ) =

**C Integrated Intensity**

Justify your requested RMS and resulting S/N for the spectral line and/or continuum observations.

For line observations also justify the bandwidth used for the sensitivity calculation.

1. How the expected flux density is estimated.
2. Which SNR is used among A, B, and C.
3. Why is the SNR enough to achieve the Science Goal?

- We may observe with fine spectral resolution for kinematics, but the **detection requirement** can be evaluated at a coarser resolution (e.g., FWHM/3) (B).

- Although it is a line observation, describe the information and arguments for the continuum

Tip: You can refer the figures in S.J. and/or cite references ( XX et al. ApJ, ###, ###)

For the same integration time,

$$\frac{RMS(NEW)}{RMS(OLD)} = \sqrt{\frac{\Delta v(old)}{\Delta v(new)}}$$

# Flux density [ mJy beam<sup>-1</sup>]

▶ Flux :  $F_\nu = I_\nu \cdot \Omega$

▶ Solid angle

▶ for gaussian beam

$$\Omega = \frac{\pi}{4 \ln 2} B_{\text{maj}} B_{\text{min}} = 1.133 B_{\text{maj}} B_{\text{min}}$$

▶ Rayleigh-Jeans limit :  $h\nu/kt \ll 1$

$$\left( \frac{T}{1 \text{ K}} \right) = \left( \frac{S_\nu}{1 \text{ Jy}} \right) \left[ 13.6 \left( \frac{300 \text{ GHz}}{\nu} \right)^2 \left( \frac{1''}{\theta_{\text{max}}} \right) \left( \frac{1''}{\theta_{\text{min}}} \right) \right]$$

# Radiative Transfer

- ▶ Use a simple radiative transfer expression:

$$I_\nu = S_\nu(T_{\text{ex}}) (1 - \exp(-\tau_\nu)) + I_{\text{bg}} \exp(-\tau_\nu) \\ \simeq B_\nu(T_{\text{ex}}) (1 - \exp(-\tau_\nu))$$

- ▶ Two common approximations:

- **Optically thick** ( $\tau \gg 1$ ):  $I_\nu = B_\nu(T_{\text{ex}})$
- **Optically thin** ( $\tau \ll 1$ ):  $I_\nu = B_\nu(T_{\text{ex}}) \cdot \tau_\nu$

Dust continuum emission :

$$I_\nu = B_\nu(T_{\text{ex}}) \cdot \tau_\nu \propto \left( \frac{\nu}{\nu_{\text{ref}}} \right)^{2+\beta}$$

# Line : radex online

Radex on-line: Main Page

var.sron.nl/radex/radex.php

## RADEX

Non-LTE molecular radiative transfer in an isothermal homogeneous medium

This program is free to use for everybody, provided that publications make a reference to our papers: Van der Tak, F.F.S., Black, J.H., Schöier, F.L., Jansen, D.J., van Dishoeck, E.F., 2007, A&A 468, 627-635; Dwiriyanti, C., Van der Tak, F.F.S., de Plaa, J., 2024, A&A, submitted.

Molecule / Data file:

Spectral Range

Minimum frequency (GHz):

Maximum frequency (GHz):

Excitation Conditions

Background temperature (K):

Kinetic temperature (K):

H<sub>2</sub> density (cm<sup>-3</sup>):

Radiative Transfer Parameters

Column density (cm<sup>-2</sup>):

Line width (km s<sup>-1</sup>):

Choose method to calculate

The escape probability (β):

The excitation temperature (T<sub>ex</sub>):

Relative tolerance (ε):

under-relaxation factor (α):

Unit: K.

Transition	Frequency (GHz)	I <sub>ex</sub> (K)	tau	I <sub>R</sub> (K)
1 -- 0	115.2712	55.656	1.799E-03	9.362E-02
2 -- 1	230.5380	18.151	1.570E-02	2.022E-01
3 -- 2	345.7960	13.543	1.980E-02	1.345E-01
4 -- 3	461.0408	13.114	8.928E-03	4.459E-02

$$\left(\frac{T}{1 \text{ K}}\right) = \left(\frac{S_\nu}{1 \text{ Jy}}\right) \left[ 13.6 \left(\frac{300 \text{ GHz}}{\nu}\right)^2 \left(\frac{1''}{\theta_{max}}\right) \left(\frac{1''}{\theta_{min}}\right) \right]$$

# Where do we start?

- ▶ low-resolution data for the same line/continuum?
- ▶ Same molecular lines in other bands
- ▶ In other source with similar characteristics?
- ▶ From model (theory...)

Higher angular resolution (smaller beam > 2x)

$$\frac{\Omega_{\text{new}}}{\Omega_{\text{old}}} \propto \left( \frac{B_{\text{new}}}{B_{\text{old}}} \right)^2$$

- Use a conservative assumption first (uniform emission)
- This often underestimates the peak flux density if the emission is compact. You should justify this using prior data or analog sources.
  - high resolution molecular line tracing similar gas shows compact emission

S.G. : CO 3-2, Line width = 1 km/s, 0.1''

- ▶ Previous data : CO 2-1, 0.3'', peak flux = 120 mJy
  - ▶ 0.3'' → 0.1 '' :  $120 \text{ mJy} * (0.1/0.3)^2 = 13.3 \text{ mJy}$

S.G. : CO 3-2, Line width = 1 km/s, 0.1''

- ▶ Previous data : CO 2-1, 0.3'', peak flux = 120 mJy
  - ▶ 0.3'' → 0.1 '' :  $120 \text{ mJy} * (0.1/0.3)^2 = 13.3 \text{ mJy}$
  - ▶ 2-1 → 3-2 :  $21.9 \text{ mJy} ( 13.3 \text{ mJy} * 1.64)$
  - ▶  $1.64 = (345.538\text{GHz}/230.538\text{GHz})^2 * (8.35\text{K}/11.5\text{K})$

$$\left(\frac{T}{1 \text{ K}}\right) = \left(\frac{S_\nu}{1 \text{ Jy}}\right) \left[ 13.6 \left(\frac{300 \text{ GHz}}{\nu}\right)^2 \left(\frac{1''}{\theta_{max}}\right) \left(\frac{1''}{\theta_{min}}\right) \right]$$

Transition	Frequency (GHz)	$T_{ex}$ (K)	$\tau$	$I_R$ (K)
1 -- 0	115.2712	37.853	2.418E-01	7.369E+00
2 -- 1	230.5380	21.521	1.234E+00	1.153E+01
3 -- 2	345.7960	17.246	1.701E+00	8.356E+00
4 -- 3	461.0408	14.077	1.109E+00	3.882E+00

S.G. : CO 3-2, Line width= 1 km/s,  
0.1", 0.12 km/s

▶ Previous data : CO 2-1, 0.3", peak flu

▶ 0.3" → 0.1 " :  $120 \text{ mJy} * (0.1/0.3)^2 =$

▶ 2-1 → 3-2 :  $21.9 \text{ mJy} ( 13.3 \text{ mJy} * 1.64$

▶  $1.64 = (345.538\text{GHz}/230.538\text{GHz})^2 * (8.35\text{K}$

▶ SNR = 5 ( request rms = 4.4 mJy)

▶ Total observing time : 4.08 hr

Planning and Time Estimate ✕

Note: The time in brackets is that required to reach the sensitivity. Operational requirements often mean that the actual observed time is longer, especially for mosaics. Please see the User Manual for more details.

**Input Parameters**

Requested sensitivity	4.400 mJy
Bandwidth used for sensitivity	0.195 MHz
Representative frequency (sky, first source)	345.785 GHz

**Estimated Total time for Science Goal** **4.08 h**

Cluster 1

Source Name	RA	Dec	Velocity
TW Hya	11:01:52.9728	-34:42:24.876	0.000 km/s

**Possible Configuration Combinations**

12-m (1)	12-m (2)	7-m	TP
C-7	C-4	No	No

**Input Parameters**

Precipitable water vapour (all sources)	1.262mm (4th Octile)
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**Time required for 12m (1) [C-7]**

Time on source per pointing (first source)	1.24 h [ 1.24 h]
Total number of pointings (all sources)	1
Number of tunings	1
Total time on source	1.24 h [1.24 h]
Total calibration time	1.92 h
Other overheads	9.48 min
Total time for 1 SB execution	1.66 h
Number of SB executions	2
Total time to complete SB	3.32 h