Technical Justification and CASA Simulator

Town hall meeting for ALMA Cycle 4 2016 March 28 Woojin Kwon





Technical Justification what cube data for your science

- Sensitivity
- Imaging
- Correlator configuration
- Choices to be justified

Sensitivity

- Multiple sources: most restrictive values
- Continuum and/or line flux
- Line: bandwidth for sensitivity $\leq 1/3$ of line width
- Spectral dynamic range: both spectral line properties and a continuum flux put in <continuum>/<line rms>

Imaging

- Imaging goals of a proposal
- Requested angular resolution
- Requested Largest Angular Structures (LAS)
 0 (zero): any 12-m configuration could be used so angular resolution might be much better
- Change OT's recommendation (ACA, default Nyquist sampling for rectangular mosaics)
 => explicitly justify

Correlator configuration

- Number of spectral resolution elements (including Hanning smoothing and spectral averaging) per line width
- Bandwidth of the Representative Window
- Example: We use the default continuum polarimetric correlator set-up.

Choices to be justified

- Non-Nyquist mosaic sampling: large field without large-scale structures
- Single polarization: e.g., for highest spectral resolution
- (High data rate: due to many high spectral-resolution spectral windows, easiest way-spectral averaging)
- Low max elevation: large atmospheric attenuation, limited time above the horizon
- User-defined calibration: must be rigorously justified
- (ACA choice overridden: depending on LAS, ACA recommended)
- Override of OT's sensitivity-based time estimate: e.g., monitor a source over a certain time span, sufficient uv coverage for imaging complicated structures => detailed justification for the time override and how the new time was estimated (including calibrations and overheads)
- Time-constrained observing: significant constraints on the scheduling of all ALMA projects

CASA simulator

Why?

- Mock observations of ALMA
- Not necessary, however:
- Show if your science can be done by ALMA
- Verify what you need for your science goals e.g., which configurations

• Comparison of different array configurations



Basics of Interferometry

- Interferometer data: uv visibility
 - Power corresponding to the correlation of the waves received at two antennas
 - FT relation with sky intensity distribution
 - (u, v) coordinates

 $V(u,v) \rightleftharpoons A_N(l,m)I(l,m).$

$$S(u,v)V(u,v) \iff FT^{-1}[S(u,v)] * FT^{-1}[V(u,v)]$$
$$B_D(l,m) * [A_N(l,m)I(l,m)].$$

 Keywords uv coverage, uv distance, synthesized beams, primary beam...



 $V(u,v) \rightleftharpoons A_N(l,m)I(l,m).$

 $S(u,v)V(u,v) \rightleftharpoons FT^{-1}[S(u,v)] * FT^{-1}[V(u,v)]$ $B_D(l,m) * [A_N(l,m)I(l,m)].$

- Simulating interferometric data (visibilites)
 1. sky intensity distribution (model): I(I,m)
 2. primary beam correction: A_N(I,m) I(I,m)
 3. FT: V(u,v)
 - 4. sampling over S(u,v): S(u,v) V(u,v)
- Interferometric data reduction
 - 1. data: S(u,v) V(u,v)
 - 2. IFT
 - 3. de-convolution of $B_D(I,m)$ to fine $A_N(I,m) | (I,m)$

Two Approaches

- CASA simulation tools
- Observation Support Tool (OST) EU ARC, University of Manchester Web-based <u>http://almaost.jb.man.ac.uk</u>

CASA 123

- Common Astronomy Software Applications
 http://casa.nrao.edu
- Install CASA version 4.3.1 (latest: version 4.5.2)
- > casapy
 : tasklist

.

- : taskhelp
- :inp(<task>)
- : project = 'sim' (example of putting in a parameter value)

```
: go (or a task name)
```

CASA simulation tools

- CASA version 4.3 <u>http://casaguides.nrao.edu/index.php?</u> <u>title=Simulating_Observations_in_CASA_4.3</u>
- Simobserve generate visibilities
- Simanalyze produce a cleaned image
- (Simalma)

particular cases: e.g., combining 12-m array and ACA data



- RMS noise should not be used for proposals
- 20% underestimates for both surface brightness and total flux in single dish maps

What you need

- Possible starting points: a model image in FITS e.g.,
 - images taken at a different wavelength numerical simulation results knowledge on object size and total flux

Simobserve

• Generate visibilities: 30 Doradus

CASA <46>: inp					obsmode	=	'int'	#	observation mode to
> 1np()	فمأحذاء	lity simulation						#	erferometer) sd(sin
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inbright	-	0.00mJy/plxel	#	scale surface brightness of brightest	refdate	=	'2014/05/21'	#	date of observation
			#	pixel e.g. "1.2Jy/pixel"				#	unless concatting s
indirection	= '	J2000 10h00m00	-400	100m00' # set new direction e.g.	hourangle	=	'transit'	#	hour angle of observ
			#	"J2000 19h00m00 -40d00m00"				#	"-3:00:00", "5h", "
incell	= '	0.15arcsec'	#	set new cell/pixel size e.g.				#	without units will
			#	"0.1arcsec"				#	hours), or "transit
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			#	model)	caldirection	-	• •	#	pt source calibrator
inwidth	=	'2GHz'	#	set new channel width e.g. "10MHz"	calflux	-	'1Jv'		
			#	(required even for 2D model)					
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complist	=	••	#	componentlist to observe				#	manual ""]
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								#	<pre>\$project</pre>

Outputs

- sim.alma.cycle3.1.ms/
- sim.alma.cycle3.1.noisy.ms/
- sim.alma.cycle3.1.observe.png
- sim.alma.cycle3.1.ptg.txt
- sim.alma.cycle3.1.quick.psf/
- sim.alma.cycle3.1.skymodel/
- sim.alma.cycle3.1.skymodel.flat/
- sim.alma.cycle3.1.skymodel.png





Simanalyze

• Generating (cleaned) image

CASA <57>: inp							_		
> inp()					analyze	=	True	#	(only first 6 selected outpu
<pre># simanalvze :: i</pre>	maae	and analyze m	neasure	ment sets created with simobserve				#	be displayed)
project	=	'sim'	#	root prefix for output file names	showuv	=	True	#	display uv coverage
image	=	True	#	(re)image \$project.*.ms to	showpsf	=	True	#	display synthesized (dirty)
			#	<pre>\$project.image</pre>				#	(ignored in single dish sim
vis	-	'default'	#	Measurement Set(s) to image	showmodel	=	True	#	display sky model at origina
modelimage	-		#	lower resolution prior image to use				#	resolution
			#	in clean e.g. existing total power	showconvolved	-	True	#	display sky model convolved
			#	image	511011001100			#	output clean beam
imsize	-	Ø	#	output image size in pixels (x,y) or	showelean	_	Тлие	#	display the synthesized image
			#	0 to match model	shownosidual	-	Falco	#	display the clean nesidual i
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			#	(otherwise center on the model)	1 11 66		-	#	(ignored in single dish sim
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			#	or "" to equal model				#	cleaned image and input mod
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threshold	-	.0.1mJA.	#	flux level (+units) to stop cleaning	graphics	=	'both'	#	display graphics at each sta
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featherimage	-	î.	#	image (e.a. total power) to feather	_				
i sa si			#	with new image	CASA <58>:				

Outputs

 uv coverage, dirty beam, model, convolved model image, clean image, differences



Observation Supporting Tool

- Web-based
- Results can be delayed depending on job load
- http://almaost.jb.man.ac.uk

Version 3 OST NEWS HELP OUEUE LIBRARY ALMA HELPDESK OST Report: OST response Select the desired ALMA antenna configuration. Stry Setup: Select the desired ALMA antenna configuration. Stry Setup: Choose a library source model or supply your own. Source model: OST Library. Certral point source is Choose a library source model for supply your own. Upload: Declination: Select the desired ALMA antenna configuration. Select the desired ALMA antenna configuration. Bay Setup: Choose a library source model for supply your own. Upload: Declination: Select the desired ALMA antenna configuration. Upload: Declination: Select the desired ALMA antenna configuration. Ensure correct formatting of this string (4/-00000m00.0s). Image peak / point flux in may: @ 0 Rescale the image data with respect to new peak value. Set to 0.0 for no rescaling of source model. Observation Setup: Observation Setup: Observation Setup: Declination: Select the total bandwidth for continuum observations. Declination: 2 is This affects the notice in the final map. Declination: Select the total bandwidth for	EUROPEAN ARC ALMA Regional Centre UK ALMA Observation	ALMA Observation Support Tool					
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Amospheric conditions: PWV = 0.472 mm (ist Octae)	Atmospheric conditions: PWV = 0.472 mm (1st Octile)	Determines level of noise due to water vapour.					
Imaging Product:	Imaging Product:						
Imaging weights: Natural	Imaging weights: Natural	This allows a resolution / sensitivity trade-off.					
Perform deconvolution?: No (Return dirty image)	Perform deconvolution?: No (Return dirty image)	Apply the CLEAN algorithm to deconvolve the image.					
Output image format: FITS O	Output image format: FITS	CASA format images are returned as a tar file					
Submission:	Submission:						
Your email address is essential! Submit	Your email address is essential!	Submit					

		Data products				
EUROPEAN ARC ALMA Regional Centre UK Job ID: 2	ALMA Observa 20160317125744WnIRv / Submitted by: wkwon@kasi.r	Your simulated image: Download FITS file	Marci / Holds and a log of the lo			
Messages						
The brightness unit of your uploaded sky mod	el was not recognised and has been adjusted to Jy/pixel.		A 2 0 -2 -4 0 4 2 0 -2 -4 Right Accession / stietlys arcsec Right Accession / pixely			
You should carefully check that your sky model i The peak pixel of your model image has been resi	remains sensible, and consider tuning the rescaling value to compensate for any caled to 100 mJv	Pitty Beam				
		(Point Spread Function):				
Overview						
Click thumonalis to view full-size images. Left: linear	colour scale, right: with histogram equalization.					
Array configuration:	ALMA Cycle 3 C36-3n (538 m baseline)		e Maria a Maria			
Source model:	M51 originally observed in H_alpha					
Input image:	77.88 degrees	Coverage in the uv-plane:	A Repl Assertion.) relative artset			
Central frequency:	93.7 GHz (ALMA Band 3)	Atmospheric transmission for all bands (latt) and				
Total Bandwidth:	7.5 GHz	the selected band (right)				
Track length:	3 hours × 1.0 visits					
Hexagonal mosaic pointings :	nal mosaic pointings : 1 required to cover requested sky area with uniform sensitivity					
System temperature:	Tsys = 68.8274779127 K		The party of the the pa			
PWV :	0.942 mm	Elevation vs time:				
Theoretical RMS noise:	5.63260725958e-06 Jy (in naturally-weighted map)					
Restoring beam (resolution):	Major axis = 1.937 arcsec, minor axis = 1.578 arcsec, PA = 81.624 deg					
For use with CASA simdata						
Input sky model:	Download processed model in FITS format		ng 0 05 10 15 20 25 10			
Download CASA simobserve/analyze file:	20160317125744WnIRv.simdata.last	Diagnostics				
Download pointing file:	20160317125744WnIRv.ptg.txt	Processing time: 37 seconds				



Summary

- ALMA simulator
- CASA simulation tasks/tools
 http://casa.nrao.edu
 http://casaguides.nrao.edu/index.php?title=Simulating_Observations_in_CASA_4.3
 simobserve
 simanalyze
 (simalma)
 - Observation Support Tool http://almaost.jb.man.ac.uk