ALMA 제안서 작성 경험 공유 & 팁

이범현

ALMA 제안서 워크샵, 천문연구원
2024.02.14

1) Personal experience

✓ Molecular gas of (spiral) galaxies in the local universe
✓ Group and cluster environments
→ Category: Galaxies and Galactic nuclei

PI: 8 ALMA proposals (Cycle 3, 4, 7, 8, 9) → 4 proposals accepted

2) Other talks and references

"Tips for writing ALMA proposals", John Carpenter
"ALMA Cycle 8 Proposal Writing Tips", Nick Indriolo
"Tips for writing ALMA proposals", Patricio Sanhueza
"Tips for writing a strong ALMA proposal", Xing Lu
"Writing ALMA proposals", Chin-Fei Lee
"I-TRAIN #13: Writing & Reviewing ALMA proposals", European ALMA Regional Centre Network → Youtube

Tips for writing ALMA proposals (my personal view)

1. **Start early (~1 - 2 months)**

2. **Check previous & ongoing ALMA projects**

3. **Know the ALMA instrument → read “ALMA Proposer’s Guide” & “Observing With ALMA – A Primer” carefully**

4. **Justify the sample and Check feasibility early**

5. **Describe ancillary data**

6. **Circulate the first draft early & discuss the draft with your collaborators**

7. **Proposal writing is different from paper writing**

8. **Do not be discouraged & disappointed**

Tips for writing ALMA proposals (my personal view)

1. Start early (~1 - 2 months)

- ✓ Reading references, justifying the sample, checking feasibility, using the ALMA Observing Tool (OT), writing & editing the draft (+ Figure and Table)

- ✓ Fully discussing your idea, strategy, methodology, and sample with your collaborators

→ **It always takes longer than you expect.**

Tips for writing ALMA proposals (my personal view)

2. Check previous & ongoing ALMA projects

(“Tips for writing ALMA proposal”, John Carpenter)

- ✓ Reading the literature
- ✓ Reading abstracts of accepted proposals (ALMA webpage → Observing: Highest Priority Projects, Cycle 1 – Cycle 10)
- ✓ Searching the ALMA archive (10 cycles) → you may use the ALMA archival data

Highest Priority Projects

Clicking on ALMA "Project Code" will spawn an ALMA Science Archive query for the project (if the link returns an empty table, then no archived data exists). Clicking on the "Abstracts" or "CoIs" links will open additional fields in the table with the corresponding metadata.

- Cycle 10 DDTs
- Cycle 10
- Cycle 9 DDTs
- Cycle 9
- Cycle 8 DDTs
- Cycle 8
- Cycle 7
- Cycle 7 DDTs
- Cycle 6
- Cycle 6 DDTs
- Cycle 5
- Cycle 5 DDTs
- Cycle 4
- Cycle 4 DDTs
- Cycle 3
- Cycle 3 DDTs
- Cycle 2
- Cycle 2 DDTs
- Cycle 1 Carryover
- Previous Cycles

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▸ Cycle 10 DDTs

▾ Cycle 10

The table below lists ALMA Cycle 10 projects with public metadata, including all Cycle 10 A- and B-graded proposals, any Cycle 10 C-graded proposals with archived observations. The public metadata includes the ALMA Project Code, program title and abstract, investigator names and institutes, the Executive to which the project is assigned (CL=Chile, EA=East Asia, EU=Europe, NA=North America, or OTHER), and the proposal science category (Category 10=Cosmology and the high redshift universe; Category 20=Galaxies and galactic nuclei; Category 31=Interstellar medium, star formation and astrochemistry; Category 41=Circumstellar disks, exoplanets and the solar system; Category 50=Stellar evolution and the Sun).

Project Code	Title (Abstracts)	PI (COIs)	Exec	Category
2023.1.00014.S	Microphysics and astrophysics at play in an assembling massive galaxy at cosmic dawn	Roberto Decarli	EU	10
2023.1.00022.S	ALMA-JWST Joint Efforts on Calibrating Gas-Phase Metallicities of Luminous Star-Forming Galaxies in the Reionization Era	Yuichi Harikane	EA	10
2023.1.00026.S	Virgo High-resolution CO(2-1) Survey: Dissecting Galaxy Quenching with Molecular Cloud Scale "Micro-physics"	Jiayi Sun	NA	20
2023.1.00030.S	High resolution characterization of early bulge and feedback in a z = 7.07 massive low-luminosity quasar	Takuma Izumi	EA	10
2023.1.00032.S	The First Cloud-Scale, Dense Gas Maps of the Nearest ALMA-Acccessible Spiral Galaxy	Thomas G Williams	EU	20
2023.1.00033.S	ALMA-FACTS: FundAmental CO 1-0 Transition Survey of Nearby Galaxies	Jin Koda	NA	20
2023.1.00038.S	Complex organic imaging towards G+0.693-0.027, the ISM COMs Rossetta Stone	Sergio Martin	EU	31
2023.1.00044.S	Unveiling the magnetic field structure in the nuclei of the Arp 220 galaxy merger	Josep M Girart	EU	20
2023.1.00045.S	Measuring the Star Forming Potential of the Galactic Bar Dust Lanes	Natalie O Butterfield	NA	31
2023.1.00052.S	The effect of the massive stellar feedback across the Carina Nebula Complex	David Rebolledo	NA	31

2023.1.00033.S	ALMA-FACTS: FundAmental CO 1-0 Transition Survey of Nearby Galaxies	Jin Koda	NA	20
COIs	Akihiko Hirota; Fumi Egusa; Tsuyoshi Sawada; Shinya Komugi; Fumiya Maeda;			
Abstract	We propose a survey of 12 nearby spiral galaxies in the fundamental CO(1-0) transition and to study the systematic variations of the CO J=2-1/1-0 ratio (R21) on GMC scales within and among the galaxies. The 12 galaxies form the complete sample of the overlaps among the ALMA PHANGS, Spitzer SINGS, and Herschel KINGFISH surveys, and hence, the rich ancillary data from these surveys, including the CO(2-1) data, are available. The variations in R21, as a function of gas physical conditions, are theoretically predicted, and have been observed in the Milky Way and some nearby galaxies with limitations. Therefore, the proposed R21 survey will show the evolution of molecular ISM on GMC scales as a function of galactic structure and star formation (SF) activity (e.g., between spiral arms and interarm regions, in and outside bars, and from circumnuclear regions to the disk outskirts). Historically, CO(1-0) has been the yardstick of molecular gas observations, while CO(2-1) is now becoming a new standard due to its relative easiness of detection. It is essential to characterize any systematic effect in R21 with a survey of a large number of galaxies.			

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3. Know the ALMA instrument

- ✓ Reading ”ALMA proposal’s Guide” & “Observing with ALMA – A Primer” (representative science cases & observing considerations) (ALMA webpage: Documentation)

- ✓ Describing why you need the ALMA shortly if needed (compared to other facilities: NOEMA, SMA, JCMT, IRAM 30m, APEX, etc; e.g., high-resolution, high-sensitivity)

Mosaicing the Nearby Spiral Galaxy M100

Science Aim: ***Map the distribution and kinematics of molecular gas in a nearby spiral galaxy***
M100 (NGC 4321) is a bright, fairly face-on spiral galaxy in the Virgo Cluster. As one of the nearest (d ~ 16 Mpc) spiral galaxies with well-defined arms and active star formation, M100 has been studied at virtually every wavelength, including the millimeter. These studies reveal a rich molecular interstellar medium (ISM) fuelling the star formation visible at optical and IR wavelengths. A bar funnels gas to the center of M100, leading to a nuclear concentration of molecular gas and star formation while fainter molecular emission traces the spiral arms. ALMA imaged M100 as a science verification target and the data are available from the Science Portal. ALMA *casaguides* provide a tutorial on combining data from the 12-m Array, the 7-m Array, and the TP Array (see https://casaguides.nrao.edu/index.php/M100_Band3).
ALMA's excellent imaging fidelity, mosaicing capabilities, and sensitivity to large angular scale (via the ACA) make a wide-field, high-resolution image of a galaxy like M100 a viable project. Such data would probe the dynamical effects of spiral arms and the nuclear bar on molecular gas, map the density distribution of the molecular ISM, and allow comparisons of molecular material to the distributions of dust, recent star formation, stellar populations, and other phases of the ISM.
Receiver(s): Band 3 (115 GHz): We consider a mosaic to observe CO (1-0) emission (~115 GHz, Band 3) across most of M100.
Spectral Sensitivity: Large molecular clouds like the Orion complex have masses ~5 × 10^5 $M_\odot$ or more. We design our survey of M100 to detect such clouds. For a CO-to-H_2 conversion factor of ~2 × 10^{20} cm^{-2} (K km/s)$^{-1}$ and assuming a CO line width of 10 km/s, a 1σ sensitivity of 3 mJy/beam corresponds to a 1σ molecular mass sensitivity of 8 × 10^4 $M_\odot$ per beam per 10 km/s channel, enough to detect Orion-like clouds at S/N ~ 5 or more.
Angular Resolution: We target a resolution of 2″, or about 150 pc at M100. This is suitable for comparison to a wide variety of multi-wavelength data and sufficient to resolve spiral arms, the bar, and large molecular complexes. At this resolution in Band 3 ALMA can achieve surface brightness sensitivity well matched to the brightness of M100 in a reasonable amount of time.
Largest Angular Scale: M100 exhibits structure over a large range of angular scales. We set the LAS to the extent of the map (270″) to recover structure at all scales down to the resolution of the observations. All three arrays (12-m Array, 7-m Array, and TP Array) will be required.
Coverage: We know the overall extent of CO from previous observations, including wide field single dish maps. A single ALMA beam covers only a small part of the galaxy, but a rectangular grid of 137 pointings spaced by ~half of the primary beam does manage to encompass most CO emission. Mosaics of up to 150 pointings per Science Goal (SG) are allowed by the *Cycle 10* call.
Sensitivity and Mosaicing: Entering the mosaicing parameters and a required sensitivity of 3 mJy/beam directly into the OT, the integration time calculator (which takes into account the overlapping of the mosaic fields) estimates an observing time of ~2.1 minutes per mosaic position. With 137 fields we expect that the program will need about 4.8 hours on source, or just over 7.6 hours with overheads. The OT estimates that 52 overlapping pointings will be needed for the 7-m Array requiring about 40 hours total, and about 78 hours for the total power observations.

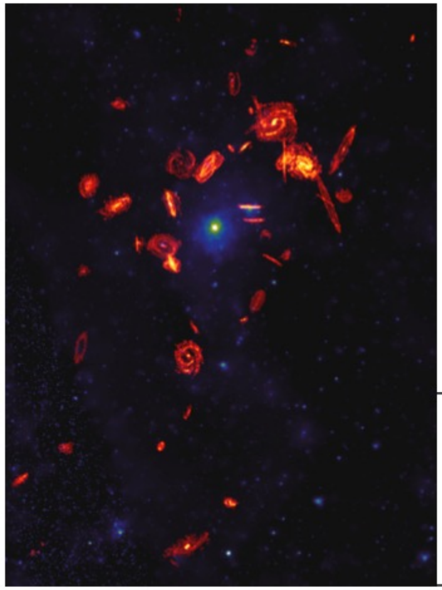

Figure 18: *The VERTICO—Virgo Environment Traced in Carbon Monoxide—Survey observed the gas reservoirs in 51 galaxies in the nearby Virgo Cluster and found that the extreme environment in the cluster was killing galaxies by robbing them of their star-forming fuel. In this composite image, ALMA's radio wavelength observations of the VERTICO galaxies' molecular gas disks are magnified by a factor of 20. They are overlaid on the X-ray image of the hot plasma within the Virgo Cluster. Credit: ALMA (ESO/NAOJ/NRAO)/S. Dagnello (NRAO)/Böhringer et al. (ROSAT All-Sky Survey)*

Observing Considerations

While considering a possible ALMA project, it is important to understand that ALMA is a very flexible instrument. Data can be obtained over a wide range of observational parameters: angular resolution, field-of-view, spectral resolution, and sensitivity. These quantities must be specifically defined and justified for a given project in a proposal, and careful choices are required to ensure that the project's scientific aims can be met. These quantities are also used during Phase 2, to guide in planning the execution of the project. Depending on the nature of a given project, the observational parameters may be interrelated. In the following, we describe the basis for choosing these parameters.

Angular resolution (or "synthesized beam") is the minimum angular separation whereby adjacent spatial features can be distinguished. Angular resolution fundamentally varies as the inverse of the product of the observing frequency and distances between the antennas used to make the image; higher frequencies or longer antenna base-

lines result in data of finer angular resolution. An important concept to remember about interferometers is that they can only observe emission on a discrete set of angular scales (*i.e.* spatial frequencies), as measured by the antenna pairs making up an array (see "*uv*-coverage", page 37). Since the number of angular scales measured is finite, the resulting image is spatially "filtered" and only reflects the emission on the observed angular scales. Even for a given baseline distribution, however, the observer has some control over the effective resolution of the image during post-processing. By using different weighting schemes to reconstruct an image, it is possible to make moderate tradeoffs between effective resolution and surface brightness sensitivity.

Quick Links

The ALMA Primer Video series provides an introduction to ALMA and radio interferometry for users who are new to ALMA.
https://almascience.org/tools/alma-primer-videos

The European ARC's I-TRAIN program provides interactive training in reduction and analysis of ALMA data. Recordings of these sessions can be found at
https://almascience.eso.org/tools/eu-arc-network/i-train

Maximum Recoverable Scale (MRS) is the largest angular scale structure that can be recoverable from observations by an interferometer, and is defined to be 0.6 × (wavelength/minimum baseline) in radians (or ~124″ × (1m/D_{min}) × (300 GHz/ν)), where D_{min} is the minimum distance between antennas in meters and ν is the observing frequency in GHz. MRS is a guideline for the largest angular structure on which some of the flux of a smooth structure can be reasonably recovered by the interferometer. This rule-of-thumb applies to the size scale of smoothly varying structures in both dimensions. Smooth structures larger than the MRS will be "resolved out" by the interferometer. This is the well known "missing flux" problem intrinsic to interferometry. The minimum baseline depends both on the array configuration (*i.e.* compactness) and source elevation. To recover emission that has been "resolved out," additional observations are needed, including observations with more compact configurations (such as compact configurations of the 12-m Array and/or the 7-m Array) or large single-dish telescopes (e.g. the TP Array). One can explore with CASA *simalma* or the Observation Support Tool whether the ACA will be required for a particular project. The OT shows the MRS for the most compact and most extended 12-m Array configurations in the *Control and Performance* tab, and based on the requested *angular resolution* and *largest angular structure* (LAS), may recommend the use of multiple 12-m Array configurations and/or the ACA (see Figure 29).

Note that if you are only interested in small details, faint extended emission of no interest can be ignored if it is of too low surface brightness (a few times the rms) at the expected resolution. However, emission which is so bright that it would be strongly detected were it not smooth can cause artefacts in high resolution images if low-resolution data are not also used.

Field-of-view (FOV) is the area on the sky over which an interferometric image is obtained. The instantaneous FOV is formally the angular size of the half-power width of the Gaussian beam (FWHM) of the individual antennas and is also called the width of the "primary beam". The size of the FOV depends on the inverse of the product of the frequency of the observation and the diameter of the individual antennas used; larger antennas or higher frequencies result in smaller FOVs. Larger FOVs and flatter map sensitivities across images can be attained by observing in series many adjacent locations on the sky (best separated by λ/2D where λ is the observed wavelength, and D is the diameter of the antennas, to achieve Nyquist sampling) and using the resulting data to create a "mosaic" map. For a single pointing, the sensitivity of the observation is not uniform across the FOV; it declines with angular separation from the center position with the approximately Gaussian re-

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4. Justify the sample and Check feasibility early

- ✓ Justifying the target(s): one target? Why one is enough? Why 20? Survey? Unique? Wealth of ancillary data? Closest (good spatial resolution)? Brightest (good signal to noise)?

Tips for writing ALMA proposals (my personal view)

Example (my case): Extended CO survey of 30 group galaxies (Cycle 9, ACA) → survey proposal (7m: 40 hrs, TP: 60 hrs)

1.3. New samples for the extended CO imaging study

... In particular, thanks to the relatively close distances of these two groups (Table), individual galaxies can be resolved down to sub-kpc scale, ...

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... using a new NGC4636 group catalog, we selected late-type galaxies with stellar masses of 10^9 – 10^{11} Msun, located within 1.5 × virial radius and ±3 × velocity dispersion of the group. Then, the sample is relatively unbiased with respect to the HI richness, ...

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The final sample consists of 7 members for the NGC 4636 group, which the recent study missed (Lee et al. 2022), and 23 galaxies for the NGC 4261 group → some galaxies in the NGC 4636 group were observed in ALMA Cycle 7.

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..., we aim to study the group environmental effects on the molecular gas and star formation activity of galaxies, by combining the ACA data with the high-resolution HI imaging data(ASKAP/VLA) and archival optical/UV/X-ray data.

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- ✓ Justifying the target(s): one target? Why one is enough? Why 20? Survey? Unique? Wealth of ancillary data? Closest (good spatial resolution)? Brightest (good signal to noise)?

- ✓ Checking feasibility: angular & velocity resolution, frequency setup, sensitivity, mosaic, maximum recoverable scale (+ 7m and total power array), etc

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2. Description of observations

We request ACA stand-alone observations of 12CO (1-0) line for 30 member galaxies in two groups...

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To fully recover the CO emission, we propose mosaic observations ...

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To fully recover the CO emission, we propose mosaic observations ...

For some samples with the large CO disk, which is larger than the maximum recoverable scale of ~62”, we will observe these targets with a combination of the 7-m and total power array to fully recover the total CO flux.

Tips for writing ALMA proposals (my personal view)

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For some samples with the large CO disk, which is larger than the maximum recoverable scale of ~62”, we will observe these targets with a combination of the 7-m and total power array to fully recover the total CO flux.

..., a 20 km/s velocity resolution will yield at least 7 independent elements across the CO disk, the kinematics can be studied in detail.

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..., a 20 km/s velocity resolution will yield at least 7 independent elements across the CO disk, the kinematics can be studied in detail.

Based on the prediction for the molecular gas surface density at the edge (3 Msun/pc^2), we aim to reach a molecular gas surface density of 3 Msun/pc^2 in 5 sigma per 20 km/s channel per synthesized beam.

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- ✓ Checking feasibility: angular & velocity resolution, frequency setup, sensitivity, mosaic, maximum recoverable scale (+ 7m and total power array), etc

- ✓ The number of targets + observing strategy → total observing time (regular programs: (i) ALMA 12 m array: <50 hours, (ii) ACA: < 150 hours)

Tips for writing ALMA proposals (my personal view)

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✓ The number of targets + observing strategy → total observing time (regular programs: (i) ALMA 12 m array: <50 hours, (ii) ACA: < 150 hours)

e.g, using the ACA, CO (1-0) survey of spiral galaxies
(i) 20 galaxies, 10 sigma with 5 km/s → 200 hours (> 150 hours) ☹
(ii) 20 galaxies, 5 sigma with 5 km/s → 140 hours (< 150 hours) ☺
(iii) 15 galaxies, 3 sigma with 10 km/s → 50 hours (< 150 hours) ☺

To achieve your scientific goals with limited observing time, you need to adjust the observational setup (e.g., spatial/velocity resolutions, signal-to-noise, the number of pointings for the mosaic observation) or you can submit your proposal as an ALMA large program

Tips for writing ALMA proposals (my personal view)

5. Describe ancillary data

- ✓ For extragalactic science, recommend combining all multiwavelength data to obtain a comprehensive understanding of the physical properties of galaxies → molecular gas (ALMA data), HI gas (HI data), stellar component (optical & IR data), star formation activity (Halpha, UV, IR data)

Tips for writing ALMA proposals (my personal view)

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1.3. New samples for the extended CO imaging study

..., we aim to study the group environmental effects on the molecular gas and star formation activity of galaxies, by combining the ACA data with the high-resolution HI imaging data(ASKAP/VLA) and archival optical/UV/X-ray data.

The HI imaging data can be greatly useful to diagnose environmental processes since a large extent of the HI disk makes it more susceptible to external perturbations. For the N4636G, we will utilize archival HI data from the ASKAP and VLA.

Optical images provide stellar maps to show signs of tidal interactions.

The UV data, a tracer of recent star formation, will be compared with our CO data to probe star formation efficiency. For this, we will also correct the dust attenuation in SFR with the WISE (infrared) data.

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Immediate scientific objectives

Goal 1: ..., we will probe a morphological correlation (e.g., gas compression) between CO and HI by comparing the ACA CO data with the HI imaging data, to confirm whether environmental processes can change the distribution of both CO and HI...

Goal 2: ..., we also investigate the relationship between the SFR surface density (UV) and the H2 gas surface density (CO), ..., to test whether group galaxies follow the same star formation mode as field galaxies.

Tips for writing ALMA proposals (my personal view)

6. Circulate the first draft early & discuss the draft with your collaborators

- ✓ Useful comments from your collaborators
- ✓ Based on the comments, improving the draft before the deadline

Tips for writing ALMA proposals (my personal view)

7. Proposal writing is different from paper writing

(“ALMA Cycle 8 Proposal Writing Tips”, Nick Indriolo, “East Asia Proposal Rankings”, Misato Fukagawa)

✓ Proposal writing → ambitious (cf. paper writing: conservative); exploring the unknown

✓ “EA proposal rankings are systematically lower than EU and NA” (see Carpenter 2019, PASP) → EA proposals sound too conservative

✓ **Get to the point quickly:**

- “state the primary goal of your proposal on the first page”
- “Do not begin the proposal by providing an extensive (1+ page) discussion of background material”

Tips for writing ALMA proposals (my personal view)

8. Do not be discouraged & disappointed

(“ALMA Cycle 8 Proposal Writing Tips”, Nick Indriolo; “Tips for Writing ALMA Proposals”, Patricio Sanhueza)

- ✓ Cycle 6 & 7: top 20% of all proposals (~1800) → accepted;
- ✓ Competition is very high + unexpected events (COVID19 in 2020, cyberattack in 2022)

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My experience (distributed peer review):

i) submitted a proposal in Cycle 8 2021 → rejected

ii) submitted the same proposal (revision based on the reviewer’s comments) in Cycle 8 2021 Supplemental Call → rejected

iii) submitted the same proposal (revision based on the reviewer’s comments) in Cycle 9 → accepted

Good Luck